CARE PRACTICES FOR FLUOROCARBON TREATED GARMENTS: A CASE STUDY

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Introduction

"Consumers today demand that clothes and other textile products smell nice, stay fresh, feel comfortable, keep clean and are easy to care for, all the while looking great."[1] Consumers expect high quality performance garments to meet their needs, to save time, to look good and be durable, all for an affordable price point.

High performance textiles are no longer restricted to the industrial or institutional textile markets. The media is flooded with high-tech claims associated with consumer products, such as fabrics that eliminate odors, moisture management systems and thermal adaptive fabrics. For example, in the spring and summer of 2002, Savane®, Dockers®, Lee® Jeans and Haggar®, all leading manufacturers of men's and women's pants, offered products with stain repellent finishes. Ads on TV and the Internet promoted a new treatment on a khaki fabric that enables stains to just roll off the pants. Kristen Thomas, Vice President of Nano-Tex pours coffee, red wine and tea with milk on a pair of beige colored cotton pants… and the three solutions bead up on the garment's surface and are wiped off with a quick brush of the hand.[2]

The technology behind these claims is a fluorocarbon finish that imparts a high-tech performance fabric protector, which enables the fabric to repel spills and stains on contact. Fluorocarbons, recognized worldwide for the superior non-stick properties as a coating on cookware, have today gained widespread acceptance as a soil and stain repellent and release finish for fabrics. The finish was first used in home furnishings and later in outdoor apparel and now it is being used as a finish in virtually every type of fabrication, from silk to all cottons. As the treatment process has been refined, the applications of fluorocarbons as a stain repellent and stain release have expanded.

In the past, stain repellent finishes altered the properties of a fabric by applying a coating or covering to the fibers. The treatments gave the fabric a stiff hand or caused other performance problems. Today the chemistry and/or the application process have changed. Instead of dissolving a substance in water and putting it on the fabric, they are applied at the molecular level and become a part of the fiber itself. The fluorocarbon stain repellent finish penetrates the individual fibers forming an invisible barrier, allowing stains and/or soils to be removed easily without affecting other properties of the fabric. The finish imparts water repellency and stain resistance as it alters the surface properties of the fabric. Not only is the finish undetectable by sight and touch, it improves the cleanability.

Fluorochemicals, known for their outstanding surface properties, are now used to finish apparel fabrics, such as the classic twill woven khaki used in pants for consumers of all ages. It is a technology that brings about a carefree fabric with wrinkle resistant, shrink proof, water and stain repellent properties. The technology is seen as the next-generation of finishes. It is one step ahead of methods that simply give wrinkle resistance and dimensional stability.

According to the claims, the functionality level of stain repellency is maintained for up to 30 home launderings, with a water repellency rating of 80 (4) and oil repellency of 4 even after 20 washes. Heat treatment, such as through ironing or tumble drying, is required for the onset of water-and-oil repellency. The process prevents stains from penetrating fibers, so liquids can be blotted up quickly and dust and soil can be easily wiped off and stains are released in the wash.

A challenge for all players in the industry today is 'maintaining a balance between hype and science.' Do the treated fabrics need special cleaning care? Are the finishes durable? To meet the challenge and answer these questions, the technical committee of the Clothes Care Research Center™ (CCRC) decided to investigate one of the fluorocarbon treated stain repellent khakis. CCRC is a cooperative effort among Cotton Incorporated; GE Consumer Products; Milliken & Company; Procter & Gamble; VF Imagewear; the University of Kentucky's Textile Testing Laboratory and Northwestern University's McCormick School of Engineering and Applied Science. The members represent every phase of clothing care in the home, from textiles and apparel to appliances and detergents. The mission of CCRC is to understand, evaluate and improve clothes care in the home.

An investigation of fluorocarbon treated garments to assess the recommended care instructions was selected as a CCRC research project. A leading brand of fluorocarbon treated pants was selected. The following instructions were recommended either on a hangtag, a care label attached to the pants, or the Internet website for this product.

"_____ should provide stain repellency for approximately 30 washings. Follow care instructions for optimal performance. Machine wash, warm with a liquid detergent. Tumble dry, durable press cycle, remove promptly. Do not use fabric softener or dryer sheets. Wash and dry with like colors. For best stain repellency, iron after fifth washing."

The objective of CCRC's research project was to benchmark the current practice for care of fluorocarbon treated garments. Current practice was defined as the existing technology from each member of the team applied to the care instructions on the stain repellent finished pants.

Experimental Design

A factorial research design was used to evaluate the aesthetic and functional characteristics of fluorocarbon treated khaki pants. The characteristics of stain repellency and stain release, colorfastness, smoothness and edge abrasion were evaluated at wash/dry intervals of 10, 20 and 30 cycles. The effects that fabric softener, water temperature, and detergent type had on the aesthetic and functional performance of the finish were factors included in the research design. One hundred and twenty pairs of fluorocarbon-treated, stain resistant khakis, consisting of 60% cotton/40% polyester were purchased from a national retail department store in sizes ranging from W33 x L30 to W44 x L30. One hundred and eight garments were cleaned according to the specified conditions of the experimental design. The additional garments were retained as controls.

Cleaning Procedures: Based on input from each CCRC's corporate industry experience, the following conditions were selected to represent a typical consumer practice.

- Vertical axis washing machine and electric dryer.
- Each load of laundry included 6 garments: Weight 7 ½ lbs.
- Detergent –
    - 10, 20 and 30 wash cycles
        - A leading national brand of liquid detergent– 98 grams
        - A leading national brand of powder detergent – 63 grams
    - Wash cycle for stained pants
        - Liquid detergent – 148 grams
        - Powder detergent – 120 grams
- Fabric Softener –
    - A leading national brand of liquid fabric softener - 30 grams
    - A leading national brand of fabric softener dryer sheets – 1 sheet per dryer load
- Temperature: Wash temperature was determined by the experimental design. All loads used a cold-water rinse.
    - Warm – 90˚ F
    - Cold – 65˚ F
- Cycle Profile
    - Washer - Easy Care/Perm Press cycle as per recommended garment care label
        - Soil Level – Medium
        - Wash Speed – Medium
        - Spin Speed - Fast
        - Water Usage – Load size large - 21 gallons of water per wash & rinse cycle
        - Water hardness – 9.5 grains
        - Time – 37 minutes of total cycle
    - Dryer – Easy Care/Perm Press Sensor Dryer Plus
        - Dryness Level – Dry
        - Heat Setting – Medium
        - Time - 56 minutes dry time

A three 'block' research design (Table 1) enabled the evaluation of detergent and fabric softener, water temperature, ironing and orientation of garment. Block 1 conditions were without fabric softener as is specified by the care instructions on the fluorocarbon treated khakis. Block 2 included liquid fabric softener. The third block included dryer sheet fabric softener.

Table 1. Experimental Research Design

Block	Pants Code	Wash Temperature	Detergent Formulation	Fabric Softener
1	CLN	Cold	Liquid	None
1	WLN	Warm	Liquid	None
1	CPN	Cold	Powder	None
1	WPN	Warm	Powder	None
2	CLD	Cold	Liquid	Liquid/washer
2	WLD	Warm	Liquid	Liquid/washer
2	CPD	Cold	Powder	Liquid/washer
2	WPD	Warm	Powder	Liquid/washer
3	CLB	Cold	Liquid	Dryer Sheet
3	WLB	Warm	Liquid	Dryer Sheet
3	CPB	Cold	Powder	Dryer Sheet
3	WPB	Warm	Powder	Dryer Sheet

Experimental Design of Care Procedures: For each condition code (e.g. XXX), nine garments were coded XXX-1 through XXX-9. For example in Block 1, garments that were tested with Cold wash, Liquid Tide, and No fabric softener were coded CLN-1 through CLN-9. Pant loads were the same for both washer and dryer. The selections of garments for each load and ironing procedures are described below.

- Within each block, six garments for each condition (e.g. CLN, WLN, CPN, and WPN) were washed and dried utilizing the conditions specified in Table 1, until all four sets of six garments had been subjected to 5 cycles. The six garments with the same code were always washed and dried together.
- Garments numbered 1, 4, and 7 were washed inside out. All other garments were washed right side out as specified by the garment care label.
- After the 5^{th}, 10^{th}, 15^{th}, 20^{th}, 25^{th} and 30^{th}, wash/dry cycle, the right pant leg of each garment was ironed (right side out) with the crease placed flat on an ironing board. Both sides of the right leg were ironed up to the intersection of the crotch seam.
    - Rowenta® Precision Iron – Synthetic Setting
- After 10 wash/dry cycles, Garments 1-3 for each condition were pulled to represent the 10 cycle performance. The right leg of each garment was ironed prior to performance evaluations.
- Garments 7, 8 & 9 were then added to the load. Garments 4-9 for each condition were washed together for 20 more cycles.
- After 20 more wash/dry cycles:
    - Garments 4-6 for each condition represented a 30-wash/dry-cycle performance.
    - Garments 7-9 for each condition represented a 20-wash/dry-cycle performance.

Table 2 summarizes the experimental design for washing and ironing in the first block. A total of 36 pants were washed and dried without the use of a fabric softener. The research design enabled CCRC to evaluate two types of detergent formulations, liquid and powder, two wash water temperatures

(warm and cold) and the effects of ironing and orientation of the garment, that is inside out or right side out. Blocks 2 and 3 were run in a similar manner with the addition of liquid fabric softener and dryer sheets respectively.

Table 2. Experimental Design of Washing and Ironing Procedures – Block 1

Action	CLN Cycles	WLN Cycles	CPN Cycles	WPN Cycles
Cycles 1-5	**CLN 1-6**	**WLN 1-6**	**CPN 1-6**	**WPN 1-6**
Iron	All right legs	All right legs	All right legs	All right legs
Cycles 6-10	**CLN 1-6**	**WLN 1-6**	**CPN 1-6**	**WPN 1-6**
Iron	All right legs	All right legs	All right legs	All right legs
Cycles 11-15	**CLN 4-9**	**WLN 4-9**	**CPN 4-9**	**WPN 4-9**
Iron	All right legs	All right legs	All right legs	All right legs
Cycles 16-20	**CLN 4-9**	**WLN 4-9**	**CPN 4-9**	**WPN 4-9**
Iron	All right legs	All right legs	All right legs	All right legs
Cycles 21-25	**CLN 4-9**	**WLN 4-9**	**CPN 4-9**	**WPN 4-9**
Iron	All right legs	All right legs	All right legs	All right legs
Cycles 26-30	**CLN 4-9**	**WLN 4-9**	**CPN 4-9**	**WPN 4-9**
Iron	All right legs	All right legs	All right legs	All right legs

Performance Measurements: For each condition, after the 10^{th}, 20^{th} & 30^{th} wash/dry cycles were complete, pants were evaluated for the performance measurements of appearance and stain repellency. The following test methods were used.

- Evaluation of Appearance Characteristics
  - Appearance of Garments After Repeated Home Laundering –
    - Color Change Rating – AATCC Gray Scale for Color Change
    - Edge Abrasion Rating – AATCC 124 Subjective Assessment
  - Smoothness Rating – AATCC 124-1996
- Evaluation of Stain Repellency _
  - 3M Oil Repellency Test I – Hydrocarbon Liquids of known Surface Tension
  - 3M Water Repellency Test II – Water/Alcohol of known Surface Tension
  - Water Repellency: Spray Test (AATCC #22-2001)

To assess the effect of ironing, all performance evaluations were made on both the right and left pant legs. The section of the pant legs below the crotch seam was the only area examined when conducting the performance evaluations.

Stain Release Evaluation: After the pants were evaluated for performance, the pants were shipped to Procter & Gamble for application of stains to evaluate stain release. Each pant leg, for all 108 garments, was stained and return shipped to the University of Kentucky. Six stains - bacon grease, orange juice, chocolate sauce, spaghetti sauce, grape juice and dirty motor oil - were applied to both the right and left pant leg of each garment to test the effect of ironing every 5 cycles. (The right leg had been ironed periodically according to the design.) Staining and testing for each block was done at the same time, resulting in three rounds of staining and testing.

- All stained pants were washed one time, according to the conditions of the block, except the amount of detergent was increased.
    - Liquid detergent– 148 grams
    - Powder detergent– 120 grams
- After washing, the pants were hung to dry before being evaluated for stain release.
- Stain Release Rating per AATCC 130 Soil Release Method.

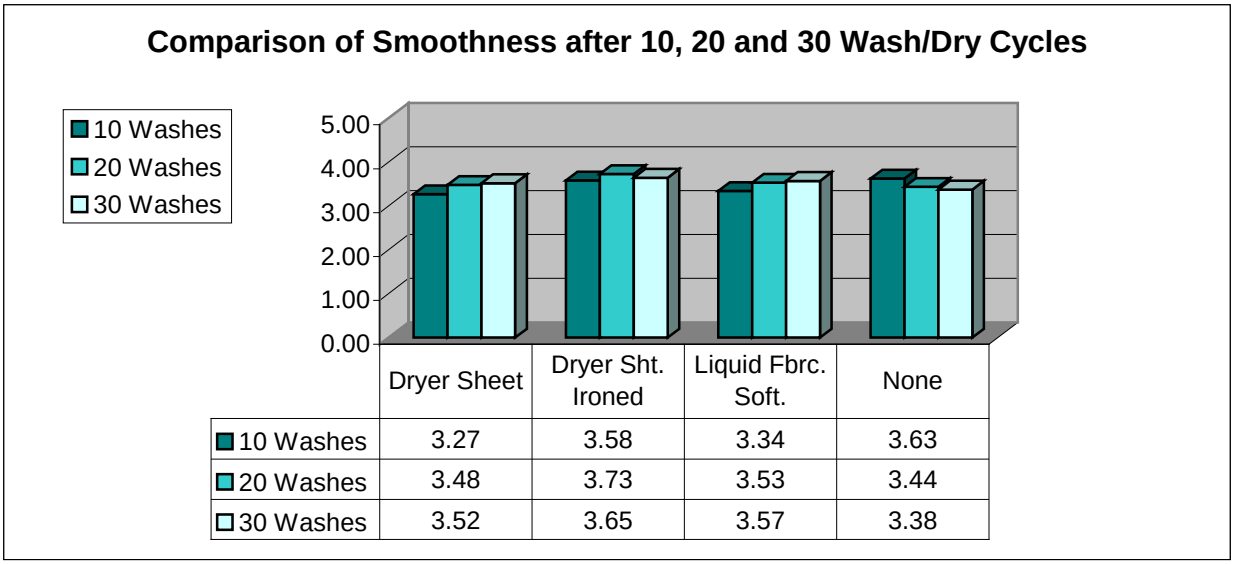
Data Analysis

When the laboratory evaluations were completed, the data was sent to Northwestern University for statistical analysis. The data from all three blocks were analyzed as a single dataset. For each of the tests performed (i.e. Smoothness, Color Change, Edge Abrasion, 3M Oil Repellency Test, etc.), an Analysis of Variance (ANOVA) model was fit to the data and tests were conducted on the statistical significance of the main effects and two-factor interactions of the following factors: Detergent (Powder or Liquid), Wash Temperature (Cold or Warm), Orientation (Inside Out or Right Side Out), Ironing (Ironed every 5th wash or Not Ironed), Fabric Softener (None, Liquid, or Dryer Sheet), and Washes (10, 20 or 30 Wash/Dry Cycles). All tests were conducted at the 99% confidence level. All statistically significant main effects and interactions were noted, displayed by plotting and discussed by the CCRC members. Many of the significant effects were no surprise, such as the large main effect of ironing on smoothness. Other effects, although statistically significant, were not of sufficient size to be noticed by consumers. However, the size of the certain effects and the interactions between certain factors were quite interesting and led to new questions and new conclusions about the care of fluorocarbon treated garments. The most noteworthy of these results are summarized in the section below.

Results

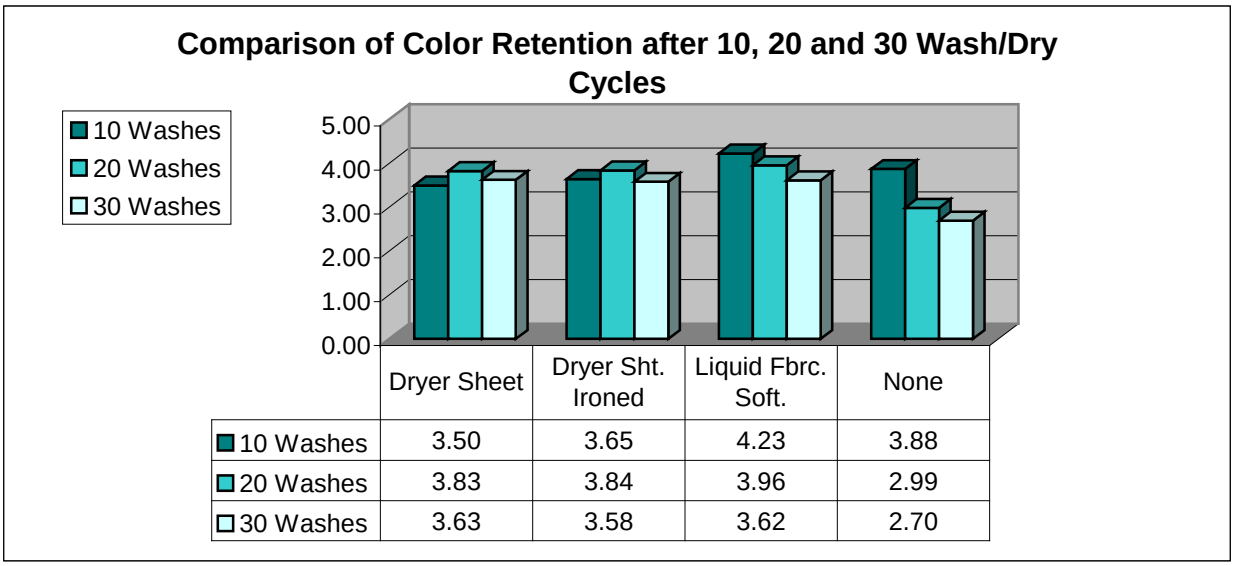
Evaluation of Appearance: The performance characteristics of smoothness, color, and edge abrasion were evaluated to support or dispute the claim that the addition of a stain repellent finishes, i.e. fluorocarbon, did not affect these properties.

- The results showed that ironing improved the smoothness rating (from 3.3 to 3.7 on average) but had no effect on color and edge abrasion.
- Washing inside out slightly improved color retention (from 3.55 to 3.69) and edge abrasion (from 3.34 to 3.58), but had no effect on the smoothness rating.
- The addition of a fabric softener, liquid or dryer sheet, improved the performance criteria for color retention, smoothness and edge abrasion (see Figures 1-3).
- Cold-water wash improved color retention (from 3.47 to 3.73), but had little or no effect on edge abrasion or smoothness ratings.
- There was little or no difference between using liquid or powder detergent for both smoothness and edge abrasion. For color retention, detergent and water temperature had a significant interaction. The powder detergent performed better (3.73 as compared to 3.28 for liquid) when using warm wash, but there was no difference in performance of the two detergents when using the cold water wash.



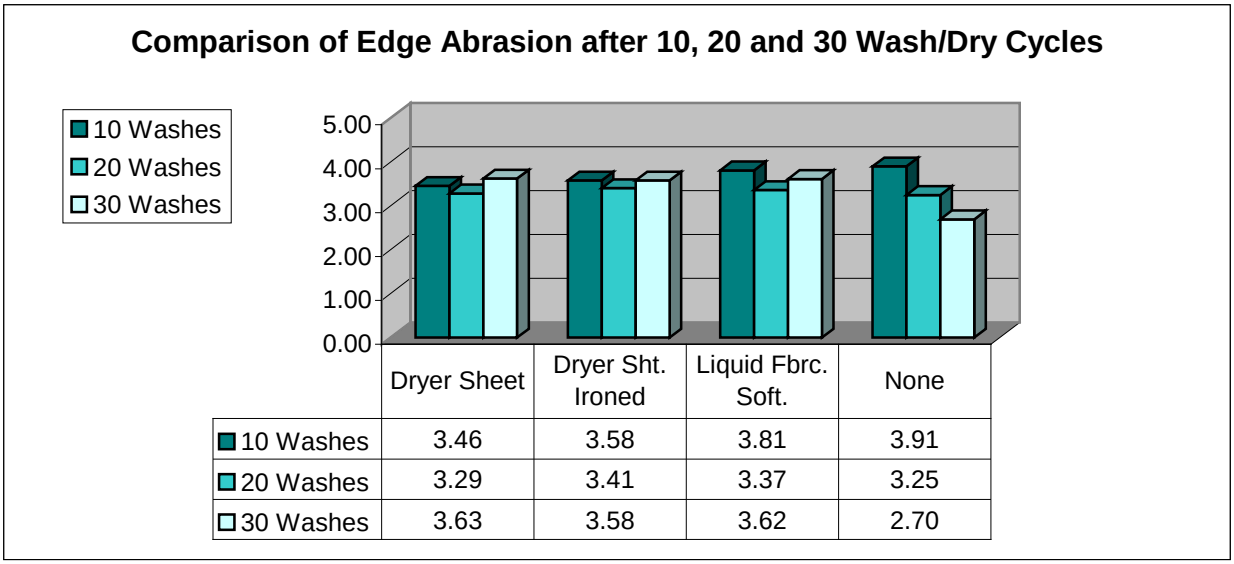
	Dryer Sheet	Dryer Sht. Ironed	Liquid Fbrc. Soft.	None
10 Washes	3.27	3.58	3.34	3.63
20 Washes	3.48	3.73	3.53	3.44
30 Washes	3.52	3.65	3.57	3.38

Figure 1. AATCC Smoothness Appearance Ratings



	Dryer Sheet	Dryer Sht. Ironed	Liquid Fbrc. Soft.	None
10 Washes	3.50	3.65	4.23	3.88
20 Washes	3.83	3.84	3.96	2.99
30 Washes	3.63	3.58	3.62	2.70

Figure 2. Evaluation of Color Retention – AATCC Gray Scale for Color Change

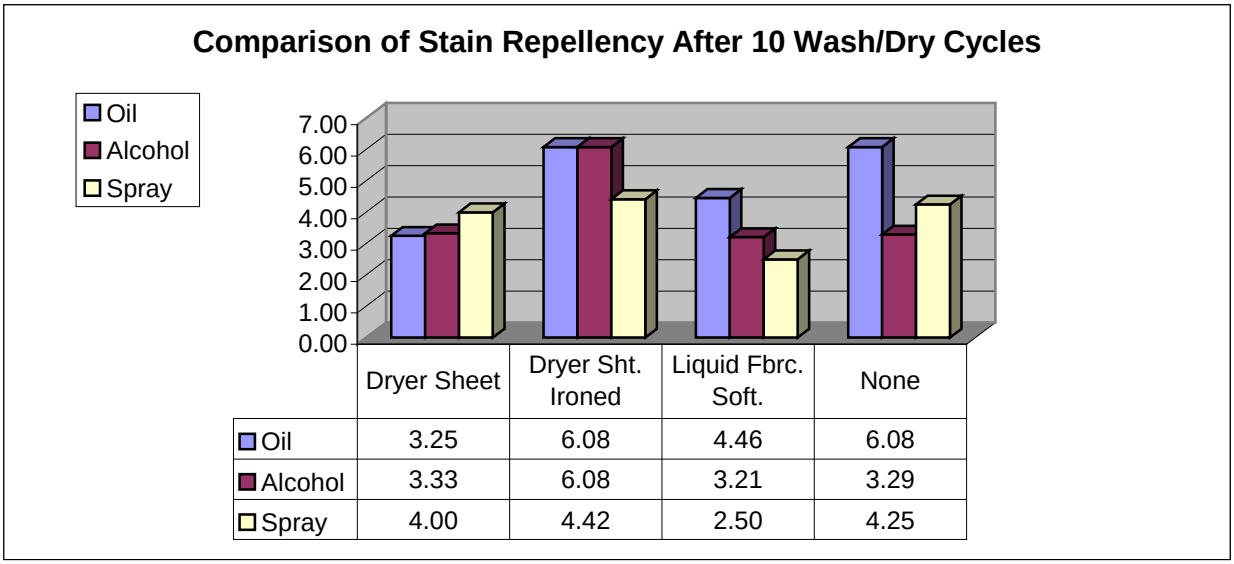


	Dryer Sheet	Dryer Sht. Ironed	Liquid Fbrc. Soft.	None
10 Washes	3.46	3.58	3.81	3.91
20 Washes	3.29	3.41	3.37	3.25
30 Washes	3.63	3.58	3.62	2.70

Figure 3. Evaluation of Edge Abrasion

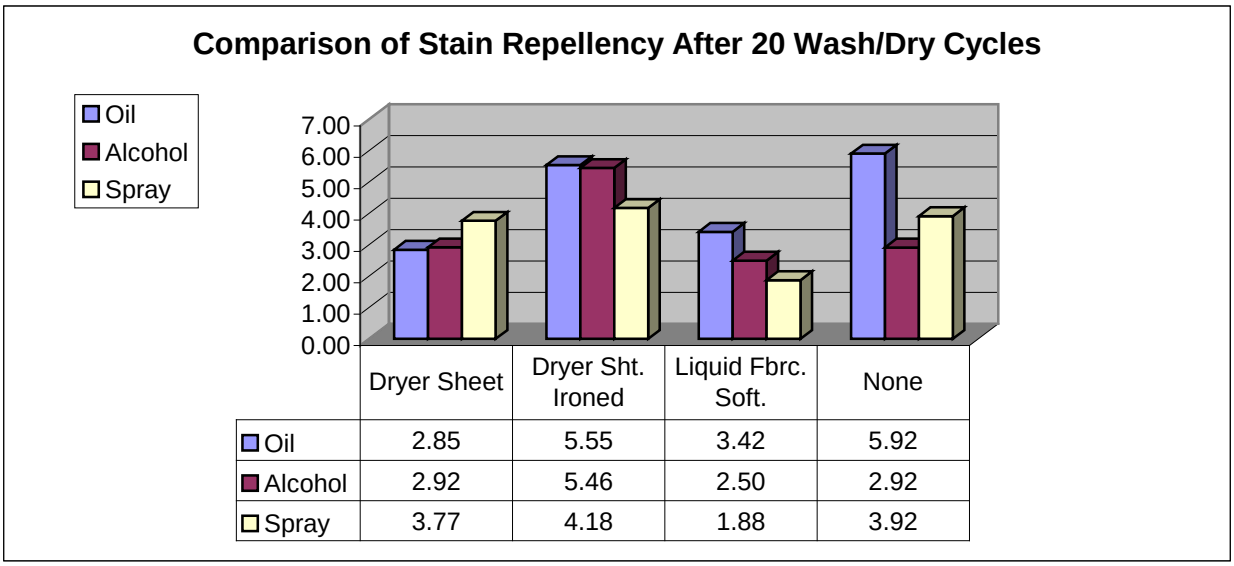
Evaluation of Performance – Stain Repellency: The AATCC Spray Test was used to evaluate water repellency. Initial evaluation of the stain repellency utilized the 3M Oil and Alcohol tests. Results were as follows.

- Ironing had no effect on the Spray Test results, however it had a strong unexpected interaction with the dryer sheet fabric softener for both the Oil and Alcohol Test. The performance of garments that used both the dryer sheet and were ironed after every fifth wash cycle was extraordinarily high for both the oil and alcohol test. (See Figures 4-6, where the garments using the dryer sheets are separately listed as ironed and not ironed to highlight the performance difference).
- Washing inside out had no effect on the Oil and Alcohol Test results. For the Spray Test, washing inside out improved the rating (from 2.60 to 3.39 on average) when using fabric softener, but had no effect when fabric softener was omitted.
- For all three tests of stain repellency, no fabric softener performed better than using a liquid fabric softener, however ironed garments using dryer sheets often performed as well or better than omitting fabric softener (see Figures 4-6).
- Warm-water wash had little effect on the Oil and Alcohol Test results or on the Spray test when fabric softener was being used. However using warm water wash improved the Spray Test rating (from 3.23 in cold water to 4.12) when fabric softener was omitted.
- Liquid detergent outperformed powder detergent for all the repellency tests. It improved the rating from 2.79 for powder to 3.67 in the Spray Test, from 2.70 to 3.78 for the Alcohol Test and from 3.95 to 5.06 for the Oil Test.



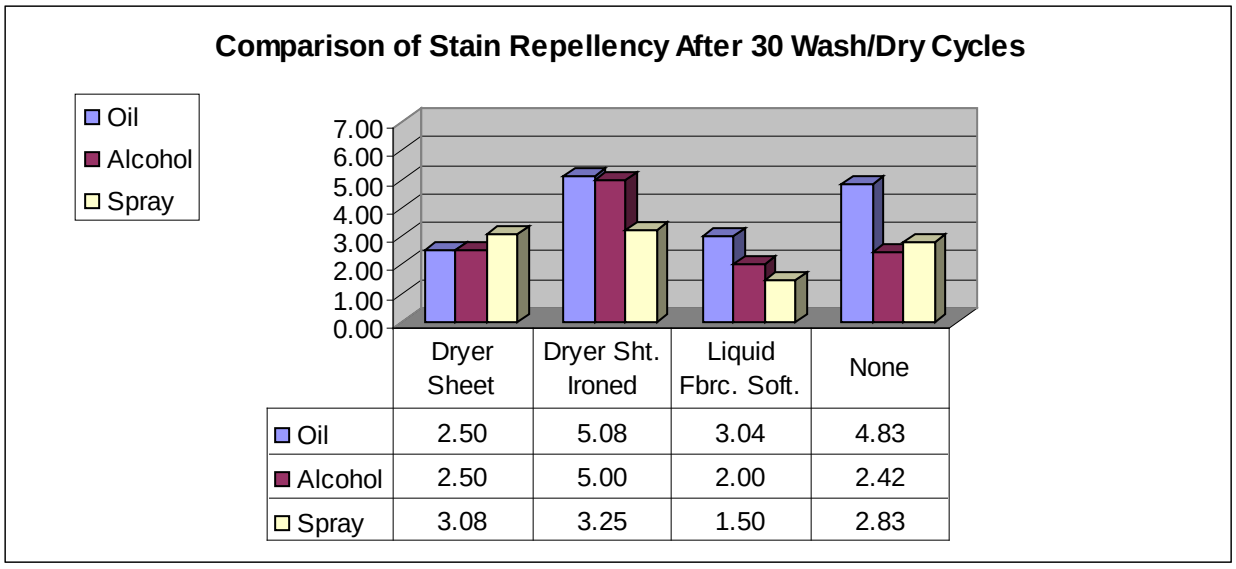
	Dryer Sheet	Dryer Sht. Ironed	Liquid Fbrc. Soft.	None
Oil	3.25	6.08	4.46	6.08
Alcohol	3.33	6.08	3.21	3.29
Spray	4.00	4.42	2.50	4.25

Figure 4. Evaluation of Stain Repellency after 10 wash/dry cycles



	Dryer Sheet	Dryer Sht. Ironed	Liquid Fbrc. Soft.	None
Oil	2.85	5.55	3.42	5.92
Alcohol	2.92	5.46	2.50	2.92
Spray	3.77	4.18	1.88	3.92

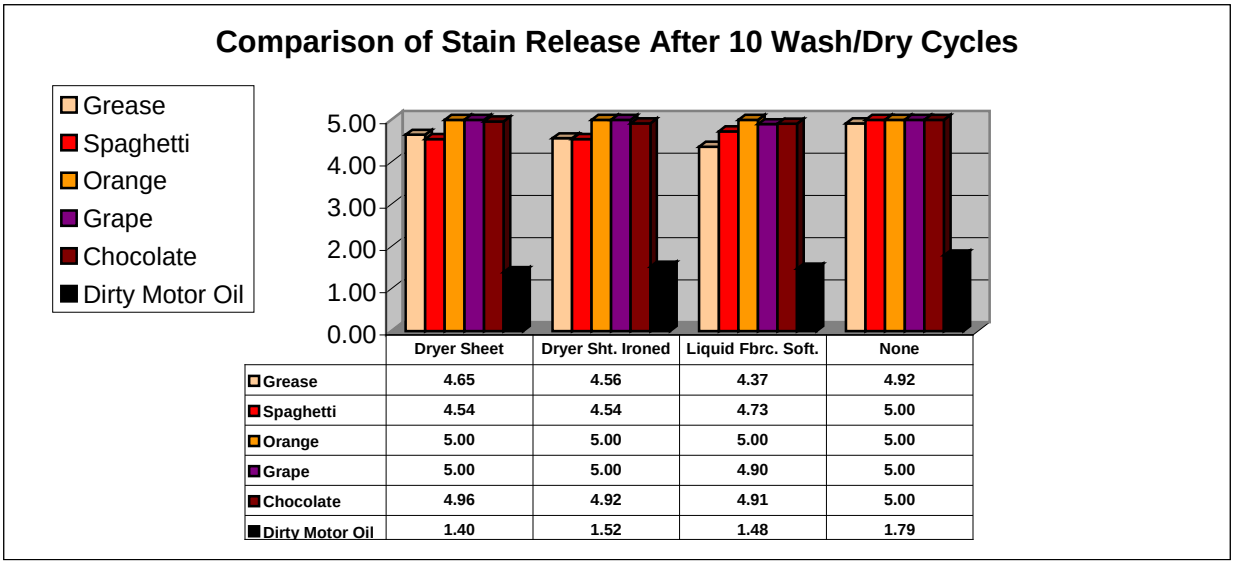
Figure 5. Evaluation of Stain Repellency after 20 wash/dry cycles



	Dryer Sheet	Dryer Sht. Ironed	Liquid Fbrc. Soft.	None
Oil	2.50	5.08	3.04	4.83
Alcohol	2.50	5.00	2.00	2.42
Spray	3.08	3.25	1.50	2.83

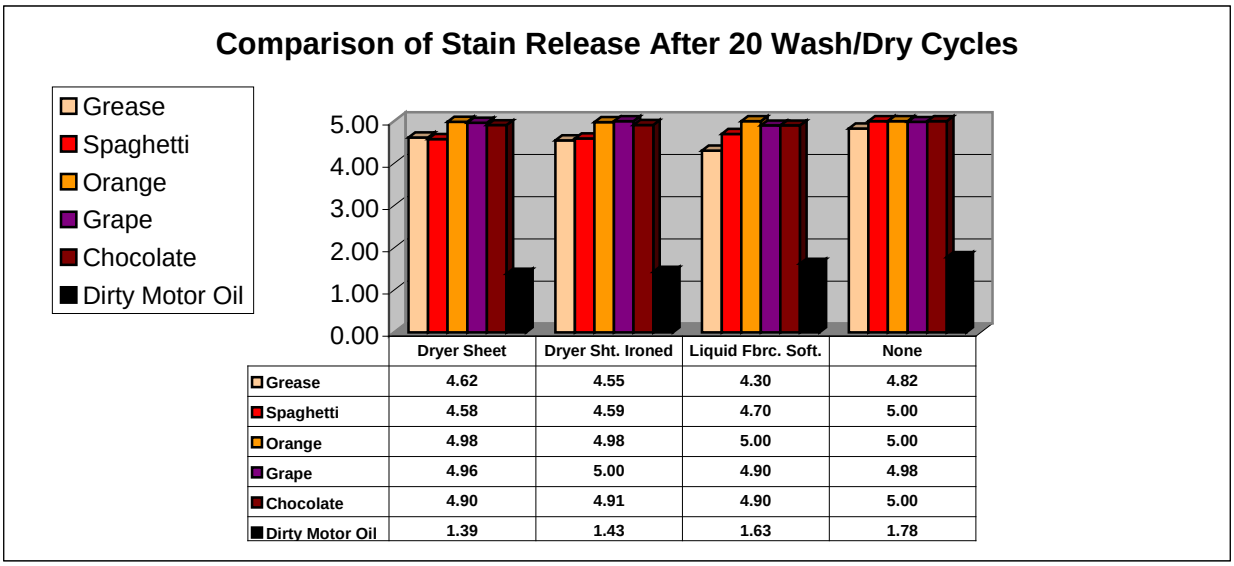
Figure 6. Evaluation of Stain Repellency after 30 wash/dry cycles

Evaluation of Performance – Stain Release: The stains that were applied by Procter & Gamble are used by the detergent manufacturer to develop and evaluate detergents. The stains are designed to discriminate between subtle changes made in formulations. These stains enabled CCRC to evaluate stain release as compared to the 3M oil and water and the AATCC Spray test that evaluated stain and water repellency. The effects of ironing, fabric softener use, detergent type, water temperature and orientation of pants, i.e. washing inside out, on stain release were evaluated. The fluorocarbon treated fabrics with or without ironing released most of the stains. The number of washes did not affect stain release. The fluorocarbon treated pants, regardless of the condition being evaluated, released chocolate sauce, grape and orange juice and spaghetti sauce. Bacon grease and dirty motor oil stained the pants but was best removed with liquid detergent, warm water and without the use of fabric softener (see Figures 7-9).



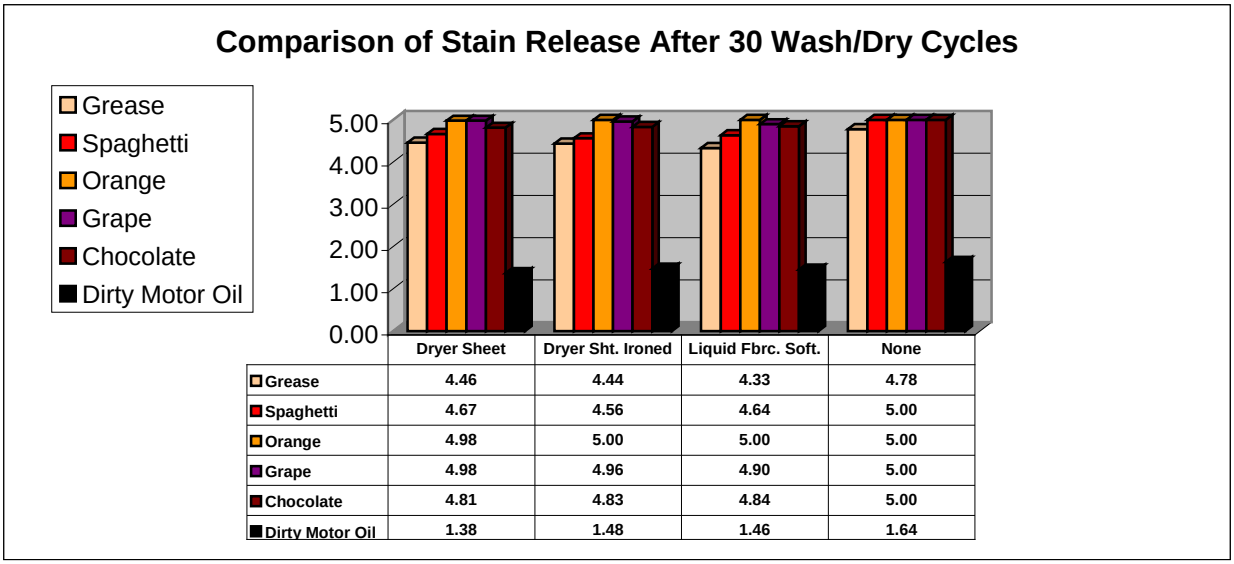
	Dryer Sheet	Dryer Sht. Ironed	Liquid Fbrc. Soft.	None
Grease	4.65	4.56	4.37	4.92
Spaghetti	4.54	4.54	4.73	5.00
Orange	5.00	5.00	5.00	5.00
Grape	5.00	5.00	4.90	5.00
Chocolate	4.96	4.92	4.91	5.00
Dirty Motor Oil	1.40	1.52	1.48	1.79

Figure 7. Evaluation of Stain Release after 10 wash/dry cycles



	Dryer Sheet	Dryer Sht. Ironed	Liquid Fbrc. Soft.	None
Grease	4.62	4.55	4.30	4.82
Spaghetti	4.58	4.59	4.70	5.00
Orange	4.98	4.98	5.00	5.00
Grape	4.96	5.00	4.90	4.98
Chocolate	4.90	4.91	4.90	5.00
Dirty Motor Oil	1.39	1.43	1.63	1.78

Figure 8. Evaluation of Stain Release after 20 wash/dry cycles



	Dryer Sheet	Dryer Sht. Ironed	Liquid Fbrc. Soft.	None
Grease	4.46	4.44	4.33	4.78
Spaghetti	4.67	4.56	4.64	5.00
Orange	4.98	5.00	5.00	5.00
Grape	4.98	4.96	4.90	5.00
Chocolate	4.81	4.83	4.84	5.00
Dirty Motor Oil	1.38	1.48	1.46	1.64

Figure 9. Evaluation of Stain Release after 30 wash/dry cycles

Conclusions

For the most part, these findings support the care label recommendations. Warm water and liquid detergent increased the ratings for stain repellency. Ad claims that the stain repellency, smoothness, and appearance are maintained for 30 washes were supported by the findings of this project. Although it is true that omitting fabric softener, as suggested by the care label, provides an improvement in stain repellency over liquid fabric softener, this experiment uncovered a large interaction between using a dryer sheet and ironing. This interaction suggests that a better care recommendation for fluorocarbon treated pants would be to use a dryer sheet and iron every fifth wash. This combination (dryer sheet and ironing) produces results that are best or "close to the best" for all tests of appearance, stain repellency, and stain release. In the case of the alcohol test, this combination produces a marked improvement over any other care procedure. We feel that CCRC is uniquely qualified to search for and investigate exactly this type factor interaction since the factors involve the products from different companies along the clothes care supply chain. Of course, because this recommendation is based on a single study, the conclusion is tentative and deserves both additional study and scientific investigation into the cause for this good performance. CCRC is conducting a follow-up experiment to understand and confirm the findings of this study.

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