

## SURFACE MODIFICATION OF SYNTHETIC TEXTILES

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**Abstract-** Due to their hydrophobic nature, textiles composed of polyester fibers are prone to accumulate electrostatic charges and to retain oily stains. Retention of oils may also be paralleled by increased redeposition of particulate soils. Hydrophilic surface finishes are known to be capable of improving these static and soiling properties. Such durable topical finishes are generally attained by modifying the fiber surface chemically, by depositing preformed polymers, or by forming insoluble polymers from appropriate monomers *in situ* the fiber, e.g. by grafting. Interfacial polymerization techniques -- similar to those suggested earlier for wool shrink-proofing -- have been investigated in the present work to deposit polyamide, polyurea and polyurethane coatings on texturized woven polyester. The effect of the coating on soiling characteristics was found to be highly dependent on the specific monomers employed. The most significant improvements in soiling characteristics were obtained with a polyamide coating formed via the polycondensation of piperazine and adipoyl chloride. Soil release problems are associated not only with 100% polyester textiles, but also with polyester/cellulosic blends, especially those treated with durable press resins. Anionic copolymers, perfluoroacrylates containing hydrophilic segments and topical finishes composed of combinations of these are the most effective in enhancing the soil release properties of such blends.

## INTRODUCTION

With the continued increase in the use of synthetic fibers and the introduction of easy-care cellulose and synthetic fiber/cellulose blends in the last fifteen years, many investigations have been carried out with the objective of obtaining a better understanding of the soiling and soil release behavior of textiles. Soiling problems on textiles generally arise from the unwanted accumulation of oily and/or particulate materials on the surfaces or interior of fibrous structures. The degree of soil removal during cleaning is a function of the substrate, soil, cleaning method and interactions between these. To achieve soil removal from textiles, the oily and particulate matter must not only be separated from the fiber, but must also be carried away from it in the wash liquor with minimum reattachment to fiber surfaces. Complete soil removal is hardly ever achieved in commercial or home cleaning operations (1). As little as 0.1-0.2% (by weight) of an oily soil is probably sufficient to form a thin layer covering most of the fiber surfaces, particularly on the relatively smooth synthetic fibers.

## SOILING MATERIALS

One common type of oily soil found on clothing is human sebum. An average of 1.2g of sebum has been extracted from T-shirts worn for only one day, an amount representing about 1% of the garment weight (2). Combined carbon tetrachloride extracts of shirts, socks, pillowcases and towels contain about 31% free fatty acids, 29% triglycerides, 15% fatty alcohols and cholesterol, 21% hydrocarbons and 3.3% short-chain fats and oils (3).

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Dust deposited from the air makes up a large part of the solid particulate soil found on outer garments, drapes, carpets and other textiles. This material is probably similar to dust found in city streets; typically over 50% of the particles in street soil is in the 0 to  $4\mu$  size range (4). Particles below about  $0.2\mu$  are nearly impossible to dislodge from textiles by laundering, probably because of their high surface-to-volume ratio and the ease with which they can become lodged in small surface irregularities.

#### FIBER SURFACES

In soiling studies not only the chemical composition of the fibers, but also the surface coatings and finishes present on the textiles should be considered. Surfaces of both fibers and their coatings represent a wide variety of organic polymers. These can conveniently be classified in a manner related to their surface energy. The ease with which soils are accumulated by textile surfaces and the resistance offered to soil removal depend to a large extent on the energy released in formation of interfaces, i.e. between soil and fiber surface or between the liquid and the solid soil. Polymers important to textiles are classified as having low surface energy, i.e. about 10 to 50 erg/cm<sup>2</sup>. In contrast, inorganic surfaces have surface energies in the hundreds or thousands of ergs/cm<sup>2</sup>. The relatively narrow 40-erg spread for textile polymers is sufficient to produce major variations in soiling behavior, depending on the chemical nature of the surfaces involved (5).

It has been shown that good soil release ratings are obtained on polyester textiles when the critical surface energy is either below 28-30 erg/cm<sup>2</sup> or above 42 erg/cm<sup>2</sup> (6). Much poorer soil release is obtained when the critical surface energy is in the 30-40 erg/cm<sup>2</sup> range, with a minimum at about 36 erg/cm<sup>2</sup>. This demonstrates that to achieve the best oily soil release performance it is desirable to use finishing agents that impart either a very low or a very high surface energy. Finishing agents that impart a low surface energy in air (thereby providing oil- and water-repellency) and a high surface energy in aqueous media (thus providing good wettability) will provide the most desirable features of both finishes.

Surface energies of polymers have been studied extensively by use of measurements of contact angles of liquids with varying surface tensions and chemical constitutions (7). From these studies has evolved the concept that the total energy of a polymer surface may be divided into polar and nonpolar effects depending on the molecular interactions involved. Nonpolar interactions (8) have been mainly attributed to Van der Waals forces which can form strong attractions even between hydrocarbon chains.

Hydrogen bond formation between interacting surfaces is chiefly responsible for the polar portion of polymer surface energies (9). The presence of ether, amide, hydroxyl, carboxyl, sulfonate and other polar groups in the surfaces of textiles can thus increase their ability to bind soil molecules. However, while the many hydroxyl and ether groups present in the surface of a cellulosic fiber contribute to its higher surface energy than that of a hydrophobic synthetic fiber, and promote the greater accumulation of surface soil, the hydrogen bonds involved are readily disrupted by water and/or surfactant solutions. Since nonpolar as well as polar bonds are responsible for soil adhesion and since other factors such as fabric geometry and soil dispersion are also involved, water alone cannot completely clean soiled fibers, even cellulose fibers.

It has been demonstrated that the surface wettability by water, and thus the hydrogen bonding capability, of a series of polyamides improved as the number of amide sites at the surface was increased by shortening the length of the hydrocarbon segments between them (10). A similar study with linear aliphatic polyesters (11) also showed improvement in wetting with increased concentration of ester sites. However, wettability for a given degree of modification in this series was poorer than with the nylons because of the relatively poorer wettability of ester vs. amide sites. While the water wettability of the widely used fiber polymer, poly(ethyleneterephthalate), is higher than that of an equivalent aliphatic polyester, it is still less than that of an equivalent polyamide.

Interactions between water-fiber-air as well as water-fiber-soil are involved in the removal of oily soil from fiber surfaces by laundering. Contact angles of oil with polymer surfaces under water increase with increased water wettability of the fibers. When a surfactant is added, oil contact angles under water increase for all but the most nonpolar fibers (Table 1). It is reasonable to expect that oil droplets would be easily removed by mechanical action during laundering when the contact angle reaches  $140^\circ$  (12).

TABLE 1. Surface characteristics of polymeric materials  
(From Ref. 12)

Substrate	Oil/fiber contact angle	
	In water	In aq. surfactant solution
Cellulose	145°	150°
Poly(acrylonitrile)	115	140
Nylon-6,6	90	145
Poly(ethyleneterephthalate)	65	140

Polymer coatings having low surface energies, *i.e.* silicones and fluorocarbons can generally reduce soil accumulation in air by repelling aqueous-based soils and many oily materials (13). However, if they do become soiled, they are difficult to clean. A compromise solution was developed (14) by combining hydrophobic and hydrophilic polymer segments in a single durable finish. The behavior of such block copolymer finishes has been explained in terms of attainment of the lowest interfacial energy state for the environment in which they are placed. In air, the hydrophilic groups are collapsed below the surface and a low-energy, soil-repelling surface is produced. In water, the hydrophilic groups swell, facilitating soil removal by providing a surface with low interfacial energy in that environment.

Electrical forces can attract soil particles to produce soiling, and to make soil removal difficult. Surfaces of most fibers are negatively charged, and fibers with extensive hydrogen-bonding capabilities, such as cellulose, glass and nylon, possess relatively the lowest zeta potentials of all fibers (Table 2). An increased fiber potential increases the difficulty of soil removal although the relative importance of this effect is in dispute (15,16).

TABLE 2. Zeta potential of textile fibers  
(From Ref. 16)

Fiber	Potential (mV)
Viscose Rayon	22
Glass	28
Nylon-6	33
Cellulose Triacetate	37
Polyester	52

The scales of wool fibers and the curled ribbon-like form of cotton fibers strongly suggest more extensive physical opportunities for both particulate and oily soils to accumulate compared to smooth, round fibers such as polyester and nylons. Soil removal studies from flat films (17) indicated that particulate carbon soil was easier to wash from cellulose than from nylon or polyester substrates. In contrast, this particulate material was more difficult to wash from cotton fabric than from nylon or polyester fabrics, which was probably a result of fiber morphology and fabric geometry (Table 3). Rough-

ness of polymer surfaces has long been recognized as an important variable affecting wetting by liquids. For instance, differences between advancing and receding contact angles have been attributed to the retention of liquids in surface irregularities as the contacting liquid is withdrawn (5). Thus fiber surface roughness may be important to the soil removal process by affecting wettability as well as soil entrapment.

TABLE 3. Effect of the substrate on the removal of particulate materials  
(From Ref. 17)

Substrate	% Carbon black removed	
	Film	Fabric
Cellulose	80	9
Nylon-6,6	35	79
Polyester	48	66

The degree to which soil particles become imbedded in the surface of fibers under equivalent external forces is dependent on the hardness of the fibers and influences the ease of soil removal. It has been demonstrated that both hard and soft finishes are capable of coating most of the crevices in cotton fibers, but hard finishes reduce while soft finishes increase soil retention since particles become imbedded in the coatings. Hard finishes must, however, be able to resist cracking, since fissures in coatings can provide sites for soil entrapment similar to those in fiber surfaces (18).

Oily components of soils can diffuse into fibers or coatings, thus becoming molecularly entangled. Variables affecting this process include the size and chemical nature of the soil molecules and fiber and the time and temperature of the interaction. Obviously the deeper the soils have diffused into the fiber, the more difficult it will be to remove them. This phenomenon of diffusion mandates that soiled fabrics should be cleaned as soon as possible to reduce the likelihood of "setting in" the soil.

Fabrics from staple polyester fibers have been shown to accumulate about five times more oily soil than those from continuous filament yarns under the same conditions, with removal of the oils about twice as difficult from the staple fabrics. Electron micrographs of cleaned staple fabrics showed soil trapped at fiber crossover points (19). The same effect has been demonstrated with particulate carbon soils (17). Roughly twice as much hydrophobic carbon was removed by laundering from a continuous filament fabric as from staple fabric. The application of a hydrophilic coating to loose polyester staple produced a 66% reduction in soil retention after washing, but this advantage was lost when the staple fiber was converted into fabric.

A widely recognized difficulty with efficient soil removal is that soils separated from the fabrics and suspended in wash liquors may redeposit on fibers before the soil is flushed from the system. Sorption of detergent components on fiber and soil surfaces provides deterrents to readherence of soils when these sorbed components are present at high enough concentrations (20). These absorbed layers can increase the contact angle of oily soil droplets to close to 180° (12) so that they have essentially no tendency to rewet the fibers on recontact. In the case of ionic surfactant molecules, an electrical repulsion which prevents redeposition can be created between the fiber and soil particles.

#### SURFACE FINISHES FOR POLYESTER TEXTILES

Increased soil release and reduced soil redeposition can be attained by increasing the surface hydrophilicity of synthetic textiles. An early method used to improve soil release and prevent soil redeposition was the treatment of polyester textiles with polyglycols. Sodium polyglycolate is capable of reacting with poly(ethyleneterephthalate) through an ester interchange reaction. Since this reaction is very sensitive to time, temperature, and moisture, this approach has been abandoned (21).

In recent years surface hydrophilicity has been improved by hydrolysing the surface with sodium hydroxide (22) or by diffusing a polyether-polyester copolymer into the surface of the polyester fiber. Such nonionic copolymers are prepared by co-condensing dimethyl terephthalate with ethyleneglycol and a poly(ethyleneglycol) of molecular weight ranging from 660 to 1500. The ethyleneglycol and poly(ethyleneglycol) proportions are carefully balanced to obtain polymer that is hydrophilic without being water soluble or overly swellable by water after deposition onto the substrate. The adhesion is claimed to be enhanced by a "co-crystallization" mechanism. The hydrophilic surface enhances wettability in aqueous launderings, thus preventing soil redeposition and improving soil release properties (23).

Acrylic acid can be grafted onto the fiber surfaces by radiation techniques. The preparation of nylon 6,6-acrylic acid graft copolymer by high energy electron beam radiation has been reported (24). A newer approach which has reached commercial acceptance employs an electrical discharge in argon gas to graft acrylic acid onto a polyester surface, thereby providing improved wettability with enhanced soil release and reduced soil redeposition characteristics (25,26). Typical hydrophilic polyester generated by this process has a poly(acrylic acid) add-on of 0.05-0.10%. The grafted product retains its wettability through 50 launderings, although there is a gradual loss of graft due to abrasion, about half of it being lost after 20 washings.

The "dual action" fluorochemicals contain alternating perfluoroaliphatic groups to repel stains and poly(ethyleneoxide) segments to provide soil release hydrophilic sites in water. These finishes form continuous films which possess low surface energy in air and low interfacial energy in water. It has been postulated that the fluorinated segments lie on the fabric surface in air, and the hydrophilic ones lie on the surface in water (14).

#### SURFACE COATING STUDIES BY INTERFACIAL POLYCONDENSATION

Due to their lower zeta potential and higher hydrophilicity nylons possess more desirable soiling, soil release and soil redeposition properties than polyesters. It thus appeared to be of interest to study the effect on these properties of depositing various polyamide coatings on texturized polyester fabric. In addition, several polyurea and polyurethane coatings were also included in this study.

Interfacial polymerization is an ideal technique for depositing polyamide coatings. It was once a commercial candidate for shrinkproofing wool fabrics. The fabric is impregnated sequentially with an organic solvent solution of an acid dichloride and an aqueous diamine solution, in either order without intermediate drying. By obvious changes in the intermediates used, polyurea, polyurethane, polyester and polycarbonate coatings may also be formed (27,28). By using less reactive intermediates, e.g. aliphatic diisocyanates (29) or activated esters (30), certain of these polymers may also be deposited on fabrics via single step, aqueous application procedures.

#### Polyamides

Using hexamethylene diamine (HMD) with either sebacoyl or adipoyl chloride, higher reaction yields were obtained by padding the fabric through the aqueous diamine solution first. The effect was less pronounced with piperazine (PIP) as the amine. Immersion times ranging from 5 to 30 sec. had only very minor effect on reaction yield (Table 4). The polymer deposition was much more even with adipoyl chloride (AC) as coreactant; when sebacoyl chloride (SC) was used, a large portion of the polymer on the fabric was in flakes or easily peelable from the surface. The effect of solvent system appeared to be dependent on the particular reagent system studied, although in general no large differences were noted.

TABLE 4. Polyamide formation on polyester substrate(IFP technique)

Solvent for acid chloride	% Weight gain				
	Methylene chloride			Varsol	
Immersion time, each step	5 sec	15 sec	30 sec	15 sec	30 sec
Reagents in order of padding					
HMD/SC	1.4	1.4	1.2	2.1	1.9
SC/HMD	0	0.1	1.3	1.3	1.1
PIP/AC	1.0	1.1	1.2	1.4	1.1
AC/PIP	0.9	0.9	1.0	0.8	0.9
HMD/AC	2.1	2.8	2.6	0.7	1.2
AC/HMD	1.0	1.3	1.4	1.3	0.6
Concentrations:					
Amine: 4g/100 ml solvent					
Acid chloride: 2ml/100 ml solvent					

To increase the polymer add-on using AC/amine systems, it was necessary to increase the concentration of acid chloride in the pad bath, but it was preferable to increase both concentrations. Increasing only the amine concentration had little or no effect (Table 5).

TABLE 5. Effect of concentration of reactants

	% Weight gain, with	
	HMD	PIP
Amine/AC	2.8	1.1
AC/amine	1.3	0.9
Amine (2X)/AC	0.7	1.0
Amine/AC (2X)	3.7	0.9
Amine (2X)/AC (2X)	3.2	3.4
AC (2X)/amine (2X)	2.2	2.2
AC (2X) only	0	0
Amine (2X) only	0	0
Concentrations: 4g amine in 100 ml H <sub>2</sub> O; 2 ml acid chloride in 100 ml CH <sub>2</sub> Cl <sub>2</sub> ; 2X indicates double concentration of reagents.		
Immersion time: 15 sec		

At add-ons of 1.0-3.4% the PIP/AC system imparted excellent vegetable oil and clean lubricating oil release to the polyester, without impairing the excellent mineral oil release of the untreated fabric. A small improvement (1-2 rating units) was also noted in dirty lubricating oil release. All these effects appeared to fall off when the add-on approached 5%. Soil redeposition was improved 2 rating units at a 1% add-on; again this decreased at higher add-ons (Table 6).

TABLE 6. Characteristics of polyamide coated polyester

Reagents in order of padding	% Wt. gain	Soil release				Soil redep.
		Veg. oil	Mineral oil	Clean lubr.oil	Dirty lubr.oil	
PIP/AC	1.0	5	5	5	2/3	3/4
PIP/AC	2.4	5	5	-	2/3	1
PIP/AC	4.9	3/4	2	-	2	1
PIP/SC	2.2	5	5	1	-	1
HMD/SC	1.2	5	5	1	-	2
HMD/AC	3.7	1	1	-	1	1/2
AC only	-	5	5	-	3	3
PIP only	-	1	5	-	1	1/2
Untreated	-	1	5	1	1	1/2
Solvent only	-	2	4/5	-	-	1

Solvent for acid chloride:  $\text{CH}_2\text{Cl}_2$

Much of the beneficial effect of the treatment appears to be due to the adipoyl chloride, as treatment with AC alone improved vegetable and dirty lubricating oil release as well as soil redeposition. Using SC/PIP, excellent vegetable oil release was seen, but no improvement in the release of clean lubricating oil. HMD with either acid chloride did not improve vegetable and in many cases impaired mineral oil release.

In a dry soiling test, PIP/AC-treated fabrics (1.0 and 3.4% weight gains) were the only samples to show any improvement, and even this was very modest.

Soiling results, overall, were dependent upon the add-on of the specific polymers rather than upon the conditions of deposition.

### Polyureas

In the single step system reacting the long chain aliphatic diisocyanate (DDI) with triethylenetetramine (TETA), tetraethylenepentamine (TEPA) or piperazine (PIP), slightly higher reaction yields were obtained in heat curing than in steaming especially at low application levels (Table 7).

TABLE 7. Polyurea formation on polyester (single step)

Polyamine, 1.0% OWB	% Weight gain	
	Heat cure	Steam
TETA	1.8	1.4
TEPA	1.5	1.0
PIP	1.7	1.2

Diisocyanate: 2.0% DDI

Using the interfacial polymerization technique at constant level of toluene-diisocyanate (TDI) with stoichiometric amount of diamine, the reaction yields followed the order of amine reactivity, *i.e.*, m-xylylenediamine (MXDA) > HMD > PIP. Weight gains were 5-10 times higher using methylene chloride rather than Varsol as solvent for the isocyanate component (Table 8).

Generally all the polyurea coated samples exhibited impaired mineral oil release with no effect on the release of vegetable or dirty lubricating oil or on soil redeposition. (DDI alone also impaired the release of mineral oil.)

TABLE 8. Polyurea formation on polyester (IFP technique)

Monomers in order of application	% Weight gain
HMD/TDI	4.0
TDI/HMD	3.7
PIP/TDI	3.0
TDI/PIP	3.3
MXDA/TDI	6.2
TDI/MXDA	4.8

Concentrations: 3g TDI in 100 ml CH<sub>2</sub>Cl<sub>2</sub>  
 3g PIP in 100 ml H<sub>2</sub>O  
 4g HMD or MXDA in 100 ml H<sub>2</sub>O

### Polyurethanes

Interfacial polymerization was carried out by condensing diethyleneglycol-bischloroformate (DGBC) with HMD, PIP and MXDA. Weight gains were significantly higher if the amine was padded second rather than the reverse. Samples prepared using Varsol as solvent for DGBC exhibited much higher add-ons than those where methylene chloride was used. Reaction yields with the different amines were consistent with their order of reactivity. At least with the DGBC/PIP system, in order to double the add-on, the concentration of both reactants had to be increased; increasing only the concentration of one of the components resulted in much smaller increases (Table 9).

The polyurethanes based on MXDA and PIP improved the release of vegetable oil with optimum results at add-ons of about 4%. All except the MXDA-based polyurethane caused a decrease in mineral oil release. Soil redeposition was essentially unchanged in all cases.



TABLE 9. Polyurethane formation on polyester

Reactants, in order of padding	Solvent	% Wt. gain	Soil release			Soil redep.
			Veg. oil	Mineral oil	Dirty lubr. oil	
HMD/DGBC (4%/3%)	CH <sub>2</sub> Cl <sub>2</sub>	1.7				
DGBC/HMD (3%/4%)	CH <sub>2</sub> Cl <sub>2</sub>	2.9	1	3	1	2/3
HMD/DGBC (4%/3%)	Varsol	2.9				
DGBC/PIP (3%/3%)	CH <sub>2</sub> Cl <sub>2</sub>	2.2				
PIP/DGBC (6%/3%)	CH <sub>2</sub> Cl <sub>2</sub>	1.4				
DGBC/PIP (6%/3%)	CH <sub>2</sub> Cl <sub>2</sub>	2.5	3/4	4	1	1/2
DGBC/PIP (3%/6%)	CH <sub>2</sub> Cl <sub>2</sub>	2.2				
PIP/DGBC (6%/6%)	CH <sub>2</sub> Cl <sub>2</sub>	4.7	5	1	1	1
DGBC/PIP (6%/6%)	CH <sub>2</sub> Cl <sub>2</sub>	4.3				
PIP/DGBC (6%/6%)	Varsol	8.8	3/4	3	1	1
MXDA/DGBC (4%/3%)	CH <sub>2</sub> Cl <sub>2</sub>	2.0				
DGBC/MXDA (3%/4%)	CH <sub>2</sub> Cl <sub>2</sub>	4.0	5	5	1	1
DGBC/MXDA (3%/4%)	Varsol	8.0				
Untreated	--	---	1	5	1	2/3

#### Summary -- surface coating deposition studies

The interfacial polycondensation of piperazine with either adipoyl or sebacoyl chloride to form a polyamide coating resulted consistently in improved vegetable oil release at add-ons up to approximately 3.5%. Improvement in clean and dirty lubricating oil release, soil redeposition and dry soiling was seen, however, only with the piperazine/adipoyl chloride system. Much of the effect seems to be due to the acid chloride, although the choice of amine is critical as hexamethylenediamine as comonomer impaired the excellent mineral oil release of the untreated fabric. Reaction variables such as solvent system, order of padding, etc., did not influence soiling behavior, except as they influenced the total polymer add-on.

Polyurea formation, either by interfacial polymerization or single-step emulsion technique, resulted in no improvements in soil release or redeposition, but did cause severe impairment of mineral oil release at add-ons as high as 4%. Polyurethane formation using a bischloroformate and either piperazine or m-xylylene diamine resulted in improved vegetable oil release, with optimum results at about 4% add-on. However, other soiling properties were either unchanged or impaired.

We may conclude that although a variety of specific polyamide, polyurea and polyurethane coatings on a texturized woven polyester fabric led to improved vegetable oil release in laundering, only a polyamide formed via the interfacial polymerization of piperazine and adipoyl chloride led to improvements in the broad spectra of soiling properties.

#### Experimental -- surface coating deposition studies

Fabric. texturized woven polyester, undyed.

Interfacial polymer deposition. The appropriate acid dichloride, diisocyanate or bischloroformate was padded onto the fabric from Varsol or methylene chloride solution; the diamines from aqueous solution. Amine solutions also

contained sodium carbonate (twice the weight of amine) as acid acceptor and a nonionic surface-active agent (Triton X-100, Rohm & Haas). Immersion times in the pad bath and order of padding were varied. Samples were not dried between or after the paddings; after the second pad they were rinsed in water, dried and, finally, oven-dry weight gains were recorded. In cases where a large amount of visible, flaking polymer remained on the fabric, samples were machine laundered in dilute Triton X-100 solution prior to recording weight gains.

Single-step, in situ polyurea formation. A stock emulsion of 50% DDI 1410 (long-chain aliphatic diisocyanate from General Mills) was prepared by adding the DDI with high speed stirring to an equal weight of an aqueous solution containing 2% anionic surfactant (Igepal CO-530, GAF). Pad baths were then prepared by adding the required amount of DDI emulsion to a diluted amine solution. The padded samples were dried at 65°C and then either steamed for five minutes or cured for five minutes at 150°C. They were washed in dilute Triton X-100 solution at 60°C for fifteen minutes, rinsed and dried.

Soil-release testing. Fabric samples were stained with the specified stains, allowed to remain for one minute under a 2250g weight, then washed at 50°C with a non-phosphate detergent in an automatic home-type washing machine and tumble-dried at medium setting. Within four hours after drying, they were rated (AATCC Method #130).

Wet soil-redeposition testing. A fabric specimen was soiled with an oil-based sludge (3M Company) by placing the specimen with the sludge in a can which was rotated for thirty minutes in a Launder-O-Meter, preheated at 50°C. The specimen was removed and rinsed in cool tap water. Without intermediate drying, the soiled specimen was machine-washed with sufficient amount of detergent to produce good suds, then it was rinsed and tumble-dried at medium setting. The soiled and washed specimen was rated against its prewashed counterpart on a white background using the AATCC Gray Scale for evaluating staining.

Dry soiling. Fabric samples, approximately 7.5 x 12.5cm, were run (two at a time) in a ball mill for ten minutes with pebbles and 10g sieved parking lot dirt. Loose soil was removed with a vacuum cleaner nozzle; samples were rated visually for any change in dry soiling propensity.

#### SOIL RELEASE FINISHES FOR DURABLE PRESS POLYESTER/CELLULOSIC BLENDS

In the case of durable press polyester/cellulosic blends, the resin-treated cellulosic fiber component, with its reduced hydrophilicity, also contributes significantly to the soiling problem. Two main types of finishes have found commercial utility on these blends, i.e. anionic polymers and the dual-action fluorochemicals discussed previously. The most successful of the class of anionic polymers are the copolymers based on acrylic acid and alkylacrylate or alkylmethacrylate monomers (31). Other anionic systems which have been proposed include copolymers of styrene with maleic anhydride or of alkylacrylates with vinylsulfonic or vinylphosphonic acids (32). Acrylic polymers employed as stain release finishes to durable press polyester/cellulosic blends provide the fiber surface with a polar, wettable coating to impart hydrophilic character (31).

A soil release finish has been disclosed based on a combination of fluorochemical emulsion polymer and polyether derivatives such as poly(ethyleneglycol) of molecular weight 660 and the corresponding monomethylether counterpart (33). This combination acts synergistically to produce a substantial improvement in soil release, particularly at high concentrations of the polyether derivative.

Another approach utilizes combinations of fluoro- and acrylic-polymers, applied to the blend fabric in a single treatment bath together with the durable press resin and catalyst (34). Polyether derivatives should also be included in this system to function primarily as compatibilizers for the acrylic acid polymer and other ingredients present in the resin bath. Suitable polyether derivatives for this system include mono- and di-oleates and stearates of poly(ethyleneglycol) of molecular weights from 660 to 3870. The acrylic acid polymers used are copolymers with ethylacrylate or terpolymers with ethylacrylate and acrylamide. Combinations of the components act synergistically to provide substantial and durable enhancement of the soil release

properties. The alkylacrylate-acrylic acid copolymer/fluorochemical system provides excellent performance with sufficient durability of the soil release properties. That the anionic emulsion polymers appear to be more effective than the nonionic polyether derivatives is an observation consistent with earlier work (35). Anionic finishes are more effective than nonionic ones, while cationic finishes may, under some conditions, actually increase the extent of particulate soil attraction and retention.

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