

CHAPTER 9

REPELLENT FINISHES

Stain Repellency is the ability of a treated fabric to withstand penetration of liquid soils under static conditions involving only the weight of the drop and capillary forces.

Oil Repellency is tested by placing a drop of oil on the fabric and observing whether the drop resides on top the fabric or whether it penetrates. A homologous series of hydrocarbons decreasing in surface tension is used to rate the fabric's oil repellency. The hydrocarbon with the lowest surface tension to remain on top and not penetrate is indicative of the fabric's repellency. The lower the surface tension of the liquid, the better the fabric's resistance to oily stains.

Water Repellency is more difficult to define because various static and dynamic tests are used to measure water repellency. Generally speaking water repellent fabrics are those which resist being wetted by water, water drops will roll off the fabric. A fabric's resistance to water will depend on the nature of the fiber surface, the porosity of the fabric and the dynamic force behind the impacting water spray. The conditions of the test must be stated when specifying water repellency. It is important to distinguish between water-repellent and water-proof fabrics.

Water Repellent Fabrics have open pores and are permeable to air and water vapor. Water-repellent fabrics will permit the passage of liquid water once hydro-static pressure is high enough.

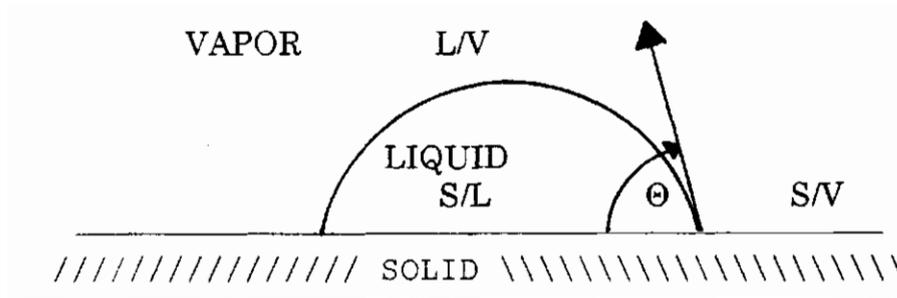
Water-Proof Fabrics are resistant to the penetration of water under much higher hydrostatic pressure than are water-repellent fabrics. These fabrics have fewer open pores and are less permeable to the passage of air and water vapor. The more waterproof a fabric, the less able it is to permit the passage of air or water vapor. Waterproof is an overstatement, a more descriptive term is impermeable to water. A

fabric is made water-repellent by depositing a hydrophobic material on the fiber's surface; however, waterproofing requires filling the pores as well.

I. PHYSICAL CHEMISTRY OF WETTING

When a drop of liquid on a solid surface does not spread, the drop will assume a shape that appears constant and exhibits an angle Θ , called the contact angle. The angle Θ is characteristic of the particular liquid/solid interaction; therefore, the equilibrium contact angle serves as an indication of wettability of the solid by the liquid. As seen in figure 52, the interfacial forces between the liquid and vapor, liquid and solid and solid and vapor all come into play when determining whether a liquid will spread or not on a smooth solid surface. The equilibrium established between these forces determine the contact angle Θ .

Figure 52. Spreading of Liquids on Smooth Surfaces



Where: L/V = the interfacial energy between liquid/vapor
 S/L = the interfacial energy between solid/liquid
 S/V = the interfacial energy between solid/vapor
 Θ = equilibrium contact angle

A. Work of Adhesion

The work of adhesion between the liquid and the solid is given by the Dupre Equation:

$$W_A = \gamma_{SV} + \gamma_{LV} - \gamma_{SL}$$

A liquid drop on a smooth solid surface is subject to the equilibrium forces described by the Young Equation:

$$\gamma_{SV} = \gamma_{SL} + \gamma_{LV} \cos \Theta$$

The relationship between the work of adhesion and the contact angle is derived by combining the two equations (the Young-Dupre Equation):

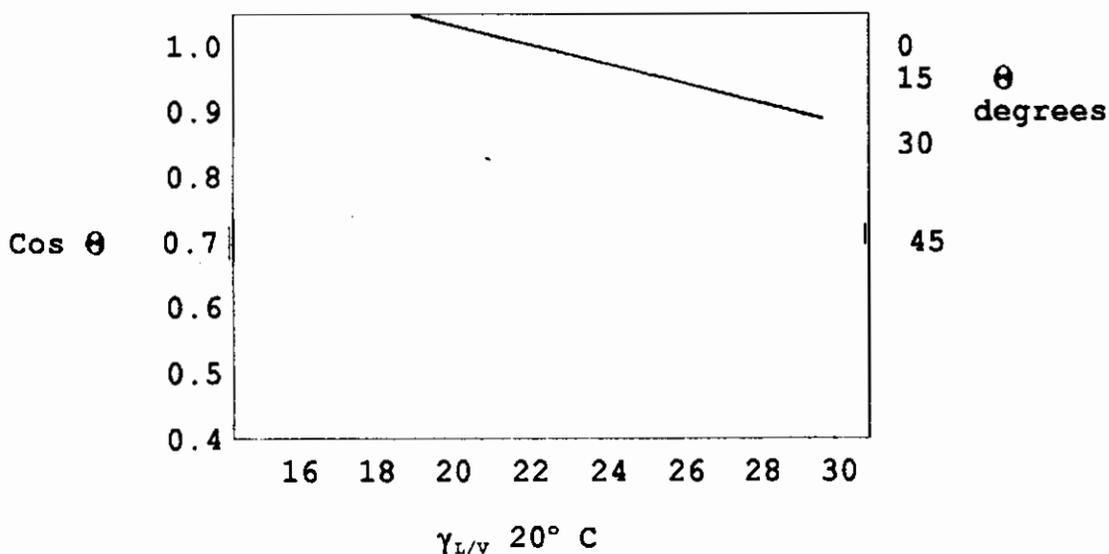
$$W_A = \gamma_{LV}(1 + \cos\Theta)$$

While the interfacial energy between a liquid and its vapor can be measured directly (this quantity is the liquid's surface tension), that between a solid and air cannot. The expression above is useful in characterizing the surface energy of solids. From this equation, it can be reasoned that as the contact angle Θ approaches 180° , the work of adhesion approaches 0, and the liquid drop will not stick. As Θ approaches 0, the work of adhesion increases and reaches the maximum value, $2 \gamma_{LV}$. The surface tension of a liquid that just spreads on a solid ($\Theta = 0$) would be representative of the surface energy of a solid and could be used to describe the surface.

B. Critical Surface Tension

The critical surface tension of a solid γ_c is defined as the surface tension of a liquid that just completely spreads on a surface. This quantity is obtained experimentally by plotting $\cos \Theta$ versus the surface tension of a homologous series of liquids on a low energy surface. γ_c is the value obtained when the curve is extrapolated to $\cos = 1, (\Theta = 0)$. An example of this type of plot is seen in figure 53. The value for teflon extrapolates to 18 dynes /cm.

Figure 53. Critical Surface Tension of Teflon



The critical surface tension of nearly all solid polymer surfaces have been determined. Table 13. lists a few of the more important fiber polymer surfaces.

Table 3

Critical Surface Tensions of Smooth Surfaces

	γ_c <u>dynes/cm</u>
Poly(tetrafluoroethylene)	18
Poly(dimethyl siloxanes)	23
Poly(vinyl fluoride)	28
Poly(ethylene)	31
Poly(vinyl alcohol)	37
Poly(vinyl chloride)	39
Poly(ethylene terephthalate)	43
Poly(hexamethylene adipamide)	46

All of the above polymers are considered hydrophobic because their critical surface tensions are well below that of pure water (72 dynes/cm at 20° C). The critical surface tension is mainly influenced by the outermost layer of atoms at the solid's surface. Zisman and his coworkers measured many condensed monolayers on solid surfaces such as glass and platinum. The technique allow them to closely pack specific groups at the surface and some of their data is tabulated in the Table 14.

Table 14

Critical Surface Tension of End Groups

	γ_c
<u>Fluorocarbon Surfaces</u>	
CF ₃ -	6
CF ₂ H-	15
-CF ₂ -	18
-CF ₂ -CH ₂ -	25
<u>Hydrocarbon Surfaces</u>	
CH ₃ -	23
-CH ₂ -	33

C. Contact Angles in Real Systems

The contact angles observed on ideal, smooth surfaces do not correspond to those found in real systems. Nearly all surfaces exhibit a degree of roughness and textiles, in particular, deviate from the ideal system. The degree of roughness will strongly change the observed contact angles on real systems. Those finishes that yield $\Theta \geq 90^\circ$ when on smooth surfaces will result in much higher contact angles on textiles. Those finishes producing contact angles less than 90° will allow the liquid drop to quickly penetrate into the fabric. This phenomenon is put to good use in repellent fabric treatments since the repellency of textile products appear to be better than the wetting characteristics of corresponding flat films.

D. Repellent Finishes

For fabrics to be water repellent, the critical surface tension of the fiber's surface must be lowered to about 24 to 30 dynes/cm. Pure water has a surface tension of 72 dynes/cm so these values are sufficient for water repellency. This section will be devoted to describing materials that are used mainly as water repellent finishes. In a later section, it will be shown that some of these can be combined with fluorochemical finishes to enhance both water and oil repellency. Oil repellency requires that the fiber surface be lowered to 13 dynes /cm. Only fluorochemicals are able to function as oil repellents so whatever is mixed with them must not interfere with how they are deposited.

II. HYDROCARBON HYDROPHOBES

A. Paraffin Waxes

The oldest and most economical way to make a fabric water repellent is to coat it with paraffin wax. Solvent solutions, molten coatings and wax emulsions are ways of applying wax to fabrics. Of these, wax emulsions are the most convenient products for finishing fabrics. An important consideration in making water repellent wax emulsion is that the emulsifying system not detract from the hydrophobic character of paraffin. Either non-rewetting emulsifiers or some means of deactivating the hydrophilic group after the fabric is impregnated with the finish must be used.

Paraffin wax melts and wicks into the fabric when the fabric is heated. This will cause most of the fibers to be covered with a thin layer of wax, especially those that are exposed to water, and the fabric will have excellent water repellent properties. The major disadvantage of wax water repellents is poor durability. Wax is easily abraded by mechanical action and wax dissolves in dry cleaning fluids. It is also removed by laundry processes.

A typical wax emulsion consists of paraffin wax as the hydrophobe, an emulsifying agent, an emulsion stabilizer (protective colloid) and an aluminum or zirconium salt to deactivate the emulsifying agent when the fabric is heated.

Table 15
Wax Emulsion Composition

	<u>%</u>
Paraffin	17.0
Bone glue	2.5
Al ₂ O ₃	3.0
Formic acid	7.0
Rosin	0.7
KOH (50°Be)	0.2
Water	to 100

The stability of wax dispersions and the durability of wax finishes have been increased by formulating polymers such as poly(vinyl alcohol), polyethylene and copolymers of stearyl acrylate-acrylic or methacrylic acids. Wax finishes are usually co-applied with durable press reactants which also adds to the repellent's durability while imparting durable press properties.

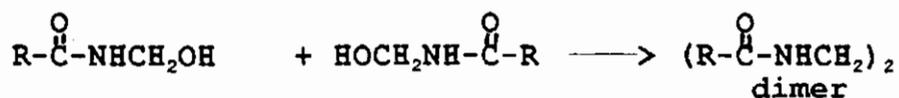
B. Fiber Reactive Hydrocarbon Hydrophobes

1. N-Methylol Stearamide

In an effort to improve the durability of hydrocarbon based water repellents, several approaches incorporating reactive groups have found commercial success. The simplest of these is N-methylol stearamide. Stearamide reacts with formaldehyde to form the N-methylol adduct. This adduct is water dispersible and either will react on curing with cellulose, dimerize or react with crosslinking reagents that are co-applied.

a. Synthesis and Reactions

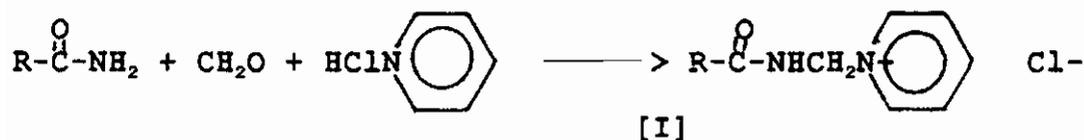




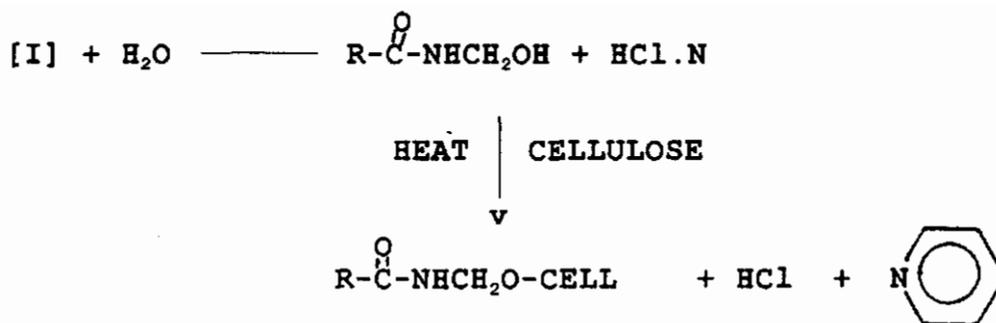
2. Pyridinium Compounds

A variation of N-methylol stearamide is the pyridinium type water repellents. These were once very popular and used extensively as reactive type water repellent finishes. Toxicological considerations have curtailed the use of pyridinium-type water repellents. Workers at the US Army Quartermaster Corp discovered that pyridinium type water repellents co-applied with fluorochemical repellents resulted in a synergistic effect by providing good, long-lasting water repellency for military fabrics. The finish was durable to field laundry procedures and named Quarpel by its inventors. The concept of adding wax type water repellents to fluorochemical repellents has been broadened and other wax type called *Extenders* are used with fluorochemicals. More on extenders will be included in the section dealing with fluorochemical repellents.

a. Synthesis and Reactions



This product is self emulsifiable because of the ionic nature of the pyridinium quat. After it is applied to cellulose fabrics and cured, the pyridinium hydrochloride serves as the catalyst to promote the reaction of the N-methylol group with cellulose.

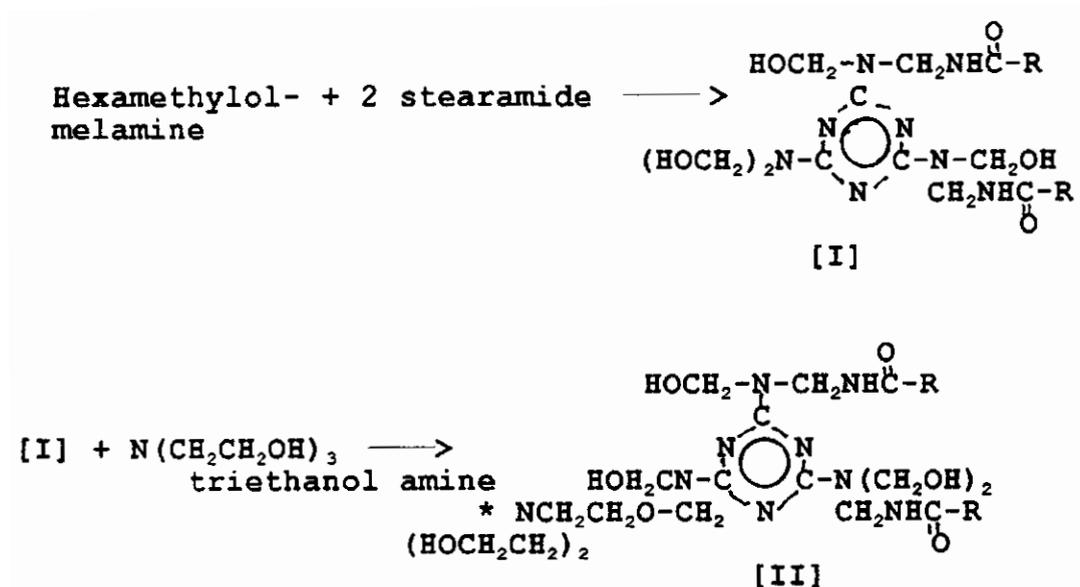


3. Resin Formers

The multiple reactive sites on methylolmelamines can be utilized for making resin-forming water repellents. The reactivity of stearamide with formaldehyde can be utilized for attaching hydrophobic groups to the melamine molecule. Part of the N-methylol groups are used to attach the hydrophobe, some are used to add a cationic site for emulsification purposes and some of the N-methylol groups are later involved in self condensation to form a resinous coating on the fiber surface or to react with

added durable press reagents. An example of this type:

a. Synthesis of Melamine Wax Type Water Repellents



The *N nitrogen in becomes cationic when acidified and serves to self-emulsify the resultant waxy material. R- groups provide hydrophobicity and the remaining N-CH₂OH groups in the melamine react with the OH groups brought in by the triethanol amine to form a crosslinked, three-dimensional polymer on the fiber surface.

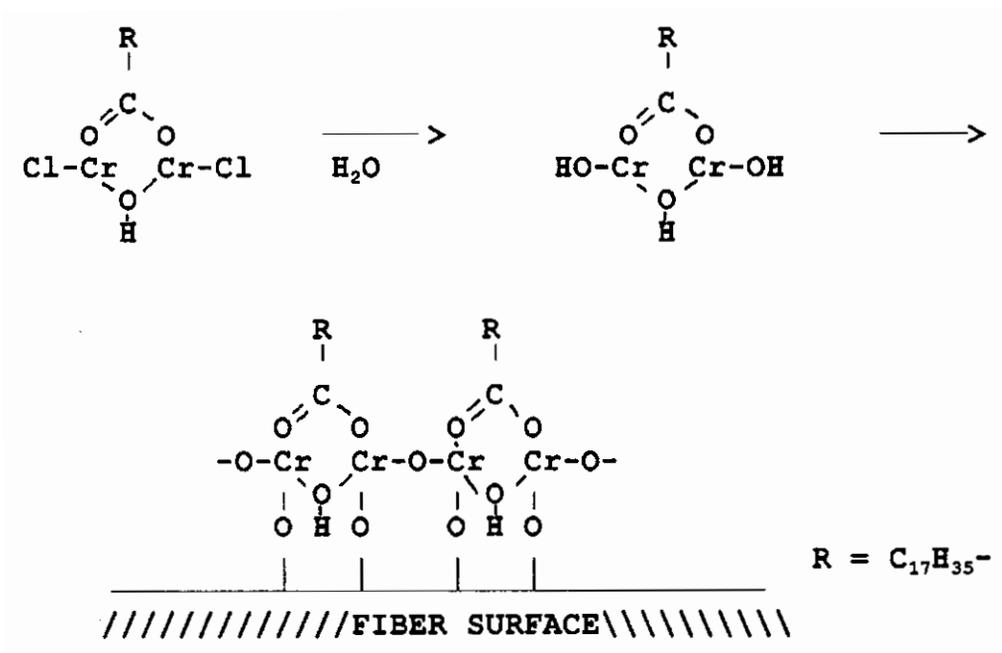
Compound [II]'s water repellency can be enhanced by incorporating paraffin wax with it. Paraffin is blended with [II] when molten. The resultant wax is sold as a solid which is emulsified prior to use. Emulsification is accomplished by melting the composition in hot water and adding tartaric or citric acid while stirring. The creamy emulsion is cooled while stirring and is ready for use. The acid also serves as the catalyst for curing the melamine.

4. Metal Complexes

Werner-type chrome complexes of stearic acid have been marketed under the trademark Quilon by DuPont. These products are especially effective on fiberglass since they can react with the glass surface. The product is made by reacting stearic acid with basic chrome chloride in an isopropanol solution. The product is diluted with water just prior to being applied to fabric causing the complex to hydrolyze.

acid with basic chrome chloride in an isopropanol solution. The product is diluted with water just prior to being applied to fabric causing the complex to hydrolyze. During application, the polymerization is not allowed to proceed so far as to cause precipitation of the polymer. On standing or when heated, the complex will polymerize to form -Cr-O-Cr-O-Cr- bonds. When the fabric is cured at 150-170° C, further polymerization of the complex occurs bonding the inorganic portion to the fiber surface. This will cause the hydrophobic tail to orient perpendicularly away from the surface, providing water repellency to the fabric.

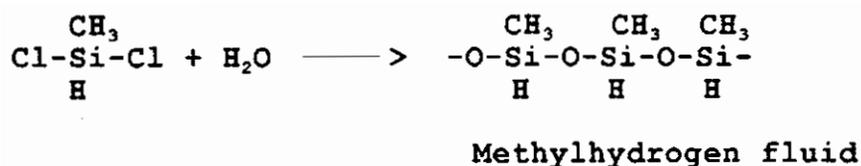
a. Synthesis and Reactions



III. SILICONE WATER REPELLENTS

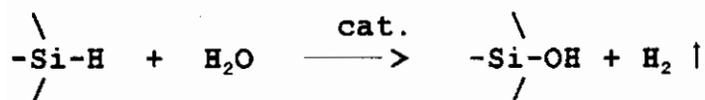
Resinous polysiloxanes, on the other hand are more resistant to abrasion and less soluble in dry-cleaning fluids or laundry products. Three-dimensional crosslinked polysiloxanes fill the need provided they could be applied to fabrics. Methylhydrogen-dichlorosilane offers a route for making a linear polysiloxane fluid with latent crosslinking potential. Hydrolysis of the dichloro groups will occur rapidly with water to form a linear polymer. As long as the aqueous pH is maintained between pH 3-4, stable emulsions can be prepared. When these emulsions are applied to a fabric with a tin catalyst (e.g. dibutyltin-dilaurate), the Si-H group hydrolyzes to the silanol and condenses to a three-dimensional resinous polymer, making the fabric highly water repellent.

A. Synthesis of Methyl Hydrogen Fluids



B. Crosslinking Reactions

1. Hydrolysis of Si-H



2. Condensation of Silanols



The resinous finishes formed by polymethylhydrogensiloxanes give a harsh fabric handle. Polydimethylsiloxanes are usually mixed in to make a more pliable film, the dimethyl fluid acts as a plasticizer. Fabric hand can be controlled by the relative amounts of each component. It should be noted that softer films are not as strong as the more highly crosslinked ones so durability is traded for softness.

C. Application to Fabrics

Silicone finishes are applied to fabrics either from an organic solvent or from water as an emulsion. When cationic emulsifiers are used to make an emulsion, the finish may be applied by exhaustion since the negative fiber surface charges attract positively charged particles. Generally however, silicone water repellents are co-applied with a durable press finish. Durable press resins enhance the durability of the water-repellent finish. Silicone repellents are also used to make upholstered furniture stain repellent. Chlorinated solvent solutions are sprayed onto upholstery by the retailer as a customer option. The fabric is resistant to water borne stains such as coffee and soft drinks.

D. Advantages and Disadvantages

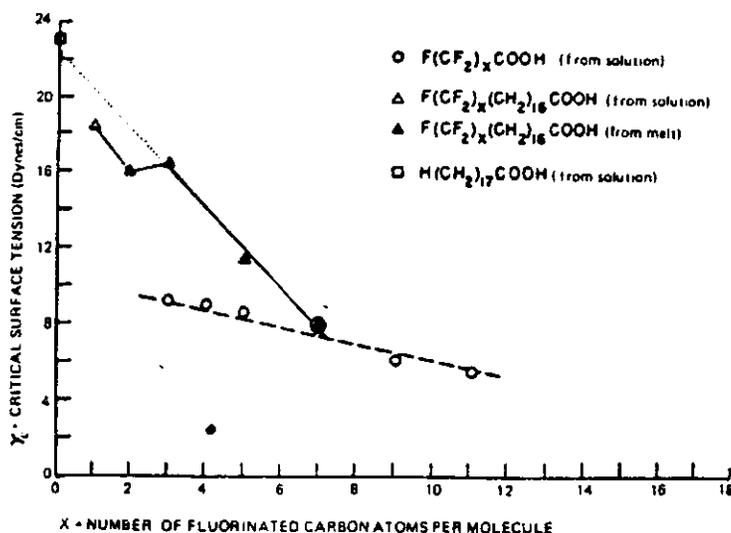
Silicone water repellents are durable to washing and dry-cleaning. Durability

is brought about by the formation of a sheath of finish around the fiber. If the sheath cracks, durability is lost. Adsorption of hydrophilic substances found in dry cleaning and laundry products also impair water repellency. Silicones are more durable than wax repellents but less durable than fluorochemical finishes. Silicones are more expensive than wax repellents and less expensive than fluorochemical repellents. Silicone finishes resist water borne stains but not oil borne stains. Fabric hand can be made soft and pliable.

IX. FLUOROCHEMICAL REPELLENTS

Fluorochemical repellents are unique in that they confer both oil and water repellency to fabrics. The ability of fluorochemicals to repel oils is related to their low surface energy which depends on the structure of the fluorocarbon segment, the non-fluorinated segment of the molecule, the orientation of the fluorocarbon tail and the distribution and amount of fluorocarbon moiety on fibers. Low surface energy can be described in critical surface tension terms. The relationship between γ_c and structure of the fluorocarbon can be seen in the figure 54. The data was obtained by adsorbing monolayers of carboxylic acids onto a smooth surface.

Figure 54. Effect of Fluorination on Critical Surface Tension



Curve A shows that as the length of fully fluorinated carboxylic acid's tail (R_f) increases, γ_c decreases. Starting with perfluoro butyric acid, γ_c slowly decreases as the perfluoro tail increases ranging from 10 down to 6 dynes/cm for perfluorododecanoic acid. Curve B shows the effect increasing the R_f portion of a

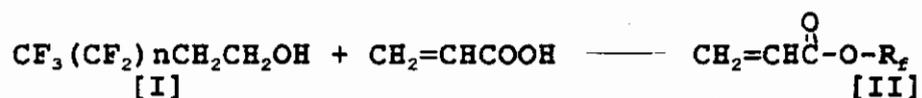
long-chain hydrocarbon acid. Octadecanoic acid measures 23 dynes/cm. Once seven outermost carbon atoms are fully fluorinated, the wettability approaches that of the corresponding perfluorocarboxylic acid, 10 dynes/cm. A terminal perfluoroalkyl chain of seven carbons is sufficiently long to shield non-fluorinated segments beneath the fluorinated segments.

A. Commercial Products

Commercial fluorochemical repellents are fluorine-containing vinyl or acrylic polymers. This is a convenient method of affixing perfluoro side chains to fiber surfaces that can orient air-ward and give a reasonably close packed surface of $-CF_2-$ and $-CF_3$ groups. For example, acrylic acid can be reacted with a perfluoro alcohol to form the corresponding acrylate ester. The acrylate monomer will polymerize to form a high molecular weight polymer that can be converted to an emulsion. The emulsion dries to a continuous film, covering the fiber surface. The perfluoro segment is there as a side chain attached to the polymer backbone. Being nonpolar, it will want to orient away from polar forces, thus forcing itself toward the air interface. Heat facilitates the orientation by increasing molecular motion.

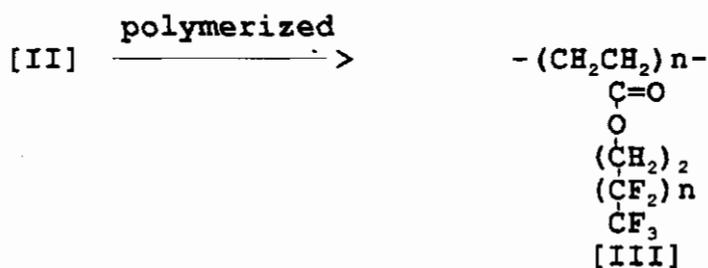
1. Synthesis and Reactions

a. Monomer Synthesis



where $\text{R}_f = \text{[I]}$

b. Emulsion Polymer Synthesis



C. Effect of Polymer Backbone

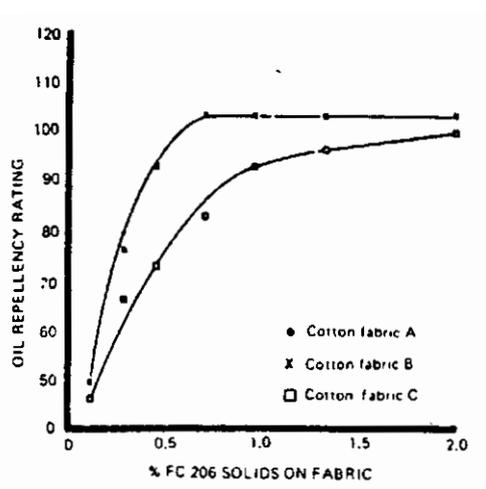
There are many articles and patents in the literature discussing a wide variety of fluorinated structures, polymers and copolymers and how they relate to repellency. It is beyond the scope of this book to review the subject in detail. However it is generally recognized that the polymer backbone must be such that it can be efficiently applied to fabric. In theory, only a one molecule thick coating is necessary to cover the fiber surface. Those polymers that lend themselves able to be spread will be more effective than those that don't. The polymer must adhere well to the fiber surface and must possess good resistance to abrasion and/or being swollen or otherwise affected by dry-cleaning and laundry products.

To achieve suitable commercial products, hydrocarbon monomers are often copolymerized with the fluoromonomers, and/or hydrocarbon polymers are admixed with the fluoropolymers. While this flies in the face of logic (diluting the fluorine content should increase the critical surface tension), the truth of the matter is that the hydrocarbon component improves both water and oil repellency over the fluoropolymer component alone. The reason for this is that the hydrocarbon portion helps in spreading the fluorochemical and reduces the temperature needed to allow the fluorinated tails to orient. It is good that this is so because fluorinated products would be prohibitively expensive as fabric finishes.

D. Add-on

The amount of fluorochemical needed to achieve oil repellency is relatively low. Figure 56 shows that on many fabrics, an add-on of 0.5% is sufficient to give optimum results.

Figure 23. Oil Repellency versus Fluorochemical Add-on



E. Extenders

Extenders are wax-type water repellents that are formulated into the fluorochemical finish bath to improve both cost and performance of the finish. The pyridinium wax type was the first to be used. In recent years, fluorochemical repellents and extenders have been co-applied with durable press resins, all in the same bath. Durability of the finish is improved, repellency ratings are better and the finish cost is lower. Extenders serve to help spread the fluorochemical more efficiently over the fiber surface. Early experiments showed that effective extenders allowed the fluorinated tail to orient air-ward essentially acting as if the hydrocarbon material was not there. Silicone repellents reduce the fluorochemical's oil repellency and are not used as extenders.

V. REPELLENT FINISHING WITH FLUOROCHEMICALS

The oil and water repellent features of fluorochemical polymers lead to finishes applicable in two consumer product areas, durable rainwear fabrics and stain/soil resistant products. For rainwear products, superior durability to repeated laundering and drycleaning is the major advantage. For stain and soil resistance, the plus features are the fluorochemical's ability to prevent oils from penetrating into the fabric or from soils sticking to the fiber surface. Most fabric stains are caused by liquids depositing coloring matter on the fabric. Water borne stains can be held out by silicone water repellents; however, oil based stains can only be repelled by the low surface energy of closely packed fluorocarbon tails. For textiles that cannot be laundered, e.g. upholstery fabrics and carpets, stain and soil repellency is an important consumer plus. For fabrics that can be laundered or dry cleaned, stain removal is more important than stain prevention. Finishes designed to facilitate soil removal by laundering will be discussed in a later section.

A. Rainwear

A typical formulation for polyester-cotton rainwear and outerwear is shown in Table 16. The finish is applied by padding the formulation onto fabric, drying at 120°C and curing 1-3 minutes at 150-182° C. The fabric will give a 100 spray rating initially and an 80 rating after 5 home laundering-tumble drying cycles. An 80 spray rating is expected after one dry cleaning cycle. In addition, oil repellency rating of 5 initially and 4 after laundering or dry cleaning is expected.

Table 16

Typical Rainwear Formulation

	<u>% Bath Conc.</u>
Fluorochemical product	2.0 - 3.0
Resin wax water repellent	2.0 - 3.0
DMDHEU	10 - 15
MgCl ₂ catalyst	2.5 - 4.0
Polyethylene softener	0.5 - 2.0
Non-rewetting surfactant	0.03 -0.05
Acetic acid	0.05 -0.1

B. Stain and Soil Retardancy

1. Upholstery Anti-Soil Finishes

Objectionable soiling of upholstery fabrics is that brought about by spilled liquids. A finish giving maximum water and oil repellency allows the consumer to wipe away the spill before it penetrates into the fabric. Fluorochemical finishes facilitate spot cleaning of any stain that is rubbed into fabric. Solvents are best used for removing oily stains. Solvent soluble fluorochemical finishes can be applied at the mill or at the retail store. Water based fluorochemicals can also be applied to upholstery fabrics. However, they must be heat treated to optimize the orientation of the fluoro tails for maximum repellency. For this reason, water based finishes are best applied in a finishing plant. Solvent based finishes are preferred for aftermarket treatments because heat isn't needed to assist the orientation of the tails, evaporation of the solvent under ambient conditions is sufficient.

Oily stains rubbed into repellent treated washable fabrics present another problem, they are much more difficult to remove than if the repellent finish wasn't there at all. For washable fabrics, a very special fluorochemical has been developed which gives both oil repellency and stain release. This will be discussed in detail in the next chapter.

VI. CARPET ANTI-SOIL TREATMENTS

A. Fluorochemical Finishes

One area where fluorocarbon finishes have met with consumer acceptance is soil retardant finishes for carpets. In this application, oil repellency per se is not what brings about the improvement, it is the fluorocarbon's extremely low surface energy which prevents soil particles from sticking to the fibers. The finish provides an anti-adhesive coating to the fiber. To function properly, the fluoropolymer must provide low critical surface tensions and at the same time be hard enough not to deform when soil particles are pressed into it. Carpet soiling is mainly hard particulate matter tracked onto the face yarns by foot traffic, the soil transfers from the shoe sole and is ground into the carpet. Polyacrylic fluoroesters tend to be soft and rubbery. While they provide the needed low surface energy, they in fact worsen carpets soiling because they deform under pressure trapping the soil particle like fly paper traps flies. This makes it even more difficult to clean the carpet. Fluorocarbon finishes that work well as carpet soil retardants have been modified to overcome the flypaper effect. Some are fluoroesters of pyromellitic acid. These products can melt at curing temperature and efficiently spread over the carpet's face yarn. At room temperature they solidify into hard, flexible low energy coatings. The way these finishes work improve carpet soiling are: 1 They reduce the transfer of soil from the shoe sole onto the carpet's face yarn. This is a function of the fluoropolymer's low surface energy. 2. They reduce the work of adhesion between the soil particle and the fiber surface. The particle tends to fall to the carpet backing and not be as visible. Reduced adhesion allows the particle to be more easily removed by vacuuming. 3. Oil repellency prevents oily surfactants from wicking up onto the face yarns from the carpet backing. Oily films on the face yarns speed up the entrapment of foot soil and the carpet will appear to be soiled much sooner than if the surfactant was not there. Shampooed rugs will appear dirty much sooner than the original unless care is taken to flush out the residual detergent. Fluorochemical treatments improve this tendency.

B. Other Carpet Antisoil Treatments

1. Light-Scattering Fibers

A new generation of soil-hiding carpet fibers have been commercialized in recent years. These fibers have been modified to enhance light scattering. As the apparent surface area of a fiber is increased, its ability to scatter light increases and the fiber becomes more opaque. Soil particles become more difficult to see therefore the carpet appears cleaner. Changing the fiber's cross section is one way of increasing light scattering. Unfortunately as light scattering increases, so does the area where particles can reside. Trilobal fiber cross sections scatter more than do

round. Another method of increasing light scattering is to create holes in the fiber cross section. By keeping the cross section round, the surface area for attracting soil is at a minimum, while the internal voids provide the needed surfaces for light scattering. These modifications do not really retard soiling, they fool the consumer into thinking the carpet is cleaner than is actually so. However, these fibers have met consumer acceptance and are becoming a major force in high quality carpets.

B. Stain Blockers

Certain water borne food stains are actually acid dyes, for example the colorants in Kool Aid and cola soft drinks. Repellency of even the best of fluorocarbon treated nylon carpets will eventually be overcome by these liquids. The coloring matter will be adsorbed by the nylon fibers much the same way as nylon adsorbs acid dyes. The net effect is that these liquids are responsible for stains that cannot be prevented or removed from the best of the anti-soil products described above. A very recent innovation is the introduction of *stain blocking* technology that render nylon carpets resistant to these stains as well. The technology involves the treatment of nylon carpets with certain *Syntans* that tie up the remaining amino groups responsible for attracting food colors. Syntans are synthetic tanning agents that are used to improve the wet fastness of acid dyed fibers, e.g. wool, leather, silk and nylon. The ones that work best on carpets are sulfonated novolaks, polymethacrylic acids and combinations of the two. The treatment can be applied by the fiber producer as part of the spin finish with fluorocarbon finishes to give the "ultimate" in carpet soil/stain protection or by the carpet manufacturer after the dyeing step. While the syntans are known to impart dye resist to nylon, the ones used are effective at room temperature allowing the pretreated fiber to be dyed at elevated temperatures. The technology has improved to the point that newer versions withstand the hot dyeing conditions without loss of the finish during dyeing.

VII. REFERENCES