THE EFFECT OF SELECTED SOAPS UPON THE REMOVAL OF SOIL FROM DACRON-AND-COTTON AND SIMILAR ALL-COTTON FABRICS

by

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CHAPTER I

INTRODUCTION

One of the best selling fabrics on the market today is the dynamic blend of 65 per cent Dacron[1] and 35 per cent cotton. A great variety in styling is now available and is making the influence of the fabric widespread. It is being used in men's dress and sport shirtings, ladies' dresses and blouses, and is expected to gain in the sportswear and suiting fields with a carry-over into all-season apparel. Even though fabrics made of this blend are higher in price, recent studies have shown that the price-conscious consumer will frequently buy a Dacron-and-cotton garment. Dacron-and-cotton and all-cotton fabrics look the same and it is only after several wearings and launderings that the superior performance of this blend is definitely established. As a result of studies it has been concluded that the Dacron-and-cotton blend offers better long-term value in looks, performance, and minimum care.[2]

An exciting factor about this blend is that it combines the comfort and good looks of cotton with the long-wearing strength and easy maintenance qualities of Dacron.[3] After considerable laboratory and wear testing of various fabrics containing Dacron and cotton, the Du Pont Company has indicated that to achieve a high level of performance at least

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1 Trademark for polyester fiber manufactured by E. I. du Pont de Nemours and Company.

2 "Dacron and Cotton," American Fabrics, XXXIX (1957), 38.

3 Jerome Campbell, "Dacron and Cotton Form Happy Union," Modern Textiles Magazine, XXXIV (February, 1954), 31.

65 per cent Dacron polyester staple is needed in an ultimate blend with long staple cotton.[4] This is the type of blend that is most often found on today's market.

Investigation has shown that very little information concerning the serviceability of this fabric is available for use by the average consumer. In reviewing three published tests on the Dacron-and-cotton shirts it was concluded that the retention of soil was a factor that was found to be objectionable in this blend.[5] The soiling behavior of this fabric and the effect of synthetic detergents upon its removal have been studied by Buchanan.[6]

Soap has been considered the best type of detergent to use in removing soil from all-cotton fabrics and this investigation was initiated to determine its effect on the removal of soil from Dacron-and-cotton fabrics. The purposes of this study were:

1. To determine the soil removal efficiency of unbuilt and built soaps on blends of 65 per cent Dacron and 35 per cent cotton and similar all-cotton fabrics.

2. To determine the efficiency of soil removal from Dacron-and-cotton fabrics as compared to all-cotton fabrics of similar construction.

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4 James S. Ramsey, "How to Handle Dacron-Cotton Blends," Modern Textiles Magazine, XXXVI (July, 1955), 69.

5 "A Dacron-and-Cotton Dress Shirt," Consumer's Research Bulletin (January, 1955), 15; Pauline E. Keeney, "Performance of Dacron-and-Cotton Shirts Compared with All-Cotton Garments of Similar Construction," Journal of Home Economics, XLIX (March, 1957), 188-189; and E. M. Sandgren and D. L. Sandgren, "Home Test of a Dacron-Cotton Shirt," Journal of Home Economics, XLVIII (November, 1956), 693-694.

6 Frances Buchanan, "A Comparison of the Soiling Behavior of Dacron-and-Cotton Fabrics with those of Similarly Constructed All-Cotton Fabrics" (unpublished Master's thesis, The Woman's College of the University of North Carolina, Greensboro, 1958).

3. To compare these results with those of Buchanan using synthetic detergents.[7]

4. To contribute to a larger study of Dacron-and-cotton blends.[8]

This information was to be determined by laundering three artificially soiled Dacron-and-cotton fabrics and three artificially soiled all-cotton fabrics fifty times each, using two unbuilt and two built popular household soaps. Through the measurement of reflectance values before and after soiling and after certain laundering intervals, the percentage of soil removal was calculated.

The remainder of this study includes Chapter II, the review of literature describing the soiling tendencies of these fabrics, the use of soiling solutions, the effectiveness of selected soaps on soil, and the methods used in the measurement and evaluation of soil removal. In Chapter III are described the procedures used in soiling the fabrics, in laundering and in determining the percentage of soil removal. The compilation and evaluation of the data from all laboratory tests are presented in Chapter IV along with a comparison of the effectiveness of selected synthetic detergents and soaps. Chapter V includes the summary, conclusions, and recommendations for further study.

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[7] Ibid.

[8] Project H-77, "The Serviceability of Materials Made of Dacron-and-Cotton Used in Shirts and Blouses" (unpublished research reports, North Carolina Agricultural Experiment Station, Raleigh, 1955 -).

CHAPTER II

REVIEW OF THE LITERATURE

There is extensive literature pertaining to the soiling of fabrics and the effectiveness of detergents. The majority of the studies pertain to the soiling of cotton and wool. Very little information has been published in regard to the soiling characteristics of the newer blends, particularly those of 65 per cent Dacron and 35 per cent cotton.

I. SOILING CHARACTERISTICS OF DACRON AND COTTON FIBERS

The cotton fiber is very versatile and combines well with other textiles in the fiber, yarn, or weaving stage. It is widely used in wearing apparel and the use of cotton as a popular fabric continues to increase with the discovery of new finishes and the blending of this fiber with many others.

Cotton is a hydrophilic fiber and therefore absorbs and releases large quantities of water.[1] It is easily soiled, but it is doubtful that solid soil greater than submicroscopic size can penetrate the interior deeply. The soiling effect on cotton is permanent and must be laundered to restore a clean appearance. This fiber can be laundered easily with any good laundry soap, since cotton resists the alkali of which soaps are made.[2]

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1 Zelma Benhure and Gladys Pheiffer, America's Fabrics (New York: The MacMillan Company, 1947), 74.

2 Isabel Wingate, Textile Fabrics (fourth edition; New York: Prentice-Hall, Inc., 1955) p.413.

Limited information is available on the soiling characteristics of the Dacron fiber. "The fact that they are hydrophobic, do not swell in water, and do not readily dye would indicate that any soil which is deposited must remain on the fiber surface."[3] An important criterion for soil evaluation is visual appearance as measured by surface reflection, therefore it appears logical to suppose that such surface soiling would be more visible to the eye since part of it cannot penetrate the fiber. The hydrophobic fibers probably resist soiling and under equal exposure conditions the total amount of soil accumulated would be less.[4] Wingate stated that Dacron fibers were not readily soiled because of their smooth surface and resistance to moisture but did not refer to actual tests.[5]

However, the Washington Section of the American Association of Textile Chemists and Colorists reported that Dacron had a greater affinity for soil than cotton. These data were obtained by inserting neck bands in men's shirts and measuring the amount of soil accumulated during specified periods of wear.[6]

The above mentioned report was the only one found which compared the relative ease of cleaning Dacron fibers. The Dacron fabrics retained more soil at the end of the laundering process than cotton fabrics,

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[3] Ernest Kaswell, Textile Fibers, Yarns, and Fabrics (New York: Reinhold Publishing Corporation, 1953), p.108.

[4] Ibid., p. 108.

[5] Wingate, op. cit., p. 428.

[6] "Soiling Fabrics in Contact with the Skin," American Dyestuff Reporter, XLIII (November 8, 1954), P755.

indicating that some of the oily soil penetrates the hydrophobic fiber and is not easily removed in an aqueous medium.[7] Kaswell stated that since water is absorbed only to a minor degree or not at all, it is probable that any dirt deposited will stay on the surface of the fibers and should be fairly easy to remove if the laundering operation were suited to the fabric.[8]

Dacron has approximately the same wet and dry properties and can be wet laundered with a minimum of concern with respect to damage, distortion, or shrinkage.[9] Hunter reported that the alkaline sensitivity of Dacron is somewhat greater than that of cotton and gradually, but uniformly, reduces the fibers in denier until completely dissolved.[10]

One of the latest trends in fabric manufacture is the blending of hydrophilic and hydrophobic fibers so that the advantages of each will compensate the disadvantages of the other.[11] From the results of a wear test, Campbell concluded that the Dacron and cotton blend does not soil as easily as the all-cotton fabric.[12] Research is now in progress to compare the affinity of the two types of fabrics for soil.[13]

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[7] Ibid., p. P757.

[8] Kaswell, op. cit., p. 413.

[9] Ibid., p. 419.

[10] R. L. Hunter, "How to Finish Dacron and Cotton Blends," Modern Textiles Magazine, XXXVII (September, 1957), 88.

[11] Kaswell, op. cit., p. 420.

[12] Jerome Campbell, "Dacron and Cotton Form Happy Union," Modern Textiles Magazine, XXXV (February, 1954), 52.

[13] Frances Buchanan, "A Comparison of the Soiling Behavior of Dacron-and-Cotton Fabrics with those of Similarly Constructed All-Cotton Fabrics" (unpublished Master's thesis, The Woman's College of the University of North Carolina, Greensboro, 1958).

II. COMPOSITION OF SOILING MIXTURES

Many methods have been proposed to be used in soiling fabrics for laboratory testing. Standard soil formulas have been accepted for use rather than trying to duplicate soil which is contacted daily. The formula used varies with different laboratories, and research workers are continuing to prepare new solutions to be used in textile testing.

Recently a chemical analysis of the oily components of dirt present on shirts, pillow-cases, tea-towels, woolen socks, and soft collars soiled under controlled conditions in actual domestic use was reported by C. B. Brown in England. This information could well form the basis for preparing a really representative artificial soil.[14]

Sanders and Lambert in this country made an analysis of ordinary street dirt collected from six American cities, and found the compositions to be remarkably similar. Lower amounts of carbon than is usually assumed were found and a very high proportion of silica.[15] With these findings and those of Brown a synthetic soil was prepared that would more nearly represent that which is found in nature.[16]

Rhodes and Brainerd agreed that, omitting iron rust and stains, the most common components of ordinary dirt are probably carbon, fatty substances and oils, and any detergent that will remove these substances

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14 Donald Price, Detergents (New York: Chemical Publishing Company, Inc., 1952), 56-57, citing C. B. Brown, Research, I (1947), 46-49.

15 Price, op. cit., p. 57, citing H. L. Sanders and J. M. Lambert, Journal of American Oil Chemist Society, XXVII (1950), 153-159.

16 Price, op. cit., p. 57.

will remove most of the dirts met in ordinary laundry practice.[17] From these conclusions the following formula was derived to be applied when using the photocolorimeter for making quantitative tests on soiled and treated samples:

2 grams lamp black
5 grams of lubricating oil
2,000 cc. carbon tetrachloride[18]

More recent mixtures have been proposed and are as follows:

(1) The formula by Holland and Petrea for the evaluation of detergents consisting of:

89.0 % Stoddard Solvent
2.5 % Vaseline
2.5 % Parafin
2.5 % Stearic Acid
2.5 % Oleic Acid
1.0 % Norit C[19]

(2) The formulas proposed by the New York Section in the 1955 Intersectional Contest:

(a) Vacuum cleaner dust[20]
(b) Synthetic soil
38.0 % Humus
17.0 % Portland Cement
17.0 % Silica (200 mesh)
1.7 % Carbon Black (Malacco furnace black)
5.0 % Iron Oxide (Red N 1860)
8.8 % White Mineral Oil (Domestic light)[21]

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17 Rhodes and Brainerd, "The Detergent Action of Soap," Industrial and Engineering Chemistry, XXI (1929), 61.

18 P. J. Wood, "Studies on Detergent Power," American Dyestuff Reporter, (XXXVI (August 25, 1947), 458, citing Siefensieder-Ztg., No. 20 (1929) 172; Industrial and Engineering Chemistry, No. 21 (1929), 60.

19 V. B. Holland and Alice Petrea, "Proposed Method for the Evaluation of Detergents," American Dyestuff Reporter, XXXII (November 22, 1943), P535.

20 Ralph B. Smith, "A Study of the Soiling of Natural and Manufactured Fibers from Aqueous Systems," American Dyestuff Reporter, XLIV (November 21, 1955), 816.

21 Ibid., p. 817.

There is a disadvantage in using artificial soils since they are much heavier than those met with in practice. If soils as light as those usually found on clothes were used, each sample would be washed completely white and differences could not be detected.[22]

III. SOAPS AND THEIR RELATION TO SOIL REMOVAL

Water is the most important chemical substance used in the laundering of textile materials in the home, but soap is a close second in importance.[23] The purpose of a detergent is to remove dirt by first changing a hydrophobic into a hydrophilic surface and then removing the layer of dirt.[24]

As a detergent, soap has many advantages. It is unsurpassed in soft water, affects the skin less than other detergents, and is cheap. Soap has been in use for nearly 2,000 years and continues to hold a leading place in the detergent field in spite of modern scientific advances.[25] Commercial laundries favor the use of soap and a water softener if needed.[26]

Soap is formed by the reaction of sodium hydroxide and a fat.[27] When the soap is used as it is formed from this reaction, it is referred

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[22] Price, op. cit., p. 130.

[23] Bruce E. Hartsuch, Introduction to Textile Chemistry (New York: John Wiley and Sons, Inc., 1950), p. 54.

[24] Price, op. cit., pp. 62-63.

[25] Ibid., p. 134.

[26] Wingate, op. cit., p. 408.

[27] Ibid.

to as an unbuilt or light duty soap. However, it has been found that a soap will be a better detergent if certain weakly alkaline substances known as builders are used with it.[28] Builders, when properly used, enable a smaller amount of soap to do a greater amount of work.[29]

Hartsuch gives the following explanation for the removal of dirt from a piece of cloth:

> The cloth consists of an outer surface and a mass of large and small capillaries in the interior of the cloth, and these capillaries are filled with air. The dirt is found on the outer surface and is also deeply imbedded among the individual fibers. Soap solution is a good penetrating, wetting, and emulsifying agent, and so when the cloth is washed the soap solution penetrates the capillaries, emulsifies the air in them, wets their walls, and removes the dirt by emulsifying the grease that holds it.[30]

IV. PH DETERMINATION AND WATER HARDNESS

The acidity or alkalinity of a solution is measured by the pH which has a range of 1 to 14. A neutral solution has a pH of 7 while alkaline solutions have higher pH values.

Although a certain amount of alkali is necessary for proper washing results, particularly for cotton fabrics, highly alkaline solutions can be harmful to fabrics. The accepted alkalinity for soaps and synthetic detergents is between a pH of 9 and 11.[31]

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28 Hartsuch, op. cit., p. 60.

29 William W. Niven, Jr., Fundamentals of Detergency, (New York: Reinhold Publishing Corporation, 1950), p. 228.

30 Hartsuch, op. cit., pp. 77-78.

31 All About Laundering, Reference Manual, Consumer Education Department, (Saint Louis: Monsanto Chemical Company, [n.d.]), Section I, p. 1.7.

Soaps, as "neutral" salts of fatty acids, have pH values much higher than organic sulfates or sulfonates. When the pH values of soaps fall in a range lower than those for the normal salts, difficulty in the way of reduced detergency or actual deposition of insoluble fatty acids may be expected. Builders are sometimes added to soaps to maintain the desired pH level.[32]

Colorimetric methods are sometimes used to determine the pH value of a solution, but the electrometric measurement is more precise. Simplified apparatus is available for electrometric measurement. This method usually requires the use of a glass electrode which may be operated from line current or battery.[33]

Hardness in water is associated with the soap-destroying power of the water; so much so that the soap-destroying quality of a water is a measure of hardness. This is most often due to calcium and magnesium salts which react with soap to form the well-known scum when soap is used with hard water. When a certain amount of soap is changed from a soluble compound to an insoluble one, this amount of soap has no cleaning power, and a precipitate is formed and deposited on the fabric. This precipitate is difficult to rinse off and makes the fabric stiff and harsh. Frequent launderings in hard water shorten the life of the fabric.[34]

Many methods are used for determining the hardness of water, but the simplest and most practical way is by means of soap titration; which

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[32] Jay C. Harris, Detergency Evaluation and Testing (New York: Interscience Publishers, Inc., 1954), p. 193-194.

[33] *Ibid.*, p. 194.

[34] Hartsuch, *op. cit.*, p. 91.

denotes the amount of soap destroyed by a certain volume of hard water.[35] This can be done by adding drops of green soap to one ounce of water until a head of suds is formed that will last five minutes. The number of drops of green soap needed denotes the grains of hardness per U. S. gallon.[36]

V. MEASUREMENT AND EVALUATION OF SOIL REMOVAL

The Launder-Ometer is the apparatus most often used in determining soil removal from fabric samples. Other machines used are the Terg-O-Tometer, Small Scale Conventional Agitator Washer, and the Deter-Meter.[37]

The soil removed by the use of one of these machines may be measured by a photometric method which measures the amount of soil retained by the fabric. Another method uses a photometer and measures the amount of soil removed from the fabric and held in suspension by the solution, disregarding the fabric as a means for evaluation of soil removal.[38]

The Hunter Multipurpose Reflectometer can be used to measure the apparent reflectance of a fabric. This instrument measures the most minute changes and is described by Hunter as follows:

> The design of the reflectometer is based on the null principle. Light from a single source is directed along two separate paths. The beam reaching one cell is reflected specularly from one specimen; that reaching the second cell is reflected diffusely from the other. A galvanometer is

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[35] Ibid., pp. 91-92.

[36] All About Laundering, op. cit., Section VIII, p. 4.1.

[37] Harris, op. cit., pp. 59-61.

[38] Ibid., p. 76.

> used to indicate when the amounts of light in the beams have been adjusted so that each cell is generating the same current.[39]
>
> Illumination at 45° and normal viewing have been internationally adopted as standard conditions for colorimetry of opaque surfaces because they represent a satisfactory average of the directional conditions under which surface colors are observed in everyday life.[40]

It has been found that the reflectance readings shown by this instrument may be affected by the presence of fluorescent dyes often added to detergents. This dye converts invisible ultraviolet rays into visible light causing the fabric to appear whiter.[41] Research has shown that the effect of these dyes is apparent with an incandescent lamp containing only a small amount of ultraviolet light.[42]

Hunter gives the following explanation of fluorescence error in relation to the Multipurpose Reflectometer:

> The Institute of Paper Chemistry has shown that fluorescence of a sample may cause error in any colorimetric instrument in which the energy striking the sample is spectrally different from that ordinarily used to observe the sample visually. A fluorescent sample has the power

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39 Richard S. Hunter, "A Multipurpose Photoelectric Reflectometer," _Research Paper RP 1345, Journal of Research of the National Bureau of Standards_, United States Department of Commerce, National Bureau of Standards, XXV (Washington: Government Printing Office, 1940), 615.

40 _Ibid._, p. 584.

41 S. N. Glarium, "Optical Bleaching--White Magic," _American Dyestuff Reporter_, XLIV (August 29, 1955), P625.

42 S. N. Glarium and S. E. Penner, "The Behavior of Optical Bleaching Agents on Cellulosic Materials." _American Dyestuff Reporter_, XLIII (May 10, 1954), P314; "Soiling of Fabrics in Contact with the Skin," _op. cit._, p. P757.

to change the spectral character of part of the energy striking it.[43]

If, as in the multipurpose reflectometer, the energy is passed through a filter before incidence on the sample, fluorescence may cause the photocell exposed to the samples to receive energy of wave lengths wholly excluded by the filter and therefore not supposed to be present for the particular measurements.[44]

When the reflectometer is used, assuming that no fluorescent dyes are present, the efficiency of soil removal can be calculated from the reflectance readings by the use of the following formula:

$$E = \frac{A - B}{C - B} \times 100$$

E = Efficiency of soil removal

A = Reflectance after laundering

B = Reflectance of original soiled fabric

C = Reflectance of original white fabric[45]

The Standard Soils Committee of the American Association of Textile Chemists and Colorists reported the use of the same formula using different symbols, but concluded the simple statistic, A - B, to be as useful as the more complicated one in measuring the effectiveness of detergents.[46]

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43 Richard Hunter, Photoelectric Tristimulus Colorimetry with Three Filters, National Bureau of Standards, United States Department of Commerce, Circular C429 (Washington: Government Printing Office, 1942), p. 30, citing Institute of Paper Chemistry, Instrumentation Studies, XX, "A Study of Photoelectric Instruments for the Measurements of Color, Reflectance and Transmittance," Paper Trade J., 105 TS293 (1937).

44 Ibid.

45 Harris, op. cit., p. 79.

46 "Progress Report of the Standard Soils Committee," American Dyestuff Reporter, XLV (December 15, 1956), 947.

Real differences in samples can be determined by computing the standard error of the mean. "The rule is: if the difference between two mean values is equal to, or greater than, twice the larger standard error, there is a real difference between the samples."[47]

Brownlee suggested the use of the Student's "t" method for the comparison of two means using the following calculations:[48]

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sigma}\sqrt{\frac{N_1 \times N_2}{N_1 + N_2}}$$

where

$$\sigma^2 = \frac{\Sigma(X_1^2) - \frac{(\Sigma X_1)^2}{N_1} + \Sigma(X_2^2) - \frac{(\Sigma X_2)^2}{N_2}}{N_1 + N_2 - 2}$$

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47 John H. Skinkle, Textile Testing (second edition; New York: Chemical Publishing Company, Inc., 1949), p. 5.

48 K. A. Brownlee, Industrial Experimentation (third American edition; New York: Chemical Publishing Company, 1949), p. 34, cited by Harris, op. cit., p. 7.

CHAPTER III

PROCEDURE

I. FABRICS USED IN THE STUDY

The fabrics used in this study were selected from those included in a larger research study sponsored by the North Carolina Agricultural Experiment Station.[1] Three all-cotton fabrics and three Dacron-and-cotton blends of similar construction were chosen to determine differences in soiling behavior when laundered with four popular household soaps. Each fabric group was composed of two batiste fabrics and one Oxford cloth to be laundered with two built and two unbuilt soaps.

For identification the fabrics were coded as follows:

All-cotton			Dacron-and-cotton		
B-1a	B-2a	O-3a	XB-6a	XB-8a	XO-4a
B-1b	B-2b	O-3b	XB-6b	XB-8b	XO-4b
B-1c	B-2c	O-3c	XB-6c	XB-8c	XO-4c
B-1d	B-2d	O-3d	XB-6d	XB-8d	XO-4d

In this code "B" refers to batiste; "O" to Oxford cloth; "X" the presence of Dacron; numbers distinguish the fabrics; and small letters denote the soap. Soaps "a" and "b" were light duty unbuilt soaps and soaps "c" and "d" were heavy duty built soaps.[2] The small letters were used only on the test fabrics and the term Soap A, B, C, and D was used for clarification in this report.

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1 Project H-77, "Serviceability of Materials Made of Dacron-and-Cotton Used in Shirts and Blouses" (unpublished research report sponsored by the North Carolina Agricultural Experiment Station, Raleigh, 1955-).

2 _All About Modern Home Laundering_ (Pittsburgh: Ruud Manufacturing Company, 1953), p. 25.

These fabrics were the same as those used by Buchanan in a study of the effect of synthetic detergents on the soiling characteristics of Dacron-and-cotton fabrics and similar all-cotton fabrics.[3]

II. PREPARATION OF FABRICS

Determination of Reflectance Values

To determine the whiteness of the original fabrics, the changes due to soiling, and the changes after certain intervals during the laundering process the Hunter Multipurpose Reflectometer was used.

The green, blue, and amber filters were used in all readings. The reflectance of each original fabric was read at six different locations on the fabric with each filter and the values averaged. The average for the three filters was recorded giving a more accurate representation of the whiteness of the fabric. The values obtained are expressed as the per cent reflectance. These reflectance readings were used to compute the percentage of soil removal at certain laundering intervals.

Application of Soiling Solution

Before soiling the fabrics were washed in a commercial type laundry machine to remove any sizing that might be present and interfere with the soiling process. They were then hung to drip dry and pressed to remove any wrinkles.

A soiling solution used by Brainerd and Rhodes was used and consisted of the following components:

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3 Frances Buchanan, "A Comparison of the Soiling Behavior of Dacron-and-Cotton Fabrics with Those of Similarly All-Cotton Fabrics" (unpublished Master's thesis, The Woman's College of the University of North Carolina, Greensboro, 1958).

2 grams lampblack
5 grams lubricating oil
2,000 cc. carbon tetrachloride[4]

This amount was tripled and mixed in a portable washing machine. The fabrics were first heated thoroughly to remove any moisture that might be present and immediately put into the solution. They were agitated for thirty minutes with stirring at various intervals so that all the cloth would be immersed in the solution and give a more even distribution of soil. At the end of this time the fabrics were drip dried. This procedure was continued until the fabrics were well soiled and showed reflectance values of approximately twenty-five per cent after they had been washed in the same commercial type laundry machine to remove excess surface soil.

Each fabric was pressed with the labeled side down and again read on the reflectometer to determine the per cent of light reflectance in the soiled fabric. Throughout the remainder of the study the readings were taken with the labeled side up or next to the ray of light so that the gloss acquired by pressing would not interfere with the reflectance. Three readings were done with each filter and recorded as before. After each reading a small sample was cut from the larger sample to be used as illustrative material.

Each of the six fabrics was divided into four pieces, approximately nine by fifteen inches in preparation for laundering with the four soaps.

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[4] P. J. Wood, "Studies on Detergent Power," The American Dyestuff Reporter, XXXVI (August 25, 1947) 460, citing Seifensieder - Ztg., Industrial and Engineering Chemistry, 1929, No. 20, p. 172.

III. LAUNDERING PROCESS

The L-2-Q Launder-Ometer[5] was used in the laundering of the fabrics. This machine was developed by the American Association of Textile Chemists and Colorists for use in textile testing. The containers with fabric specimens are clamped to a rotating shaft which moves at constant speed through a water bath of desired temperature.[6]

Each fabric sample was laundered in a 2-quart container with 0.5 gram of the specified soap and 500 cc. of water in a water bath of 105°F. for thirty minutes. The fabric was rinsed and allowed to drip dry. The procedure was adapted from standard test procedures using the Launder-Ometer.

Since the hardness of the water affects the soil removal efficiency of soaps the water was tested by using tincture of green soap. In a bottle containing one ounce of water, drops of green soap were added until a head of suds was formed that would stand for five minutes. The water hardness number was determined by the drops of green soap necessary to form the head of suds. If five drops of green soap were used the water would be 5 grains hard per U. S. gallon.[7]

The pH of the soap solutions used in laundering was determined by the use of a pocket potentiometer manufactured by Analytical Measurements Incorporated of Chatham, New Jersey, to show the differences in alkalinity of the four soaps used.

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5 Manufactured by Atlas Electric Devices Corporation, Chicago, Illinois.

6 Jay C. Harris, Detergency Evaluation and Testing (New York: Interscience Publishers, Inc., 1954), p. 60.

7 "Water Hardness Test," All About Laundering, Reference Manual, Consumer Education Department (Saint Louis: Monsanto Chemical Company, [n. d.]), Section VIII, p. 4.1.

IV. EVALUATION OF SOIL REMOVAL

Reflectance readings were taken at intervals of 1, 2, 5, 10, 20, 35, and 50 launderings. These intervals were used since more change is likely to occur at the beginning of the period than at the end. The fabrics were laundered fifty times to determine the optimum performance of the soaps. As in the determination of the reflectance of the original fabric, the three readings taken with the green, amber and blue filters were averaged and the value obtained expressed in terms of the per cent light reflectance.

The fabrics that had been laundered with each of the four soaps were tested with ultraviolet light for the presence of fluorescent dyes. The presence of this dye will affect the accuracy of the reflectance values.

Using the reflectance values obtained the percentage of soil removal was computed after each reading by using the following formula:[8]

$$E = \frac{A - B}{C - B} \times 100$$

E = Efficiency of soil removal

A = Reflectance after laundering

B = Reflectance of original soiled fabric

C = Reflectance of original white fabric

These percentages were presented in both tabular and graphic form and were used in making comparisons within this study and also with the results of Buchanan.[9]

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[8] Harris, op. cit., p. 75.

[9] Buchanan, loc. cit.

The average per cent of soil removal from the two types of fabrics at the end of the fiftieth laundering was used to determine whether the difference in the soil retention of these fabrics was significant. The null hypothesis was used and computed at the 95 per cent level of confidence using the following Student's "t" formula.[10]

$$\frac{\overline{X}_1 - \overline{X}_2}{\sigma} \sqrt{\frac{N_1 \times N_2}{N_1 + N_2}}$$

where

$$\sigma^2 = \frac{\Sigma(X_1^2) - \frac{(\Sigma X_1)^2}{N_1} + \Sigma(X_2^2) - \frac{(\Sigma X_2)^2}{N_2}}{N_1 + N_2 - 2}$$

This formula was also used in comparing the soil removal efficiency of the two built and the two unbuilt soaps.

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10 K. A. Brownlee, Industrial Experimentation (third American edition; New York: Chemical Publishing Company, 1949), p. 34, cited by Harris, op. cit., p. 7.

CHAPTER IV

PRESENTATION OF DATA

I. FABRICS USED IN THIS STUDY

Six fabrics were selected for this study from those purchased for a research project sponsored by the North Carolina Agricultural Experiment Station to be conducted at The Woman's College of the University of North Carolina.[1] The purpose of the project was to compare the serviceability of Dacron-and-cotton fabrics used for shirts and blouses with similar all-cotton fabrics.

Three all-cotton fabrics considered most appropriate for use in shirts and blouses were selected and three Dacron-and-cotton fabrics of similar construction were then chosen to be compared with the all-cotton fabrics. These were the same fabrics used by Buchanan[2] in her study of the effect of synthetic detergents on the efficiency of soil removal. Fabric specifications secured from the manufacturer or supply house are presented in Table I.[3]

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1 Project H-77, "The Serviceability of Materials Made of Dacron-and-Cotton Used in Shirts and Blouses" (unpublished research reports, North Carolina Agricultural Experiment Station, Raleigh, 1955-).

2 Frances Buchanan, "A Comparison of the Soiling Behavior of Dacron-and-Cotton Fabrics with those of Similarly Constructed All-Cotton Fabrics" (unpublished Master's thesis, The Woman's College of the University of North Carolina, Greensboro, 1958).

3 Project H-77, *loc. cit.*

TABLE I

FABRIC SPECIFICATIONS GIVEN BY MANUFACTURER OR SUPPLIER

Type of fabric	Fabric number	Fiber content (Per cent)		Cost per yard		Manufacturing Firm	Supplier	Miscellaneous Information
		Dacron	Cotton	Retail	Wholesale			
All Cotton	B- 1		100.0	1.29	—	Jackson & Jackson	Belk's Dept. Store	Batiste
	B- 2		100.0	.98	—	Logantex, Inc.	Meyer's Dept. Store	Batiste, 40" wide
	O- 3		100.0	1.19	—	" "	Pomeroy's Dept. Store	Oxford
Dacron-and-Cotton	XB-6	60	40	—	1.30	—	Travis Fabrics	"Cairo"
	XB-8	66 2/3	33 1/3	—	1.35	—	" "	"Pyramid"
	XO-4	65	35	—	1.25	Deering, Milliken & Company	Manhattan Shirt Co.	Finished at Bradford Dyeing Association Name: Daeford

TABLE II

LABORATORY ANALYSIS OF FABRIC CONSTRUCTION

Type of fabric	Fabric Number	Fiber content (Per cent)		Weave	Width Inches	Thickness Inches	Weight (oz./sq. yd.)	Thread count		Yarn number		Staple length		Twist count	
		Dacron	Cotton					Warp	Filling	Warp	Filling	Warp	Filling	Warp	Filling
All-cotton	B- 1		100.0	Plain	38	.004	1.4	114	108	93.8	135.8	1.6	1.5	32Z	32Z
	B- 2		100.0	"	40	.005	1.9	96	98	62.6	80.8	1.2	1.3	26Z	32Z
	O- 3		100.0	2x1 Basket	38	.023	4.0	94	45	42.2	13.5	1.3	1.1	20Z	11Z
Dacron-and-Cotton	XB-6	69.3	30.7	Plain	45	.008	2.4	91	79	49.0	56.0	1.6	1.6	29Z	28Z
	XB-8	68.7	31.3	"	46	.008	2.9	103	98	46.0	60.0	1.6	1.6	26Z	33Z
	XO-4	68.9	31.1	2x1 Basket	45	.021	4.4	94	46	39.9	12.1	1.5	1.7	26Z	14Z

II. LABORATORY ANALYSIS OF FABRIC CONSTRUCTION

The fabrics used in this study were analyzed in a previous study. The data from the analysis are presented in Table II.[4] In coding these fabrics "B" was used to denote the batiste type, "O" the Oxford cloth, and "X" the presence of Dacron. The numbers were used to differentiate the specific fabrics selected for this study.

Fiber content. Fabrics B-1, B-2, and O-3 were 100 per cent cotton. Each of the Dacron-and-cotton fabrics was approximately 2/3 Dacron and 1/3 cotton with the specific amounts differing slightly in the three fabrics. According to the manufacturer this proportion is desirable for satisfactory performance as a minimum care fabric.

Weave. The weave of the two groups of fabrics was similar. All batiste fabrics had a plain weave and the Oxford fabrics had a 2 x 1 basket weave.

Width. The width of the fabrics is not important to the study. However, the Dacron-and-cotton fabrics were wider than the all-cotton fabrics.

Thickness. The all-cotton batiste fabrics were sheerer than those of Dacron-and-cotton. The Oxford cloth was a much thicker material, with both the all-cotton fabric and the Dacron-and-cotton fabric measuring approximately the same.

Weight. In the weight analysis the all-cotton batiste was found to be lighter in weight than the Dacron-and-cotton batiste. The density

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[4] Ibid.

of the Dacron makes this difference. The all-cotton fabrics, B-1 and B-2, weighed 1.4 and 1.9 ounces per square yard respectively as compared to 2.4 ounces per square yard for fabric XB-6 and 2.9 for fabric XB-8. The Oxford fabrics were similar in weight. The all-cotton fabric, O-3, weighed 4.0 ounces per square yard and the Dacron-and-cotton fabric, XO-4, weighed 4.4 ounces per square yard.

Thread count. The thread count was taken to determine the number of threads per inch. The all-cotton batiste fabric, B-1, had a warp count of 114 and a filling count of 108 threads per inch. Fabric B-2 showed a warp count of 96 and a filling of 98 threads per inch. The Dacron-and-cotton fabrics had a slightly lower thread count, with fabrics XB-6 and XB-8 having 91 and 103 warp threads and 79 and 98 filling threads per inch respectively.

There was almost no difference in the thread count in the Oxford type fabrics. Both fabrics O-3 and XO-4 had a warp count of 94 threads per inch. Since the weave was a 2 x 1 basket there were only half as many filling as warp threads. The all-cotton fabric, O-3, had 45 and the Dacron-and-cotton fabric, XO-4, had 46 threads per inch.

Yarn number. The fineness of a yarn is denoted by yarn number and as the yarn number increases so does the fineness of the yarn. In all the fabrics, a variation in the warp and filling showed that different yarns were used for each. There was a greater variation in the yarn number of the all-cotton batiste fabrics than in the Dacron-and-cotton batiste fabrics. The Dacron-and-cotton batiste fabrics were not as fine as the all-cotton batiste fabrics.

The Oxford type fabrics showed little variation in yarn number. The all-cotton fabric, O-3, had a warp of 42.2 and a filling of 13.5 as compared to fabric XO-4 with a warp of 39.9 and a filling of 12.1 hanks per pound.

Staple length. The staple length of the fibers in the all-cotton fabric, B-1, was 1.6 inches in the warp yarn and 1.5 inches in the filling. The length in fabric B-2 was 1.2 inches in the warp and 1.3 in the filling. The all-cotton Oxford fabrics had a warp staple length of 1.3 inches and a filling of 1.1 inches.

The staple length of the Dacron and of the cotton fibers used in the blended fabric was approximately the same.

Twist count. All the fabrics used in this study had a Z, counter clockwise, twist in both the warp and filling yarns. Both the warp and filling in fabric B-1 had 32 turns per inch. Fabric B-2 had 26 turns per inch in the warp and 32 in the filling. The all-cotton Oxford had 20 turns in the warp and 11 turns per inch in the filling.

The Dacron-and-cotton fabric, XB-6, had 29 turns in the warp and 28 in the filling. This was very similar to fabric XB-8 which had 26 turns per inch in the warp and 33 in the filling. Fabric XO-4 had 26 in the warp and 14 turns per inch in the filling.

III. COMPARISON OF LIGHT REFLECTANCE VALUES OF TEST FABRICS

The percentage of light reflectance of the six fabrics before and after soiling is shown in Table III. This was measured by using the Hunter Multipurpose Reflectometer. Each of the all-cotton fabrics showed a higher original light reflectance than the Dacron-and-cotton

TABLE III

AVERAGE PER CENT LIGHT REFLECTANCE OF ORIGINAL WHITE AND SOILED FABRICS

All-cotton				Dacron-and-cotton			
Fabric	White	Soil	Difference	Fabric	White	Soil	Difference
B-1	83.5	15.3	68.2	XB-6	76.1	12.2	63.9
B-2	85.5	18.4	67.1	XB-8	78.6	12.6	66.0
O-3	85.0	27.7	57.3	XO-4	76.8	15.1	61.7
Average	84.7	20.5	64.2	Average	77.2	13.3	63.9

fabrics. The average for the all-cotton fabrics was 84.7 per cent as compared with 77.2 per cent for the Dacron-and-cotton fabrics.

The three Dacron-and-cotton fabrics appeared to have lower reflectance values which would indicate greater tendency toward soiling. This in the final analysis was not true, since the differences between the soiled fabrics and the original white fabrics in each group were very small. The percentage difference between the average all-cotton and Dacron-and-cotton was only 0.3 per cent, indicating that approximately the same amount of soil was absorbed by each.

IV. DIFFERENCES IN THE PER CENT OF LIGHT REFLECTANCE AFTER LAUNDERING

One of the purposes of this study was to compare the soil retention of three Dacron-and-cotton fabrics with three all-cotton fabrics of similar construction when laundered with popular household soaps. Four soaps were used in laundering each of the six fabrics. The first group was laundered with Soap A and the second group with Soap B, both of which were unbuilt soaps. Group three was laundered with Soap C and group four was laundered with Soap D, these being built soaps.

The average pH of 0.5 gram of Soap A in 500 cc. of water was 9.7; for Soap B, 9.6; Soap C, 9.4; and Soap D, 9.4. The average water hardness was 5 grains per U. S. gallon.

A study of the whiteness retention of these same fabrics after laundering with Soaps A, B, C, and D showed some irregularity in reflectance.[5] In many instances the reflectance values of the laundered fabrics were higher than those of the original fabric.

It appeared that the fabrics might be absorbing some type of material during the laundering process that would cause the fabrics to reflect more light. Whether this increase in reflectance was due to the presence of fluorescent dyes present in the soaps could not be determined with the present equipment and procedure.

Since fluorescence will cause an error in the apparent reflectance shown by the Hunter Multipurpose Reflectometer, the original and laundered fabrics were tested in ultraviolet light for the presence of fluorescent dye.

Although no fluorescent dye was indicated in the original fabrics, the fabrics laundered with Soaps A, C, and D did contain a fluorescent dye. The all-cotton fabrics appeared to absorb more of the dye than the Dacron-and-cotton fabrics. The Oxford type fabrics appeared to absorb more of the dye than the batiste type fabrics.

Since equipment was not available to remove the ultraviolet light, the data presented in this study may include errors caused by the fluorescent dyes.

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[5] Project H-77, loc. cit.

The average reflectance reading for each original white and soiled fabric after 1,2, 5, 10, 20, 35, and 50 launderings is shown in Table IV. The average per cent light reflectance of the original white and soiled fabrics and of the two types of fabrics after the stated laundering intervals is shown graphically in Figure 1.

According to the average reflectance of all fabrics in each group the all-cotton fabrics tended to lose the soil a little more readily than the Dacron-and-cotton fabrics during the first laundering. The all-cotton fabrics increased 5.1 per cent in light reflectance from the original soil reflectance as compared with 4.0 per cent for the Dacron-and-cotton fabrics.

During the second laundering the light reflectance of the Dacron-and-cotton fabrics increased 5.0 per cent, which was more than the increase of 3.4 per cent in the all-cotton fabrics. At the end of the fifth laundering, the Dacron-and-cotton fabrics continued to lose more soil than the all-cotton fabrics and increased 8.7 per cent as compared with 7.9 per cent for the all-cotton fabrics since the second laundering. This was the highest increase for the Dacron-and-cotton fabrics during any period. The highest increase during one period for the all-cotton fabrics occurred during the sixth through the tenth launderings with an increase of 11.0 per cent as compared to 7.2 per cent for the Dacron-and-cotton fabrics. The per cent increase in the all-cotton fabrics continued to be higher than in the Dacron-and-cotton fabrics through the twentieth laundering. During the twenty-first through the thirty-fifth launderings the per cent increase of light reflectance was approximately the same for the all-cotton fabrics and Dacron-and-cotton fabrics. This was also true during the thirty-sixth through the fiftieth launderings.

TABLE IV

PER CENT LIGHT REFLECTANCE
(Average of Three Filters)

Fabric Number	All-Cotton Fabrics									Fabric Number	Dacron-and-Cotton Fabrics								
	Original White	Original Soil	Times laundered								Original White	Original Soil	Times laundered						
			1	2	5	10	20	35	50				1	2	5	10	20	35	50
SOAP A (LIGHT DUTY, UNBUILT)																			
B-1	83.5	15.3	18.7	20.0	31.1	41.3	47.0	52.0	55.0	XB-6	76.1	12.2	18.1	25.4	36.9	42.3	46.9	49.3	53.4
B-2	85.5	18.4	25.9	30.2	38.6	43.4	47.2	50.8	52.4	XB-8	78.6	12.6	19.6	22.0	27.5	31.5	35.7	38.5	41.2
O-3	85.0	27.7	28.1	29.8	36.7	47.0	57.5	62.9	64.9	XO-4	76.8	15.1	17.4	21.5	31.4	43.3	50.6	53.7	57.5
Av.	84.7	20.5	24.2	26.7	35.5	43.9	50.6	55.2	57.4		77.2	13.3	18.4	23.0	31.9	39.0	44.4	47.2	50.7
SOAP B (LIGHT DUTY, UNBUILT)																			
B-1	83.5	15.3	18.1	21.1	34.0	44.1	52.4	60.6	61.8	XB-6	76.1	12.2	20.2	27.1	36.5	43.7	49.5	52.1	54.6
B-2	85.5	18.4	24.9	33.5	39.5	46.4	51.8	55.6	57.3	XB-8	78.6	12.6	17.8	20.2	26.3	30.7	35.7	38.3	40.0
O-3	85.0	27.7	29.9	33.7	42.1	51.6	60.5	68.4	69.8	XO-4	76.8	15.1	18.2	27.9	40.1	48.7	55.3	57.7	59.5
Av.	84.7	20.5	24.3	29.4	38.5	47.4	54.9	61.5	63.0		77.2	13.3	18.7	25.1	34.3	41.0	46.8	49.4	51.4
SOAP C (HEAVY DUTY, BUILT)																			
B-1	83.5	15.3	23.7	25.9	32.8	46.8	59.2	60.1	63.6	XB-6	76.1	12.2	14.8	23.2	31.5	39.7	44.1	48.9	52.8
B-2	85.5	18.4	29.0	31.6	37.8	49.5	53.8	55.9	59.2	XB-8	78.6	12.6	13.1	17.0	25.0	28.4	34.1	38.7	40.6
O-3	85.0	27.7	33.4	37.1	37.8	51.5	60.0	63.6	67.6	XO-4	76.8	15.1	21.9	28.6	35.4	40.6	49.0	53.2	55.1
Av.	84.7	20.5	28.7	31.5	36.1	49.3	57.7	59.9	63.5		77.2	13.3	16.6	22.9	30.6	36.2	42.4	46.9	49.5
SOAP D (HEAVY DUTY, BUILT)																			
B-1	83.5	15.3	18.8	18.2	30.5	48.3	58.2	62.6	64.7	XB-6	76.1	12.2	14.3	14.8	25.4	35.6	41.3	45.8	48.1
B-2	85.5	18.4	26.3	27.4	34.3	47.0	52.5	57.5	57.8	XB-8	78.6	12.6	14.8	16.5	24.9	30.6	34.9	39.0	40.0
O-3	85.0	27.7	30.2	30.6	38.1	48.1	53.1	60.9	64.1	XO-4	76.8	15.1	17.1	23.7	32.0	44.0	51.5	56.6	57.9
Av.	84.7	20.5	25.1	25.4	34.3	47.8	54.6	60.3	62.2		77.2	13.3	15.4	18.3	27.4	36.7	42.6	47.1	48.7
Average of averages	84.7	20.5	25.6	28.2	36.1	47.1	54.4	59.2	61.5		77.2	13.3	17.3	22.3	31.0	38.2	44.0	47.6	49.1

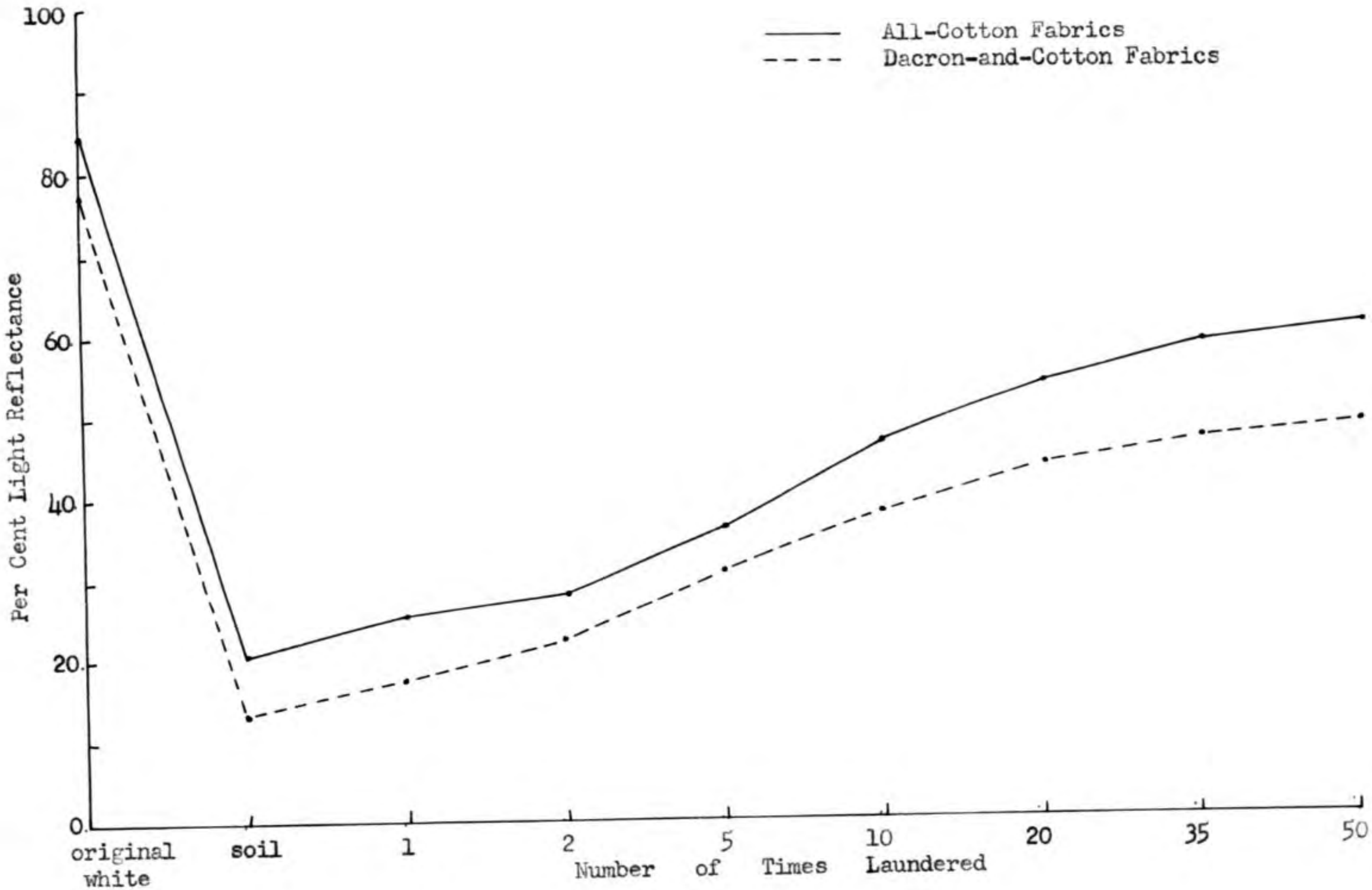

FIGURE I

AVERAGE PER CENT LIGHT REFLECTANCE BEFORE AND AFTER LAUNDERING

After fifty launderings the all-cotton fabrics had a 41.0 per cent increase in light reflectance. During this same period the Dacron-and-cotton fabrics had a 35.8 per cent increase. The increase continued through the fiftieth laundering on each of the fabrics.

V. DIFFERENCES IN THE PER CENT OF SOIL REMOVAL AFTER LAUNDERING

The reflectance values of the original and soiled fabrics varied considerably. The apparent percentage of soil removal was calculated and was used for clarification in the interpretation of the data.

The following standard formula was used:[6]

$$E = \frac{A - B}{C - B} \times 100$$

E = Efficiency of soil removal

A = Reflectance after laundering

B = Reflectance of original soiled fabric

C = Reflectance of original white fabric

The percentage of soil removal is presented in Table V, and shown graphically in Figure 2.

There was not a great amount of variation in the per cent of soil removal from the all-cotton fabrics as compared to the Dacron-and-cotton fabrics. Neither type of fabric was consistently higher throughout the laundering period.

The all-cotton fabrics lost 8.0 per cent soil in the first laundering and the Dacron-and-cotton fabrics lost 6.2 per cent. During the

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[6] Jay C. Harris, Detergency Evaluation and Testing (New York: Interscience Publications, Inc., 1954), p. 79.

TABLE V

PER CENT SOIL REMOVAL

All-Cotton Fabrics								Dacron-and-Cotton Fabrics							
Fabric number	Times Laundered							Fabric number	Times Laundered						
	1	2	5	10	20	35	50		1	2	5	10	20	35	50
SOAP A (LIGHT DUTY, UNBUILT)															
B-1	5.4	6.9	23.2	38.1	46.5	53.8	58.2	XB-6	9.2	20.7	38.6	47.1	54.3	58.1	64.5
B-2	11.2	17.6	30.1	37.3	42.9	48.3	50.7	XB-8	10.6	14.2	22.6	28.6	35.0	39.9	44.8
O-3	.7	3.7	15.7	33.7	52.0	61.4	64.9	XO-4	3.7	10.4	26.4	45.7	57.5	62.9	68.7
Av.	5.8	9.4	23.0	36.4	47.1	54.5	57.9	Av.	7.8	15.1	29.1	40.5	48.9	53.6	59.3
SOAP B (LIGHT DUTY, UNBUILT)															
B-1	4.0	8.5	27.4	42.2	54.4	66.4	68.3	XB-6	12.5	21.8	38.0	49.3	58.4	62.4	66.4
B-2	9.7	22.5	31.4	41.7	49.8	55.4	58.0	XB-8	7.9	11.4	20.8	27.4	35.0	38.9	41.5
O-3	3.8	10.5	25.1	41.7	57.2	71.0	73.5	XO-4	5.0	20.8	40.5	54.8	65.2	69.0	72.0
Av.	5.8	13.8	28.0	41.9	53.8	64.3	66.6	Av.	8.5	18.0	33.1	43.8	52.9	56.8	60.0
SOAP C (HEAVY DUTY, BUILT)															
B-1	12.3	15.5	25.7	46.2	64.4	65.7	70.8	XB-6	4.1	17.2	30.2	43.0	49.9	57.4	62.0
B-2	15.5	15.7	28.9	46.3	52.8	55.9	60.8	XB-8	.7	6.7	18.8	23.9	32.6	39.5	42.4
O-3	11.7	16.4	17.5	41.5	56.4	62.5	68.6	XO-4	11.0	21.9	32.9	41.2	54.9	61.8	66.4
Av.	13.3	17.2	24.0	44.7	57.9	61.4	66.7	Av.	5.3	15.3	27.3	36.0	45.8	52.9	56.9
SOAP D (HEAVY DUTY, BUILT)															
B-1	5.1	4.2	22.3	48.4	62.9	68.9	71.0	XB-6	3.3	4.1	16.6	36.6	47.1	52.6	56.2
B-2	11.8	13.4	23.7	46.6	50.8	58.3	58.7	XB-8	3.3	5.9	18.6	27.3	33.8	40.0	41.5
O-3	4.5	5.1	18.2	35.6	44.3	57.9	63.5	XO-4	3.2	13.9	27.4	46.8	59.0	67.3	69.4
Av.	7.1	7.6	21.4	43.5	52.7	61.7	64.4	Av.	3.3	8.0	20.9	36.9	46.6	53.3	55.7
Average of averages	8.0	12.0	24.1	41.6	52.9	60.5	63.9		6.2	14.1	27.6	39.3	48.6	54.2	58.0

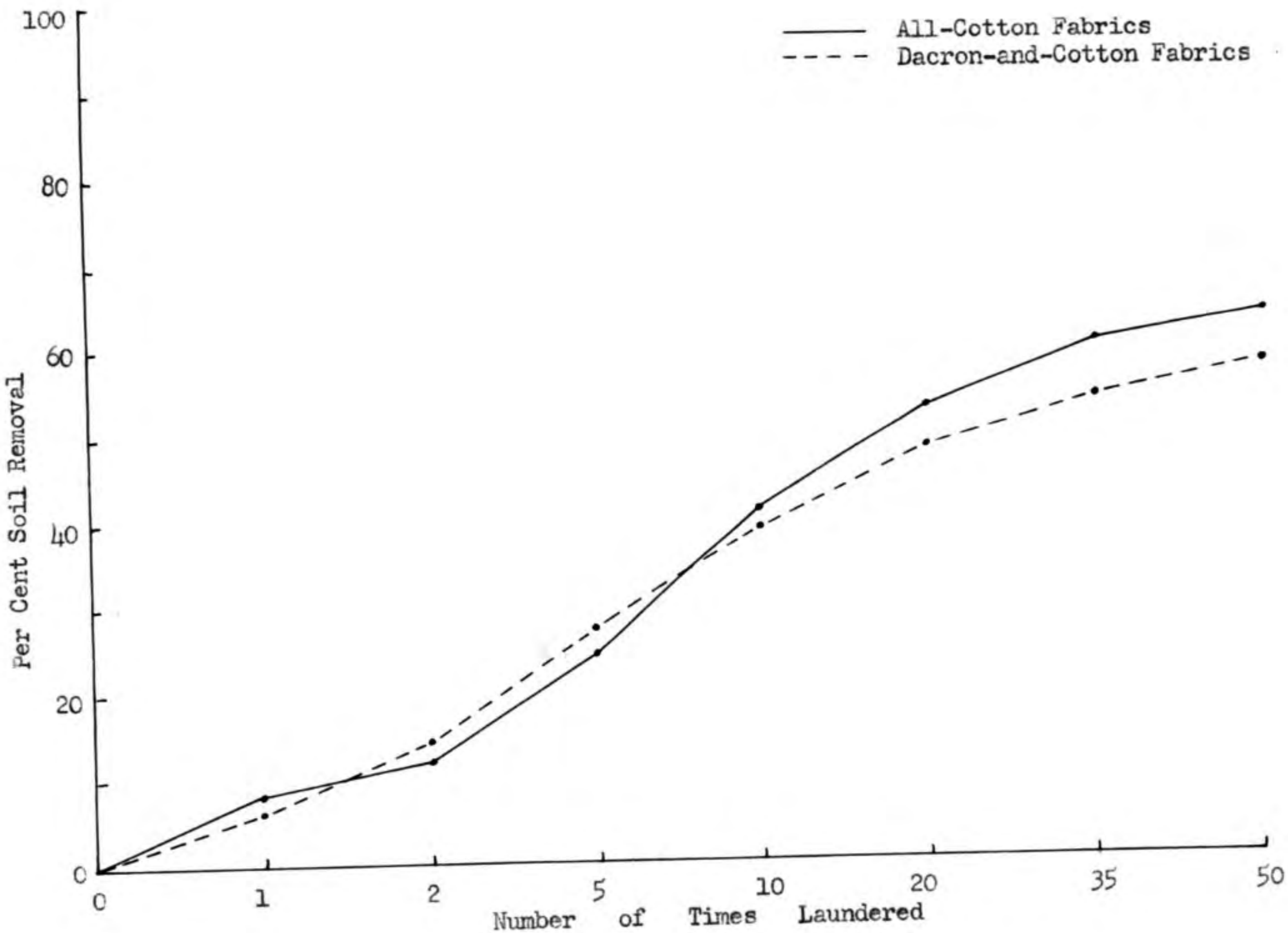

FIGURE 2

AVERAGE PER CENT SOIL REMOVAL

second laundering the Dacron-and-cotton fabrics had a higher percentage loss than the all-cotton fabrics and also a higher percentage loss than after the first laundering, whereas the percentage for the all-cotton fabrics was lower. The Dacron-and-cotton fabrics had a soil loss of 7.9 per cent as compared with 4.0 per cent for the all-cotton fabrics.

The Dacron-and-cotton fabrics continued to lose more soil than the all-cotton fabrics during the third through the fifth launderings. The Dacron-and-cotton fabrics had a soil loss of 13.5 per cent as compared with 12.2 per cent from the all-cotton fabrics. This was the highest loss from the Dacron-and-cotton fabrics during any laundering interval.

More soil was removed from the all-cotton fabrics during the sixth through the tenth launderings than at other laundering intervals and these fabrics continued to lose a greater per cent of soil than the Dacron-and-cotton fabrics through the thirty-fifth laundering. There was little difference in the per cent of soil removal from either type of fabric during the thirty-sixth through the fiftieth launderings.

The final calculations showed that the all-cotton fabrics lost 63.9 per cent soil and the Dacron-and-cotton fabrics 58.0 per cent. The all-cotton fabrics lost 5.9 per cent more soil than the Dacron-and-cotton fabrics.

VI. DIFFERENCES IN PER CENT SOIL REMOVAL FROM THE SIX FABRICS

The six fabrics followed somewhat the same pattern of behavior in the percentage of soil removal except for XB-8 which did not lose soil as readily as the other fabrics. These changes are shown in Table VI and also graphically in Figures 3 and 4.

TABLE VI

AVERAGE PER CENT SOIL REMOVAL

Fabric	Times Laundered						
	1	2	5	10	20	35	50
All-cotton							
B-1	6.7	8.8	27.2	43.7	57.0	63.7	67.1
B-2	12.0	17.3	28.5	43.0	49.1	54.5	57.0
O-3	5.2	8.9	19.1	38.1	52.5	63.2	67.6
Dacron-and-cotton							
XB-6	7.3	16.0	30.8	44.0	52.4	57.6	62.3
XB-8	5.6	9.6	20.2	26.8	34.1	39.6	42.6
XO-4	5.7	16.8	30.4	47.1	59.2	65.2	69.1

All-Cotton Fabrics. Fabric B-2 lost more soil during the first laundering than the other two all-cotton fabrics. This continued during the second laundering.

Fabric B-1 lost more soil during the third through the fifth launderings than at any other period. At the end of five launderings, fabrics B-1 and B-2 had lost approximately the same amount of soil, but fabric O-3 was approximately 9 per cent lower.

The three fabrics had lost more nearly the same amount of soil at the end of the tenth laundering than at any other period. Fabrics B-2 and O-3 lost more soil during the sixth through the tenth launderings than at any other period. From this point, B-2 did not continue to lose soil at as fast a rate as the other two fabrics and was approximately 10 per cent lower in per cent soil removal at the end of fifty launderings.

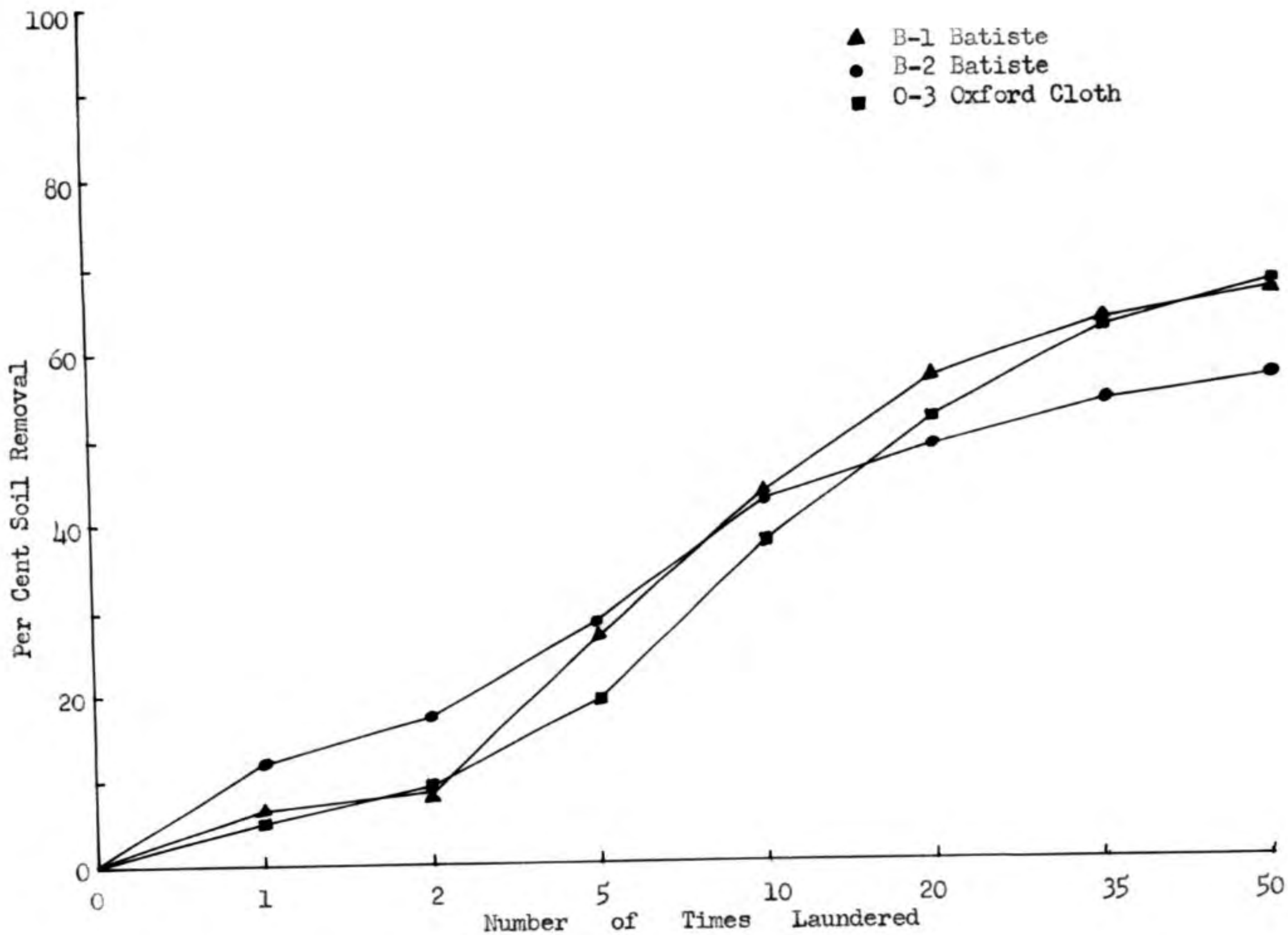

FIGURE 3

AVERAGE PER CENT SOIL REMOVAL FROM EACH ALL-COTTON FABRIC

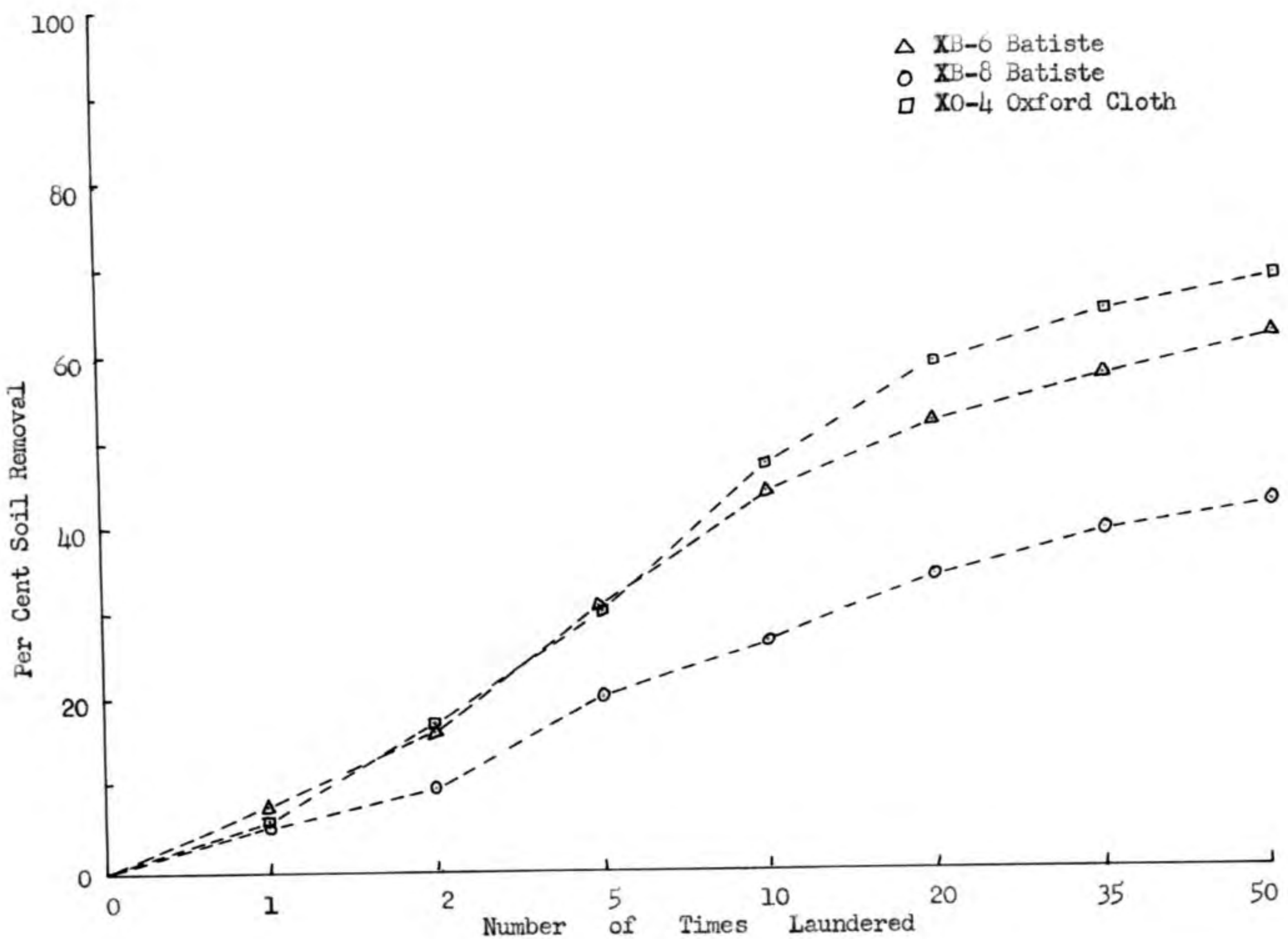

FIGURE 4

AVERAGE PER CENT SOIL REMOVAL FROM EACH DACRON-AND-COTTON FABRIC

The final calculation showed that fabric O-3 lost the highest per cent of soil, 67.6, as compared with 67.1 from fabric B-1 and 57.0 from fabric B-2.

Dacron-and-Cotton Fabrics. There was little difference in the soil removal from each of the Dacron-and-cotton fabrics during the first laundering.

Fabric XB-8 did not lose as much soil during the second laundering as the other two fabrics. This fabric lost more soil during the third through the fifth launderings than at any other period. The rate of soil removal declined through the remainder of the testing period and the per cent of soil removal was much lower than from the other two fabrics.

There was little difference in the per cent of soil removal from fabrics XB-6 and XO-4 at the end of five launderings. Fabric XB-6 lost more soil during the third through the fifth launderings than at any other period. This was true for fabric XO-4 during the sixth through the tenth launderings. The per cent of soil removal was greater from fabric XO-4 than from fabric XB-6 during the eleventh through the thirty-fifth launderings. The per cent of removal was slightly greater from fabric XB-6 than from fabric XO-4 during the thirty-sixth through the fiftieth launderings.

The final calculations showed that fabric XO-4 lost the highest per cent of soil, 69.1 per cent, as compared to 62.3 per cent from fabric XB-6 and 42.6 per cent from fabric XB-8.

VII. EFFECTIVENESS OF SOAPS IN REMOVING SOIL

The soaps were compared to determine the efficiency of soil removal on the all-cotton and Dacron-and-cotton fabrics. Two unbuilt soaps, A and B, and two built soaps, C and D, were used. The comparisons were made using the per cent of soil removal from each fabric. The observed differences were slight and are shown graphically in Figures 5 and 6.

Effectiveness on All-Cotton Fabrics. Soap C removed a higher percentage of soil from the all-cotton fabrics during the first laundering than the other soaps. There was little difference in the effectiveness of Soaps A, B, and D. Soap C removed 13.3 per cent soil as compared with Soap D which removed 7.1 per cent, and Soaps A and B each of which removed 5.8 per cent.

Soap B removed 8.0 per cent soil in the second laundering; Soap C, 4.9 per cent; Soap A, 3.6 per cent; and Soap D, only 0.5 per cent.

During the third through the fifth launderings there was little difference in the effectiveness of Soap B which removed 14.2 per cent soil, Soap D which removed 13.8 per cent, and Soap A which removed 13.6 per cent. Soap C removed 6.8 per cent soil. The light duty soaps, A and B, removed more soil during this interval than at other intervals in the laundering period.

The heavy duty soaps removed approximately the same amount of soil during the sixth through the tenth laundering. These soaps removed more soil at this interval than at other intervals in the laundering period.

There was little difference in the effectiveness of the four soaps during the eleventh through the twentieth launderings.

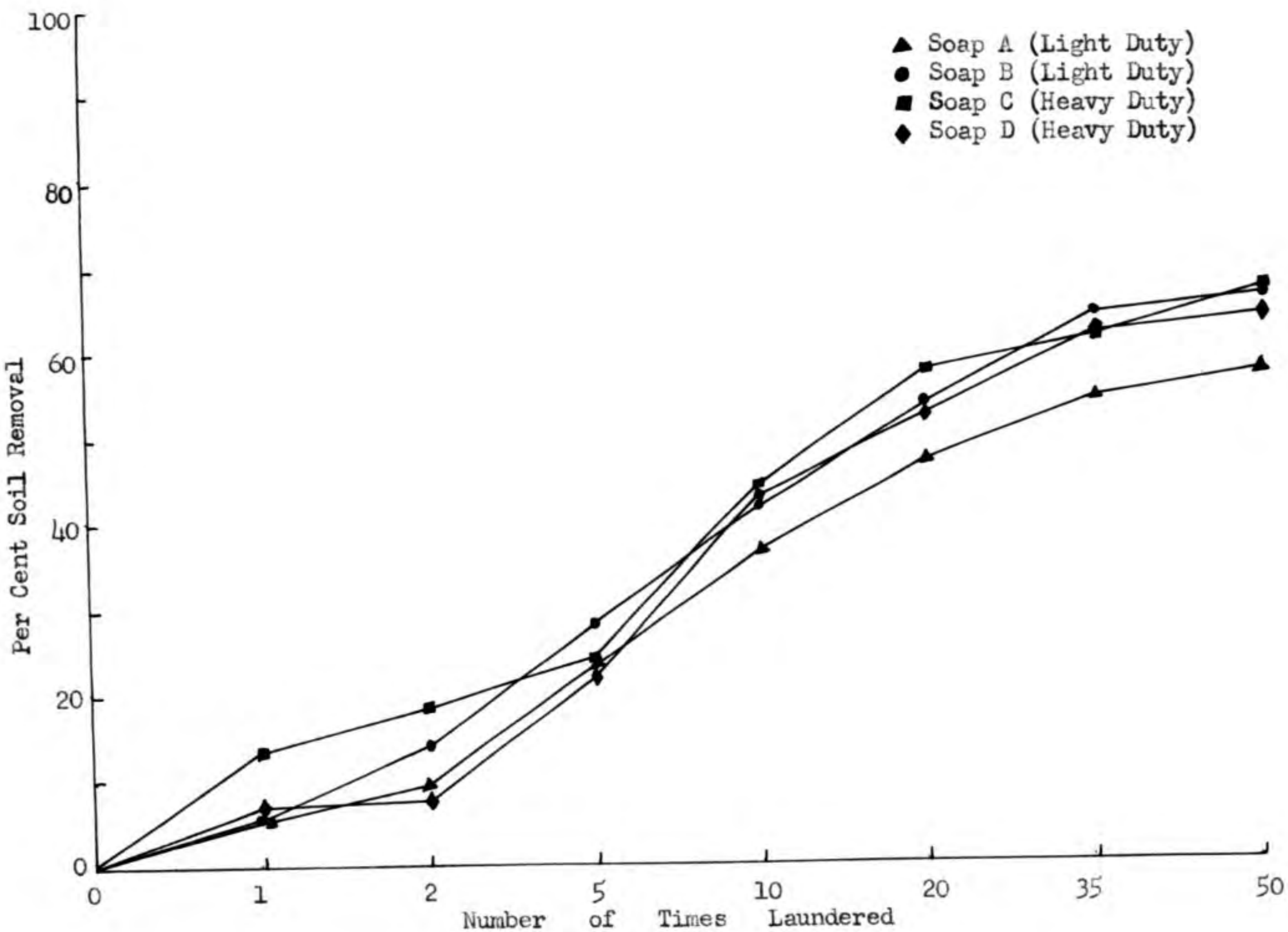

FIGURE 5

EFFECTIVENESS OF SOAPS ON ALL-COTTON FABRICS

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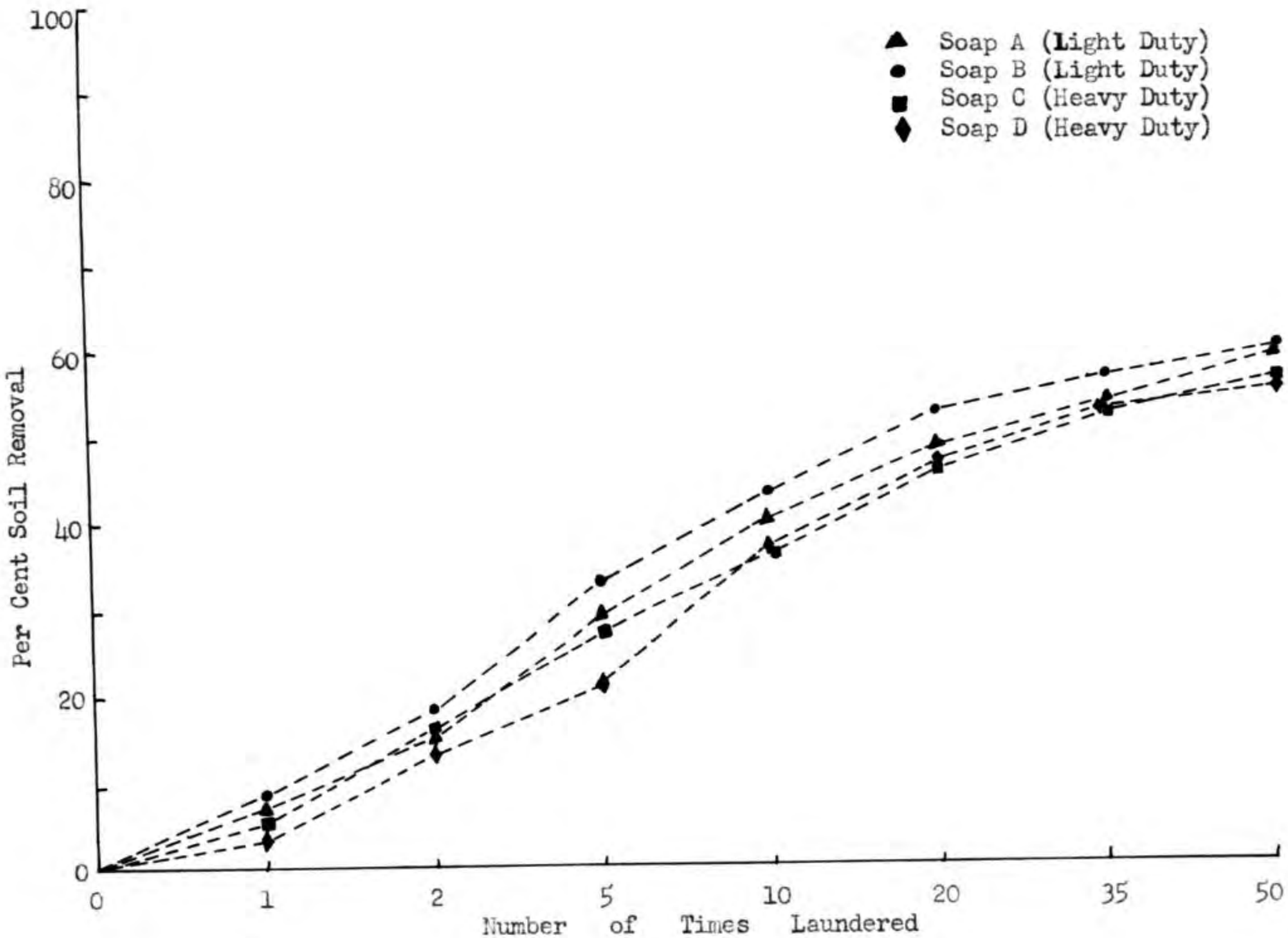

FIGURE 6

EFFECTIVENESS OF SOAPS ON DACRON-AND-COTTON FABRICS

Soap C removed less soil than the other soaps during the twenty-first through the thirty-fifth launderings. Soap C removed 3.5 per cent soil as compared to 10.5 per cent removed by Soap B, 9.0 per cent by Soap D, and 7.4 per cent by Soap A.

All the soaps continued to remove soil throughout the laundering period and there was little difference in the efficiency of the soaps after fifty launderings. The final calculations showed that Soaps C and B removed almost the same amount of soil, 66.7 and 66.6 per cent respectively, as compared to Soap D, which removed 64.4 per cent and Soap A, which removed 57.9 per cent.

Effectiveness on Dacron-and-Cotton Fabrics. There was little difference in the percentage of soil each of the four soaps removed from the Dacron-and- cotton fabrics. Soap B removed 8.5 per cent soil during the first laundering as compared with 7.8 per cent by Soap A, 5.3 per cent by Soap C, and 3.3 per cent by Soap D.

Soap D continued to remove less soil than the other soaps during the second laundering, but there was little difference in the efficiency of the soaps during the third through the fifth launderings.

Soap D removed 16.0 per cent soil during the sixth through the tenth laundering; Soap A, 11.4 per cent; Soap B, 10.7 per cent; and Soap C, 8.7 per cent. From this point through the thirty-fifth laundering, each soap removed approximately the same per cent of soil.

During the thirty-sixth through the fiftieth laundering Soap A removed more soil than in the preceding interval, whereas the other soaps declined in soil removal efficiency.

Each soap continued to remove soil throughout the entire laundering period. The light duty soaps, A and B, removed 59.3 and 60.0 per cent soil respectively. The heavy duty soaps, C and D, removed 56.9 and 55.7 per cent soil respectively. Soap A was the only soap that removed a greater percentage of soil from the Dacron-and-cotton than from the all-cotton fabrics.

When the percentages of soil removed from the six fabrics were plotted graphically according to the soap used, it appeared that the data did not substantiate advertising claims for the performance of types of soap or the performance of specific brands of soap. At each testing period there was a difference of ten per cent or less in the total per cent of soil removed by the soaps from the all-cotton fabrics and also from the Dacron-and-cotton fabrics.

VIII. MATHEMATICAL COMPARISON OF SOIL REMOVAL EFFICIENCY

The null hypothesis stated that there was no difference in the amount of soil retained by the Dacron-and-cotton blends and similar all-cotton fabrics when laundered with selected household soaps. This was computed at the 95 per cent level of confidence using Student's "t" formula. The per cent soil removal was used in the computation, assuming that if there was no difference in the amount of soil removed there would be none in the amount retained. The following formula was used and the computation is shown in Table VII.[7]

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[7] K. A. Brownlee, Industrial Experimentation (third American edition; New York: Chemical Publishing Company, 1949), p. 34, cited by Harris, op. cit., p. 7.

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sigma} \sqrt{\frac{N_1 \times N_2}{N_1 + N_2}}$$

where

$$\sigma^2 = \frac{\Sigma(X_1^2) - \frac{(\Sigma X_1)^2}{N_1} + \Sigma(X_2^2) - \frac{(\Sigma X_2)^2}{N_2}}{N_1 + N_2 - 2}$$

The mean percentage of soil removal for the all-cotton fabrics was 63.9 and 58.0 for the Dacron-and-cotton fabrics. When these percentages were used in the Student "t" formula, "t" was 1.44 and "t" at the 95 per cent level of confidence for twenty-four samples is 2.07. Since 1.44 is less than 2.07 there is no difference in the percentage of soil retained by the three Dacron-and-cotton blends and the three all-cotton fabrics after fifty launderings with four selected household soaps at the 95 per cent level of confidence.

This same formula was used in comparing the efficiency of unbuilt and built soaps on both types of fabrics. It was concluded that there was no significant difference in the efficiency of the two unbuilt and the two built soaps in removing soil from the all-cotton fabrics and also the Dacron-and-cotton fabrics.

IX. COMPARISON OF THE EFFECTIVENESS OF SOAPS AND SYNTHETIC DETERGENTS IN REMOVING SOIL FROM DACRON-AND-COTTON BLENDS AND SIMILAR ALL-COTTON FABRICS

A study of the effect of synthetic detergents on soil removal from Dacron-and-cotton blends and similar all-cotton fabrics was made by

TABLE VII

COMPARISON OF SAMPLE MEANS AFTER FIFTY LAUNDERINGS

All-cotton fabrics		Dacron-and-cotton fabrics	
X_1	X_1^2	X_2	X_2^2
58.2	3387.2	64.5	4160.2
50.7	2570.5	44.8	2007.0
64.9	4212.0	68.7	4719.7
68.3	4664.9	66.4	4409.0
58.0	3364.0	41.5	1722.2
73.5	5402.2	72.0	5184.0
70.8	5102.6	62.0	3844.0
60.8	3696.6	42.4	1797.8
68.6	4706.0	66.4	4409.0
71.0	5041.0	56.2	3158.4
58.7	3445.7	41.5	1722.2
63.5	4032.2	69.4	4816.4
767.0	49534.9	695.8	41949.9

$$\sigma^2 = \frac{\Sigma(X_1^2) - \frac{(\Sigma X_1)^2}{N_1} + \Sigma(X_2^2) - \frac{(\Sigma X_2)^2}{N_2}}{N_1 + N_2 - 2}$$

$$\sigma^2 = \frac{49534.9 - 49060.8 + 41949.9 - 40344.8}{22}$$

$$\sigma = 9.7$$

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sigma}\sqrt{\frac{N_1 \times N_2}{N_1 + N_2}}$$

$$t = \frac{63.9 - 58.0}{9.7}\sqrt{\frac{12 \times 12}{12 + 12}}$$

$$t = 1.44$$

$$t \text{ at } .025 = 2.07$$

Buchanan.[8] Part of the data from the study by Buchanan was compared with corresponding data from this study to indicate differences in the effectiveness of soaps and synthetic detergents on the removal of soil from these two types of fabrics. The average percentages of soil removal calculated in both studies is given in Table VIII, and shown graphically in Figures 7 and 8.

TABLE VIII

AVERAGE PER CENT SOIL REMOVAL FROM DACRON-AND-COTTON AND ALL-COTTON FABRICS WHEN LAUNDERED WITH LIGHT AND HEAVY DUTY SOAPS AND SYNTHETIC DETERGENTS

Type of detergent	Times Laundered						
	1	2	5	10	20	35	50
				ALL-COTTON FABRICS			
Soaps							
Light duty	5.8	11.6	25.5	39.1	50.5	59.4	62.2
Heavy duty	10.2	12.4	22.7	44.1	55.3	61.6	65.6
Average	8.0	12.0	24.1	41.6	52.9	60.5	63.9
Synthetic Detergents							
Light duty	4.3	5.6	7.9	11.6	16.1	18.8	19.6
Heavy duty	4.4	7.4	13.6	16.4	20.2	24.6	28.7
Average	4.4	6.5	10.8	14.0	18.2	21.7	24.6
				DACRON-AND-COTTON FABRICS			
Soaps							
Light duty	8.2	16.6	31.1	42.2	50.9	55.2	59.7
Heavy duty	4.3	11.6	24.1	36.4	46.2	53.1	56.3
Average	6.2	14.1	27.6	39.3	48.6	54.2	58.0
Synthetic Detergents							
Light duty	4.2	7.0	10.8	15.0	19.4	23.8	24.8
Heavy duty	7.8	11.0	16.8	19.6	24.0	28.2	33.6
Average	6.0	9.0	13.8	17.3	21.7	26.0	29.2

[8] Buchanan, loc. cit.

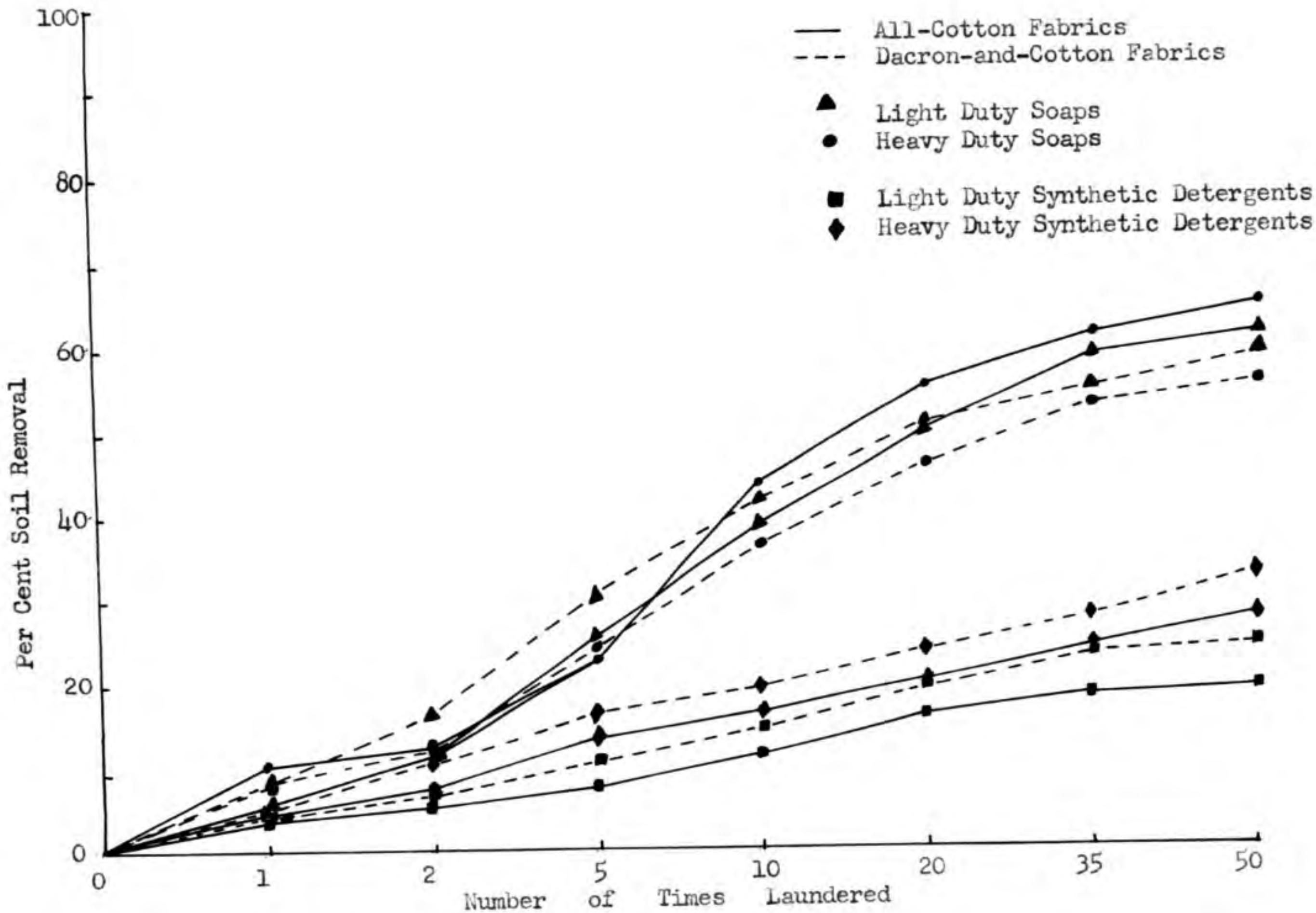

FIGURE 7

EFFECTIVENESS OF LIGHT AND HEAVY DUTY SOAPS AND SYNTHETIC DETERGENTS

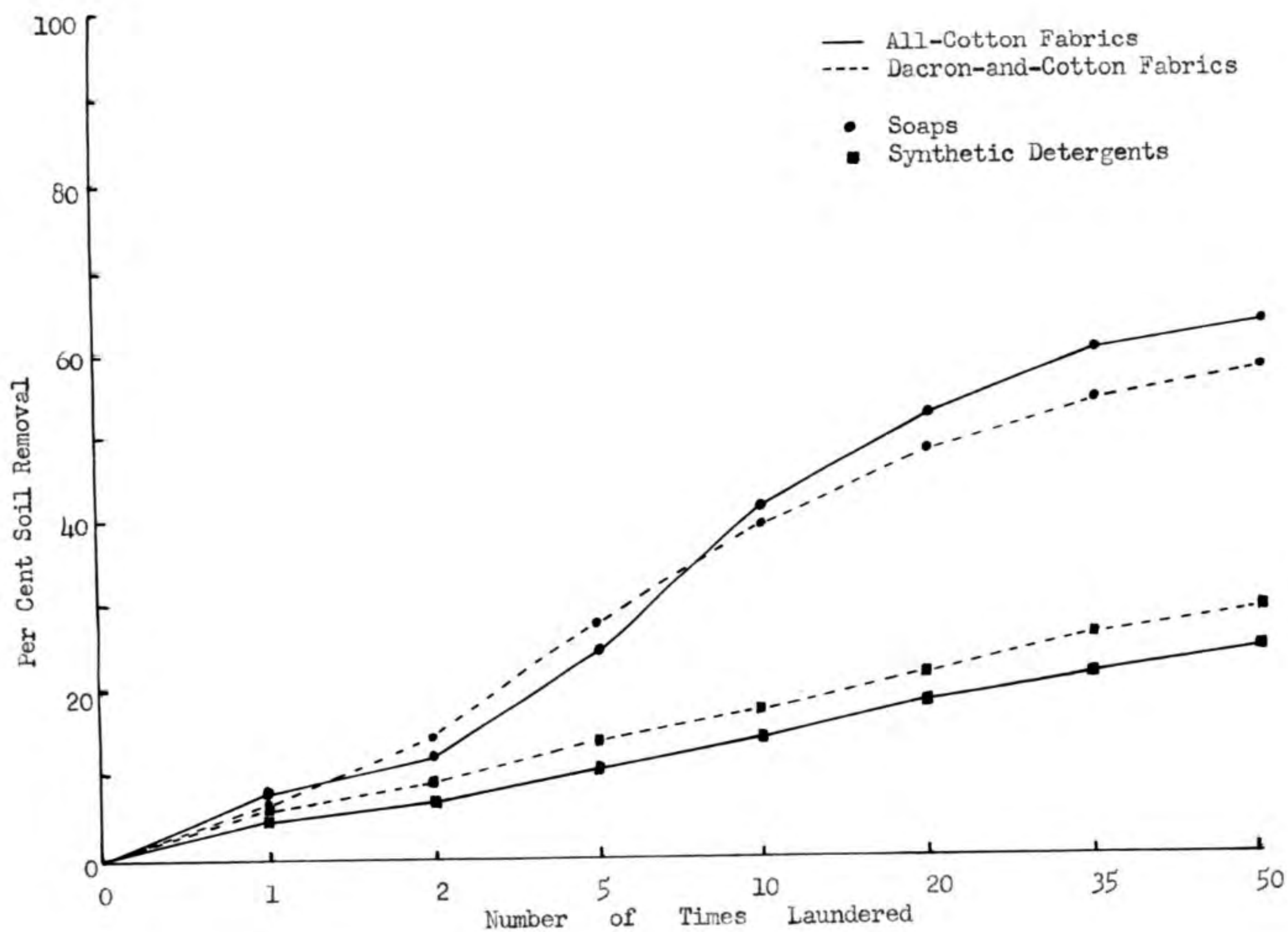

FIGURE 8

EFFECTIVENESS OF SOAPS AND SYNTHETIC DETERGENTS

During the first two launderings there was little difference in the amount of soil removed from either type of fabric when using either soaps or the synthetic detergents. The differences between the soil removal efficiency of the soaps and the synthetic detergents was greater at the end of the fifth laundering than during the first two launderings. The greatest difference in the efficiency of the two types of detergents occurred during the eleventh through the twentieth launderings. The difference was slightly less from this point through the fiftieth laundering.

At the conclusion of the fiftieth laundering there was little difference in the amount of soil removed from the two types of fabrics when laundered with soaps. While the amount of soil removed by the synthetic detergents was considerably less than that removed by the soaps, there was still little difference in the effectiveness on the two types of fabrics. There was little difference between the effectiveness of the light and heavy duty soaps on either type of fabric. This was also true of the light and heavy duty synthetic detergents. It may be of interest to point out that the light duty soaps were slightly more effective in removing soil from the blended fabrics than were the heavy duty soaps at each testing period.

From this comparison of data it may be concluded that the soaps were more effective in removing artificial soil than the synthetic detergents.

CHAPTER V

SUMMARY

Minimum care fabrics are increasing in popularity to help meet the demands of a fast moving society. Many of the new blends have not been on the market long enough for the consumer to have sufficient information and experience concerning the care necessary for optimum performance.

The blend of 65 per cent Dacron and 35 per cent cotton has made rapid advances as an easy-to-care for fabric, yet still presents some concern to the consumer when considered as a competitor to the all-cotton fabrics. This study, part of a larger research project directed toward the serviceability of materials made from Dacron-and-cotton used in shirts and blouses,[1] was made to determine the effect of selected soaps on the removal of soil from this blend as compared to similar all-cotton fabrics.

Three all-cotton and three similar Dacron-and-cotton fabrics from this project were selected and artificially soiled. These fabrics were laundered fifty times each with two unbuilt and two built popular household soaps. Each sample was washed in 500 cc. soft water containing 0.5 gram of specified soap for thirty minutes at 105°F. All launderings were done in an L-2-Q Research Launder-Ometer.

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1 Project H-77, "The Serviceability of Materials Made of Dacron-and-Cotton Used in Shirts and Blouses" (unpublished research reports, North Carolina Agricultural Experiment Station, Raleigh, 1955-).

The Hunter Multipurpose Reflectometer was used to determine the apparent reflectance of the original white soiled fabrics and also of the soiled fabrics after 1, 2, 5, 10, 20, 35, and 50 launderings. From the values obtained in these readings the apparent per cent soil removal was calculated. With the equipment used, any error that may have been caused by the presence of fluorescent dyes could not be corrected.

There was little difference in the per cent of soil removed from the Dacron-and-cotton and all-cotton fabrics. Neither type of fabric was consistently higher in the per cent of soil removed during the laundering period. After fifty launderings the all-cotton fabrics lost only 5.9 per cent more soil than the Dacron-and-cotton fabrics.

The six fabrics followed somewhat the same pattern of behavior in the percentage of soil removal except for one of the Dacron-and-cotton batiste fabrics which did not lose soil as readily as the others.

There was little difference in the efficiency of the four soaps in removing soil. At each testing period there was a difference of 10 per cent or less in the total per cent of soil removed by the soaps from the all-cotton fabrics as well as from the Dacron-and-cotton fabrics.

Since differences in apparent soil removal were small, the Student's "t" method for comparison of means was used to determine whether the difference was significant at the 95 per cent level of confidence. There was no significant difference in the per cent of soil retained by the Dacron-and-cotton fabrics as compared with the all-cotton fabrics. It was also concluded that there was no significant difference in the efficiency of the two unbuilt and two built soaps in removing soil from all-cotton fabrics as well as from Dacron-and-cotton fabrics.

The data obtained in this study were compared with that obtained by Buchanan using synthetic detergents.[2] When laundered in soft water the soaps were more effective in removing artificial soil than the synthetic detergents.

Conclusions

1. There was no significant difference in the efficiency of the two unbuilt and two built soaps in removing soil from the all-cotton fabrics and also the Dacron-and-cotton fabrics after fifty launderings.

2. There was no significant difference between the percentage of soil retained by the Dacron-and-cotton fabrics and similar all-cotton fabrics after fifty launderings.

3. When using soft water, the soaps were more effective than the synthetic detergents in removing artificial soil from both types of fabrics.

Recommendations for Further Study

1. The soil removal efficiency of selected soaps on Dacron-and-cotton blends and similar all-cotton fabrics when laundered in hard water.

2. The effect of the alkali in soaps on the Dacron fiber after repeated launderings.

3. The soil removal efficiency of a larger number of soaps on Dacron-and-cotton blends and similar all-cotton fabrics to substantiate data obtained in this study.

4. The soil retention of a larger number of Dacron-and-cotton fabrics and similar all-cotton fabrics.

5. The correlation of these data with data obtained in the absence of ultraviolet light.

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2 Frances Buchanan, "A Comparison of the Soil Behavior of Dacron-and-Cotton Fabrics with those of Similarly Constructed All-Cotton Fabrics" (unpublished Master's thesis, The Woman's College of the University of North Carolina, Greensboro, 1958).

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