V. Textile Maintenance

19. Textile Soiling and Soil Removal

The maintenance of a textile product after purchase is of prime interest to the consumer and to commercial fabric care operations. The major factor to be considered is cleaning and soil removal of the textile during continued use. In order to have a fuller understanding of the cleaning process, one must examine the nature of textile soils, detergency, and soil removal, and the wet (laundering) or dry (solvent) cleaning processes used.

TEXTILE SOILS

Soils come from a number of sources in the environment that textile structures are subjected to during wear and use. These soils include (1) solid particulate matter (clays, minerals, soot), (2) oil-borne soils (fats, greases, etc.), and (3) water-borne soils (water-soluble salts, etc.). Solid particulate matter such as clays, metal oxides, and soot is often mixed with water- and oil-borne soils but can also soil a textile alone through application in the dry state. When applied from the dry state, these solid soils can often be removed by mechanical action such as brushing and shaking.

Clays in general are complex inorganic silicates with color derived from the structure of the silicate. Oil-borne soils are organic hydrocarbons or related derivatives which are soluble in oils. The aliphatic and aromatic hydrocarbons and fatty acid esters of glycerol are the most predominant oil-borne soils. Less polar hydrocarbons such as mineral oil are more easily removed from textile substrates than are the more polar glycerol esters of fatty acids. Carbon-based matter such as soot is not

completely soluble in most hydrocarbon solvents or oils but must be considered an oil-borne soil. These soils can be removed by solvent (dry) cleaning or through emulsification and removal in laundering systems. Water-borne soils are usually water-soluble inorganic and organic salts or natural proteins and starches and can be readily removed by water-based laundering systems. Soils from foods can be oil- and/or water-borne soils, depending on the composition of the particular food.

DETERGENCY AND SURFACTANTS

Detergency and Soil Removal

Detergency is a term used to specify the ability of an agent to lift and remove soil from a substrate and to suspend the soil within the cleaning media. Agents which aid directly in soil removal are called detergents or surface active agents (surfactants). Since the term detergent has come to mean complex laundry formulates containing several components, the soil lifting components of such formulations will be referred to as surfactants here to avoid confusion.

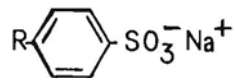
Surfactants are compounds containing an oleophilic (oil-searching) hydrocarbon tail and a hydrophilic (water-seeking) polar head that can effectively aid in wetting of a soiled textile surface, in penetration and removal of the soil from the surface, and in suspension of the soil in the liquid medium. Surfactants are materials which effectively make the transition between the relatively nonpolar hydrocarbon soil and the polar cleaning medium such as water. The hydrocarbon tail of the surfactant associates with the surface of the oily soil, whereas the polar head of the surfactant associates with the aqueous medium, thus making a transition from the oily soil to the aqueous media. When oily soil is lifted from a fiber by the surfactant. the oily soil-detergent combination is suspended as small particles in the medium through micelle formation.

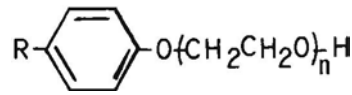
The low-energy micelle formed must be sufficiently stable to permit its removal in the laundering process. Mineral soils, being partially hydrophilic in nature, undergo a more complex process in soil removal. The soil mixes with the surfactant to form a liquid crystal. Additional surfactant forms a complex micelle which includes myelinic tubes to provide sufficient surface area to remove and stabilize the solubilized soil.

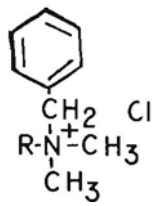
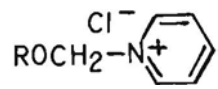
Surfactants

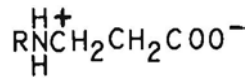
Surfactants are divided into five major classes: soaps, anlonlC, non-ionic, cationic, and amphoteric surfactants. Each contains a hydrocarbon tail and a polar head. Typical surfactants of each class are represented below:

SOAP $R\text{-}COO^{-}Na^{+}$

ANIONIC $ROSO_3^{-}Na +$ 

NONIONIC $RCOO(CH_2CH_2O)_nH$ 

CATIONIC  

AMPHOTERIC 

R=L1NEAR C12-C18 HYDROCARBON CHAIN

Soap: Soap has been known since antiquity as a surfactant for removal of soil from textiles. Soap is readily made by basic hydrolysis (saponification) of animal fats (fatty esters of glycerol). Soap is the resultant sodium salt of the fatty acids, with the composition depending on the source of fatty acid esters. Soap suffers from one major deficiency as a surfactant: in hard water containing calcium and magnesium cations, the sodium ion in soap is replaced by these multivalent ions to form insoluble salts which cannot act effectively as surfactants.

Anionic Surfactants: Anionic surfactants by definition contain an anion (negative ion) as the hydrophilic head of the detergent and are usually sodium, potassium, or ammonium salts of organic sulfonates or sulfates such as alkylbenzene sulfonates or alkyl sulfates. Anionic surfactants are effective in removal and suspension of oily soil and remain soluble in the presence of calcium and magnesium ions. For this reason, they are preferred over soap and are the most used surfactant in laundry formulations. The alkylbenzene sulfonates and particularly sodium dodecylbenzene sulfonate are used in such formulations. In the 1950s, foaming problems in water supplies were attributed to these surfactants due to their low degree of biodegradability. Studies at that time showed that branching of the alkyl group substituted on the benzene ring was responsible for this problem. Reaction conditions for formulation of these surfactants were changed so that the more biodegradable linear alkyl derivative was produced, thereby correcting the problem. Since anionic surfactants tend to foam readily, they are seldom used textile processing.

Nonionic Surfactants: The nonionic surfactants contain a polar head which provides sufficient hydrophilicity to give detergent activity. Polymers of ethylene oxide (called polyethylene glycols or polyethoxyethanols) commonly are used as the polar head attached as the the alkylbenzene or alkyl moiety to form the nonionic surfactant. The hydrophilicity of the ethoxy repeating unit comes from the hydrogen bonding capability of the ether oxygen with water. The nonionic surfactants are used in conjunction with anionic surfactants in some laundry formulations and as wetting agents in many textile dyeing and finishing wet processes.

Cationic Surfactants: Cationic surfactants possess a positive cation and are usually quaternary amine salts. Owing to their high cost, they are less important than anionic and nonionic surfactants in detergent formulations. They are mainly used as fiber wetting agents and as bacteriostats and fabric softeners in selected applications.

Amphoteric Surfactants: Surfactants that have both positively and negatively charged hydrophilic groups within the molecule are referred to as amphoteric surfactants. The detergency of these surfactants varies with pH, and they show bacteriostatic activity at appropriate pH. Amphoteric surfactants are effective leveling agents and aid in controlled diffusion of dyes and finishes onto the fiber.

LAUNDERING AND LAUNDRY FORMULATIONS

Laundering

Laundering is essentially a wet cleaning process in water solvent in the presence of a detergent formulation. The physical parameters, agitation and temperature affect the ease and effectiveness of soil removal. Agitation permits the aqueous surfactant solution to flow through the textile structure, conveying the surfactant to the soil, and aids in removal of emulsified soil from the fabric. As the laundering temperature increases, the surface activity of the surfactant solution increases, which in turn increases the ease and rate of soil removal. Although higher temperatures markedly improve soil removal, the maximum temperature that can be used may be tempered by a number of factors, including the stability of the textile and its washfastness.

The nature of the impurities in the water has a major effect on soil removal from a textile. If the water is hard and contains significant amounts of calcium and magnesium salts as carbonates, sulfates, or chlorides, these salt ions will interfere with the soil lifting action of the surfactant unless appropriate water softening agents are added. Dissolved iron salts or the presence of clays, silts, and other colorants can interfere with cleaning, also.

Laundry Formulation

Laundry powder formulations or synthetic detergents (often called syndets) are complex mixtures of surfactant and other materials including many of the following (average range of composition in syndets in parentheses): surfactant (10-30%), builders and chelating agents (5%-40%), anti-soil-redeposition agents (0.5%-2%), corrosion inhibitors (5%-10%), foam stabilizers and antifoaming agents (0%-5%), electrolytes and fillers (5%-40%), oxygen bleaches (0%-25%), fluorescent brighteners and colorants (0.1%-1%), bacteriostats (0%-2%), perfumes (0%-1%), and moisture (0-10%). The compo-

sition of the detergent formulation will change with the manufacturer and intended use. The liquid detergents are aqueous solutions of similar composition to detergent powders with the following exceptions: (1) the anionic surfactants present will tend to be the more soluble miscible potassium, ammonium, or alcohol amine salts; (2) the nature of added foam stabilizers will differ, and (3) the amount of builder present will be lower. A series of specialized product formulations, including enzymes, bleaches and brighteners, water softeners, etc., also are on the market as auxiliary cleaning agents.

Builders: Builders are salts added to a detergent composition to improve the effectiveness of the surfactant present through complexation or precipitation of calcium and magnesium and other multivalent salts. The builders act through complexation (chelation) with these cations to form a stable complex or through reaction with the cations to form an insoluble salt that precipitates from the wash bath. Complexing builders include the sodium polyphosphates (trisodium tripolyphosphate and tetrasodium pyrophosphate), amine carboxylates, citrates, carboxylate polymers, and zeolite ion exchange resins. These builders all complex with calcium and magnesium ions to form water-soluble complexes (chelates) or suspensions that do not interfere with the action of the surfactant. The polyphosphate builders are the most effective builders but have come under increasing pressure over the last decade due to their role as biological nutrients and contributors to algae growth. The percentage of polyphosphates used in detergent formulations has declined in recent years, but substitutes that are as effective have been difficult to find at a comparable cost. Nitrilotriacetic acid was introduced in the late 1960s as a builder, but adverse factors, including its possible activity as a carcinogen, caused it to be withdrawn from the market.

Precipitating builders include sodium bicarbonate and sodium carbonate, sodium sesquicarbonate (a mixture of the two), and the borate salts. These builders provide basicity and react with calcium and magnesium ions to form the insoluble carbonates or borates. These builders are not as effective as chelating builders. After repeated washes they leave deposits of carbonates mixed with soil on the textile being cleaned. They also may decrease the water absorbency of the textile with time.

Anti-Soil-Redeposition Agents: Soil removal is a dynamic process in which suspended soil may be redeposited on the textile as well as removed during the laundering process. Addition of agents with appropriate soil-repelling functional groups inhibits such redeposition. Carboxymethyl-

cellulose is an inexpensive negatively charged water-miscible polymer that forms a thin deposit or coating on the textile and repels the charged soil-detergent micelle. Other polar or charged water-miscible polymers such as polyvinylpyrollidone are particularly useful on synthetics as effective anti-soil-redeposition agents and can be incorporated with carboxymethyl-cellulose to improve the overall effectiveness of anti-soil-redeposition particularly on synthetic-natural fiber blends.

Corrosion Inhibitors: The basicity and reactivity of ingredients found in laundry formulations lead to attack and corrosion of various metal parts in laundry equipment. To minimize this effect, the sodium silicates are added to the detergent formulation.

Foam Modifiers: Excess foaming during laundering can occur readily due to agitation and can lower the overall effectiveness of soil removal. On the other hand, the consumer views moderate and stable foam formation during laundering as an indication of detergency and soil removal. Two approaches have been used to provide products which meet both of these concerns. Antifoaming agents such as long-chain aliphatic alcohols, emulsified terpenes (naturally occurring alcohols), and organosilicones are used in conjunction with foaming surfactants to lower and moderate foam formation. The second approach has been the use of detergentlike derivatives that modify and stabilize foaming in conjunction with surfactant. These foam modifiers include monoalkylolamine adducts of fatty acids and their polyethylene oxide derivatives.

Electrolytes and Fillers: Inorganic salts such as sodium sulfate are added to laundry formations to bring them up to uniform cleaning strength and to provide appropriate measurable quantities for addition in laundering by the consumer. These materials may be considered fillers but also are electrolytes in solution that serve to enhance to some degree the migration and action of the surfactant as well as improve the physical characteristics of the product.

Bleaches and Fluorescent Brighteners: Oxygen bleaches such as sodium perborate are often added to enhance the whitening power of the formulation through destruction of color centers remaining on the fabric. Fluorescent brighteners are added to nearly all synthetic fibers in manufacture to cover yellow coloration through blue fluorescence of these colorless dyes in the 1ight. Fluorescent brighteners added to laundry formulations are mixtures of brighteners which have affinity for all fiber types commonly found in a wash load. Bleaches and brighteners also can be purchased and

used separately to enhance whitening of the textile substrate. Additional information concerning the structure and action of bleaches and brighteners appears in Chapter 18.

Germicides: Biologically active germicides are added to some syndets and are particularly important in low-temperature laundering, where biological agents are not destroyed by heat. The germicides include cationic surfactants and phenol derivatives as well as natural products such as contained in pine oil. Chlorine bleaches also act as germicides in laundering.

Perfume: Perfumes are added to laundry formulations to mask odors of other ingredients and to convey a pleasant odor which may be suggestive of a natural fragrance or of a clean wash. The perfume has essentially nothing to do with effective soil removal but adds to product aesthetics and aids in consumer acceptance of the product.

Fabric Softener: Fabric softeners are product compositions containing a cationic or nonionic surfactant or a1koxya1ky1amide, and they may be applied during the laundering rinse cycle or transferred to the textile during drying from an inert cellulosic or polyurethane substrate. Liquid softener compositions usually contain alcohol (0%-2%) (to increase solubility of the softeners), softeners (2-8%), surfactant (0-2%), electrolytes (0%-0.25%), fluorescent brighteners (0%-0.32%), germicides (0%-2%), colorants (0%-0.2%), and perfumes (0%-2%). The rest is water. Fabric softener components used in dryers are less complex, containing softener with a carrier and perfume in an inert substrate.

Starches: Starches used to give a textile stiffness and body are usually added during the rinse or applied as a spray after washing. Starches include naturally derived starch, starch derivatives, and acrylic polymer emulsions.

Enzymes: In the late 1960s enzyme presoaks and laundry products containing enzymes were introduced. The proteolytic enzymes contained within the products must have a presoak period to be effective. They act as catalysts is speeding the hydrolytic attack of protein and carbohydrate components in soi1s, breaking them down into more easi1y removed decomposition products. Since oily soils are not readily attacked by the enzymes, their use and effectiveness is limited.

DRYCLEANING

Drycleaning is not carried out under dry conditions at all but rather uses a solvent other than water in the cleaning method. The cleaning is carried out in petroleum hydrocarbon (Stoddard solvent), in a chlorinated solvent (tetrachloroethylene and trichloroethylene), or in a fluorohalocarbon (Freon). Although the solvents will effectively remove saturated or oily soils, the solvent is charged with water plus surfactant to aid in soil emulsification of the more hydrophilic soils. Tetrachloroethylene is the predominant solvent used in drycleaning in the United States. The drycleaning process involves prespotting by an appropriate method to clean any badly soiled areas on the textile. The textile is immersed in the cleaning fluid, and the fluid is circulated through the textile and then filtered through activated charcoal and diatomaceous earth to remove impurities. After a certain period of continued use, the drycleaning solvent is redistilled to remove residual oils and so forth and then recharged with water and detergent. Drycleaning solvents cause less fiber swelling and deformation and have less tendency to remove dye from the textile. Less agitation is involved than in laundering, and drycleaning is therefore preferred for textiles in which water-induced dimensional change will occur. Care must be taken in drycleaning some textiles, since damage may occur due to attack of the fiber, of finishes on the fiber, or of one or more components in the fiber structure.