CREECH, PEGGY QUINN. The Performance of Selected Cotton Sheetings as Indicated by Three Methods of Abrasion Resistance. (1968) Directed by: Dr. Pauline E. Keeney. pp. 69

The objectives of the study were to determine the influence of the cotton fiber properties, staple length and strength, on abrasion resistance; to determine the effect that laundering only and use and laundering had on abrasion resistance of sheetings and to compare three methods of measuring abrasion resistance as an indication of the value of each method in predicting fabric performance.

As a study related to the Southern Regional Textile Project SM-18, data were collected from two methods of testing abrasion resistance which were used in the project: the Stoll Weartester flexing and abrasion method, and the Taber Abraser strength difference method. The Taber Abraser yarn breakdown method was employed to obtain abrasion resistance measurements for this study.

Test specimens for this study consisted of cotton sheetings which underwent experimental treatment at the University of North Carolina at Greensboro as specified in the regional project. The sheetings, which were classified into four fiber property groups, were divided into two treatment groups, (1) used and laundered and (2) laundered only. Measurements were made by the three test methods prior to treatment and following completion of thirty and sixty treatment intervals.

An analysis of variance was made to determine the differences in abrasion resistance of those sheetings made from fibers differing in staple length and strength, as well as those sheetings which underwent use and laundering as compared to laundering only.

The results of the study indicated that (1) the difference in fiber length and fiber strength did not significantly affect the abrasion resistance of the cotton sheetings as measured by the three test methods, (2) the three methods of testing abrasion resistance produced varied results among fiber property groups from laundering interval to laundering interval, (3) the yarn breakdown test method was the most consistent in detecting differences in abrasion resistance among cottons varying in staple length and strength, and (4) the two treatments, laundering only and use and laundering, significantly affected the abrasion performance of the cotton sheetings.

THE PERFORMANCE OF SELECTED COTTON SHEETINGS AS INDICATED BY THREE METHODS OF ABRASION RESISTANCE

by

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APPROVAL SHEET

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CHAPTER I

INTRODUCTION

It has long been recognized that the cotton fiber is the most versatile of all textile fibers. Its versatility, durability, and low cost account for the fact that cotton is the most widely used of textile raw materials, and it continues to maintain this position of dominance despite a steady increase in the consumption of man-made fibers. In view of its extensive usage, the investigation of cotton fiber properties and their relation to fabric performance is an important area of research for those interested in the utilization of cotton.

Resistance to abrasion is one of the major factors determining the degree of serviceability obtained from a textile fabric. As pointed out by McNally and McCord:

> Cotton's satisfactory wearing qualities have long been held in high regard by consumers. A major reason for this is cotton's ability to resist damage from abrasion or rubbing. In recent years, however, competition from certain synthetic fibers . . . has made reappraisal of cotton's abrasion performance desirable.[1]

Extensive research has been directed toward the study of cotton fiber properties in the raw state, while investigation of the relationship between fiber properties and serviceability of the end-product is fragmentary. The

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[1]John P. McNally and Frank A. McCord, "Cotton Quality Study, Part V: Resistance to Abrasion," Textile Research Journal, Vol. 30, No. 10, (October, 1960), p. 715.

effect that the cotton fiber properties staple length and staple strength might have upon serviceability has been of interest to Home Economics Research Personnel of the agricultural experiment stations in six Southern states. Under the sponsorship of the United States Department of Agriculture, this group conducted Southern Regional Research Project SM-18 in order to study the relation of fiber properties to end-product performance.[2]

A portion of this regional project was devoted to measurement of the abrasion resistance of muslin sheeting manufactured from experimental cottons varying in staple length and strength. Two different methods, the Taber Abraser strength difference method and the Stoll Weartester flexing and abrasion method, were used to measure resistance to abrasion. However, the variation in the results of these tests indicated a need for further investigation of methods to measure abrasion resistance.

This study was related to the regional project described above in that a third method of measuring resistance to abrasion, the Taber Abraser yarn breakdown method, was investigated. It was thought that this method would measure resistance to abrasion more consistently than the two methods used in the regional project.

The specific objectives of this study were:

> To study abrasion characteristics of selected sheetings made from cottons of varying properties of fiber length and fiber strength, using the Taber Abraser yarn breakdown method of testing.

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[2]Technical Committee Project SM-18, "The Relation of Fiber Properties to End-Product Performance," (Manual of Procedures, Southern Regional Research Project SM-18).

a. To determine whether differences in fiber length and fiber strength influence abrasion resistance.

b. To determine the significance of differences in abrasion resistance of selected cotton sheetings that have (1) been used and laundered and (2) been laundered only.

To compare the data obtained from the above test procedure with that obtained previously from the Stoll Weartester method and the Taber Abraser strength difference method as an indication of the value of each method in predicting fabric degradation.

Data used in this entire study were obtained from tests performed on those sheetings which underwent experimental treatment at the University of North Carolina at Greensboro according to specifications set forth in the regional research project. Specimens for each of the three tests were taken from sheetings withdrawn for testing following completion of zero, thirty, and sixty periods of (1) use and laundering and (2) laundering only.

Abrasion measurements using the flexing and abrasion method and the strength difference method of testing were made at those experiment stations specified in the regional project. These data were compiled for comparison with those measurements made for this study using the yarn breakdown method of testing.

Definitions of Terms

Although the terms abrasion and wear have been used interchangeably over the years to refer to the mechanical destruction of textiles, they are not synonymous. Abrasion is defined by the American Society for Testing and Materials as "the wearing away of any part of a material by rubbing against

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> Abrasion, derived from the verb 'to abrade', very distinctly suggests a 'rubbing off' . . . . The term 'wear' is believed to be more closely associated with the thought of the conditions surrounding every-day use and service, and implies the combined effect of several factors of which abrasion or rubbing is only one . . . . It is suggested therefore, that 'wear' be considered as a broader scope than 'abrasion' and be used to apply whenever other important destructive actions, with or without abrasion, are existent.[5]

For research purposes, the term serviceability should also be defined. Kaswell states that:

> A fabric which serves the function for which it is intended may be defined as being 'serviceable'. The word is a broad one and encompasses all those criteria of performance which permit [sic] a fabric to be accepted or rejected for use.[6]

Organization of Remainder of the Study

Chapter II is a review of the literature pertaining to the mechanism of abrasion resistance and its measurement, as well as studies involving the wear

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[3] ASTM Standards on Textile Materials, sponsored by ASTM Committee D-13 on Textile Materials, (Philadelphia: American Society for Testing and Materials, 1963), p. 469.

[4] Ernest R. Kaswell, Textile Fibers, Yarns, and Fabrics, (New York: Reinhold Publishing Corporation, 1953), p. 299.

[5] Ibid., citing H. J. Ball, "Problems Which Abrasion and Wear Testing Present," Textile Research Journal, Vol. 8, 1938, p. 134.

[6] Ibid., p. 298.

and serviceability of cotton fabrics. Chapter III describes the procedures for the measurement of abrasion resistance and the statistical analysis used. The compilation and results of the abrasion resistance measurements are presented in Chapter IV. Chapter V includes the summary and conclusions of this study and recommendations for further study.

CHAPTER II

REVIEW OF LITERATURE

Abrasion resistance has received steadily increasing attention during the last thirty years, because it is recognized as one of the most important factors contributing to the serviceability of textile products. Textile technologists admit that the measurement of abrasion resistance is a complex process which is affected by many variables, but the amount of research concerning abrasion and wear clearly indicates the importance of this topic.

I. MEASURING ABRASION RESISTANCE

Authorities in the field of textile research disagree on several points relating to the measurement of abrasion resistance and the subsequent interpretation of test results. Some of the factors which are involved in the study of abrasion resistance include: reliability of testing machines, evaluation of test results, correlation between different testing machines, and the relation of laboratory tests to the performance of fabrics in use.

Methods of Determining Abrasion Resistance

It is generally recognized that the phenomenon of abrasion, insofar as it is involved in the wear of textiles, is not completely understood; and, just as there is no single abrasion mechanism, so there is no single abrasion test that can determine the ability of a material to perform satisfactorily under all types of exposure to wear. John P. McNally and Frank A. McCord comment that:

> Attempts to produce a uniform, constant, and reproducible abrading action which simulates and, if possible, correlates with service wear have resulted in the development of more abrasion testing devices than perhaps any other type of textile testing apparatus.[1]

The difficulty in designing satisfactory testing equipment had led to the development of more than fifty abrasion and wear testing machines by 1950.[2] McNally and McCord maintain that many others have been developed during the past decade.[3]

Such a prolific number of instruments claiming to perform essentially the same test is an indication of the textile industry's urgent need for a satisfactory testing procedure in this field. From this wide variety of abrasion testing machines available, Meredith and Hearle state that the five most commonly used abrasion test methods in the United States are the inflated diaphragm; the flexing and abrasion; the oscillatory cylinder; the rotary platform, double head; and the uniform abrasion method.[4]

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[1] John P. McNally and Frank A. McCord, "Cotton Quality Study, Part V: Resistance to Abrasion," *Textile Research Journal*, Vol. 30, No. 10, (October, 1960), p. 738.

[2] Margaret Harris Zook, "Historical Background of Abrasion Testing," *American Dyestuff Reporter*, Vol. 39, No. 19, (September 18, 1950), p. 625.

[3] McNally and McCord, *loc. cit.*

[4] R. Meredith and J. W. S. Hearle, *Physical Methods of Investigating Textiles*, (New York: Textile Book Publishers, Incorporated, 1959), p. 271.

The ASTM Standards on Textile Materials outlines the scope of each of these five test methods.

Inflated diaphragm method:

This method is intended for use in determining the resistance to abrasion of woven and knitted textile fabrics when the specimen is inflated over a rubber diaphragm under controlled air pressure and rubbed either unidirectionally or multidirectionally against an abradant of given surface characteristics under controlled pressure conditions.[5]

Flexing and abrasion method:

This method is intended for use in determining the resistance of woven fabrics to flexing and abrasion when the specimen is subjected to unidirectional reciprocal folding and rubbing over a bar having specified characteristics, under known conditions of pressure and tension.[6]

Oscillatory cylinder method:

The oscillatory cylinder method is used for determining the abrasion resistance of textile fabrics when the specimen is subjected to unidirectional rubbing action under known conditions of pressure, tension, and abrasive action. The abrasion resistance is evaluated in terms of an objective end point.[7]

Rotary platform double head method:

This method is intended for use in determining the abrasion resistance of fabrics or cloth durability when the specimen is subjected to rotary rubbing action under controlled conditions of pressure and abrasive action.[8]

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[5]ASTM Standards on Textile Materials, sponsored by ASTM Committee D-13 on Textile Materials, (Philadelphia: American Society for Testing and Materials, 1963), p. 469.

[6]Ibid., p. 472.

[7]Ibid., p. 477.

[8]Ibid., p. 480.

Uniform abrasion method:

> The uniform abrasion testing machine method is applicable to testing the resistance to abrasion of a wide range of textile materials under a very great range of constant testing conditions. The abrasive action is applied uniformly in all directions in the plane of the surface of the specimen about every point in it. The setting of the machine, method of mounting specimens, conditions of test (as, dry or wet), and criteria to be used in evaluating abrasive wear in the test depend upon the nature of the specimen to be tested and use to be made of the results.[9]

The descriptions of these five abrasion methods point out the fact that there are basic differences in the methods of testing, and these differences make accurate comparisons of the results obtained from each method difficult. McNally comments on the variables within the testing on a single machine which makes scientific comparison of results difficult:

> . . . On any given machine the results obtained are sensitive to the following test conditions, variations of which can cause considerable non-reproducibility: general conditions of the test, such as wet or dry abrasion; nature of the abradant; nature of the motion between specimen and abradant; pressure and tension on the specimen; removal of debris produced during the test; and method of evaluation of the amount of abrasion damage.[10]

Evaluation of Abrasion Tests

The selection of criteria for evaluating the extent of damage which took place during an abrasion test is a significant factor in the validity of the test. Authorities disagree on the value of various methods of evaluation, but frequently used end-points, or methods of evaluation, include changes in thickness, air

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[9] Ibid., p. 485.

[10] McNally and McCord, op. cit., p. 739.

permeability, weight, strength, and visual appearance.[11]

Kaswell states that the criteria selected to judge abrasion resistance must be based on the fabric's function, and he continues by commenting on the most commonly used methods of evaluation:

> . . . Probably the three most widely used laboratory criteria are: (1) direct visual comparison of fabric appearance against a known standard, after both the test sample and the standard have been abraded for a selected number of cycles; (2) determination of the number of abrasion cycles required to form a hole or for the fabric to fail; (3) determination of the strength loss caused by a selected number of abrasion cycles or, more properly, a graph of abrasion cycles versus strength loss.[12]

McNally and McCord suggest that the "selection of the property to be evaluated depends upon the specimen being tested and the importance of the property in particular end-use application."[13] They hold the opinion that loss in breaking strength is a convenient method of measuring abrasion resistance, and that changes in thickness and weight are not reliable because the differences are so small they are difficult to measure.[14]

The number of cycles of abrasion required to form a hole in the specimen is a convenient and frequently used method of evaluating the results of laboratory tests. The cycles, which indicate the abrasion life of a material, can be compared for different fibers, and they may also be evaluated quantitatively

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[11]Zook, op. cit., p. 626.

[12]Ernest R. Kaswell, Wellington Sears Handbook of Industrial Textiles, (New York: Wellington Sears Company, Inc., 1963), p. 359.

[13]McNally and McCord, op. cit., p. 740.

[14]Ibid.

when obtained on the same testing machine.[15] However, this method of evaluation is subject to criticism on the basis that the end-point is usually impossible to define quantitatively and reproduce.

Correlation of Results Among Different Abrasion Machines

Of the more than fifty abrasion testing machines available, there are numerous differences among them in the operating conditions of the machines. The most important factors which influence the results obtained by the various abrasion machines include:

1. Type of motion
2. Nature of abradant
3. Pressure of abradant on the sample
4. Tension on the sample
5. Completeness of lint removal
6. Determination of the end point.[16]

A study which points out the degree of correlation between results obtained from four different machines was reported by Louis I. Weiner and Clarence J. Pope. The abrasion resistance of fifteen prototype fabrics were evaluated on the Stoll, Bocking (BFT), Sand, and Taber abraders. Recognition was given to a possible association between the action of these machines and two

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[15]George Susich, "Abrasion Damage of Textile Fibers," Textile Research Journal, Vol. 24, No. 3, (March, 1954), p. 211.

[16]Jules Labarthe, Textiles: Origins to Usage, (New York: Macmillan Company, 1964), p. 392.

types of wear designated as "adhesive" and "abrasive". The abrasive action of the Stoll and BFT machines was considered predominantly "adhesive", while the Sand and Taber machines produced "abrasive" action. A statistical analysis of the data by means of correlation coefficients revealed the highest correlation was obtained between the Stoll and BFT, with an R value of 0.95, and between the Sand and Taber, with an R value of 0.86.[17]

> The results of this study suggest that difference in types of wear action have a significant influence on the correlation of laboratory abrasion instruments. Those instruments which produce similar types of wear correlate within rather close tolerance limits. Correlations of these types prove to be quite useful in laboratory wear studies.[18]

A subcommittee of the American Society for Testing and Materials, Committee D-13, initiated a study with eleven laboratories to determine the correlation between different abrasion tests. The laboratories were free to choose their own method and procedure of testing. The committee found it was not possible to obtain a correlation among ten different machines utilized, because the eleven laboratories reported results for 64 distinct testing procedures and abrasion methods.[19] It was concluded that:

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[17]Louis I. Weiner and Clarence J. Pope, "Correlation of Laboratory Abrasion Testers," Textile Research Journal, Vol. 33, No. 9, (September, 1963), pp. 762-763.

[18]Ibid., p. 763.

[19]Charles Simon, "Results of Service Wear and Laboratory Abrasion Tests on Seven Shirt Type Fabrics," Task Group on Abrasion, ASTM Committee D-13, 1958, pp. 1,2.

. . . The current methods and procedures of abrasion testing are not sufficiently advanced, developed, and standardized so that absolute test results can be obtained on a group of fabrics when tested at different laboratories. The current methods and procedures of abrasion testing are adequate, however, for obtaining good quantitative comparative results among a group of fabrics . . . provided a good plan of testing is followed.[20]

Relation of Laboratory Abrasion Tests to Service Tests

Opinion varies considerably as to the value of abrasion tests in predicting service performance, but the fundamental question in this area is, to what extent should laboratory wear tests approximate service during wear? Two different philosophies are maintained by authorities. The first requires reproduction of actual wear conditions for a specific fabric use, while the second philosophy recommends selection of the most influential factors which account for wear, and correlating them with service tests.[21]

When stating the following, the late H. DeWitt Smith expressed the philosophy held by many in the textile field:

I should like to see fabrics classified as to use, the most important classes in which wearability is a factor grouped, the cause of wear determined, machines designed to duplicate service results, and properties which affect wearability determined.[22]

Laboratory abrasion tests are of value, McNally and McCord maintain, but they point out the danger of predicting wear life of fabrics based on laboratory tests alone. Present methods of testing can be relied upon to predict

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[20]Ibid., p. 6.

[21]Zook, op. cit., p. 625.

[22]Ibid., citing statement by H. DeWitt Smith.

performance of fabrics only if service tests have proved the relationship between the abrading action of the machine and abrasion encountered during wear.[23]

Since abrasion is only one of the variables involved in wear, the difficulties encountered in correlating laboratory abrasion tests and service performance of textiles are numerous. As pointed out by E. M. Hicks and A. G. Scroggie:

> . . . It has been necessary to conduct field tests in end uses to obtain information on wear, because of the difficulty in correlating data observed in the laboratory with wear observed in service. This difficulty probably resides in the fact that wear is a composite result involving abrasion, flexing, strength, elongation, and other factors, all exerting their individual effects simultaneously.[24]

There is a recognized need for controlled service testing and correlation with laboratory test methods, but few quantitative service tests have been made because of lack of personnel, time, and facilities. The Quartermaster Corps of the United States Army conducted a study for the purpose of determining the correlation between wear on the Combat Course and abrasion resistance in the laboratory.

Fifteen uniforms of 8.2-ounce twill, 9-ounce sateen, and 9.3-ounce herringbone twill were made and worn on the Combat Course. Evaluation of the worn fabrics pointed out that (1) the sateen wore out slowest, (2) the herringbone

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[23]McNally and McCord, op. cit., p. 739.

[24]E. M. Hicks and A. G. Scroggie, "Taber Yarn-Sheet Abrasion Test," Textile Research Journal, Vol. 17, No. 7, (July, 1948), p. 416.

twill wore out 1.8 times faster than the sateen, and (3) the twill wore out 2.1 times faster than the sateen.[25]

Two conventional abrasion machines, the M.I.T. unidirectional and the Taber multidirectional, were used to abrade identical fabrics in the laboratory. Tensile strength evaluations of the abraded fabrics ranked them in substantially the same order as the Combat Course.[26] Where the laboratory tests showed large differences in abrasion resistance of the fabrics, the results were borne out on the Combat Course. However, where only small differences were detected in the laboratory, they were not borne out on the Combat Course, for the laboratory tests gave a more sensitive measure of abrasion resistance than did the wear test.[27]

Kaswell, who reported this study, maintains:

> . . . It is not necessary that the laboratory abrasion machine actually reproduce service wear. If wear produced by the abrasion machine can be correlated with service wear, then the machine can predict the serviceability of a fabric, provided the results are interpreted correctly.[28]

The results of the study indicate that laboratory abrasion tests can, with

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[25]Ernest R. Kaswell, "Wear Resistance of Apparel Textiles, I: Tests of Military Fabrics on Quartermaster Combat Course," Textile Research Journal, Vol. 16, No. 9, (September, 1946), pp. 414-416.

[26]Ibid., p. 417.

[27]Ernest R. Kaswell, "Wear Resistance of Apparel Textiles, II: Laboratory Evaluation of Military Fabrics and Correlation with Combat Course Tests," Textile Research Journal, Vol. 16, No. 10, (October, 1946), p. 521.

[28]Kaswell, "Tests of Military Fabrics on Quartermaster Combat Course," p. 414.

reasonable accuracy, predict the serviceability of fabrics with less expenditure of time and energy than is possible in service tests.

Abrasion testing should be regarded as a laboratory attempt to give information relevant to the probable wear of a textile, but such tests do not contribute all of the desired information. Since actual wear consists of several factors, a single laboratory evaluation method which would correctly evaluate all types of fabric in terms of performance results cannot be expected to evolve. However, when abrasion test conditions correspond closely to abrasion conditions in wear, a good correlation can be found between the laboratory test and the wear test.

Abrasion tests have not succeeded in adequately predicting service performance of fabrics because of the numerous factors involved in the wearing process. There is a serious need to determine the contribution of these various factors to fabric failure so as to more accurately relate accelerated abrasion testing with actual wear life.

II. FACTORS RELATING TO ABRASIVE WEAR

Factors contributing to wear can be classified as either mechanical or chemical in nature, according to McNally and McCord. Mechanical wear includes "gradual deterioration resulting from abrasion and tensile stressing as well as the accidental causes of failure."[29] Chemical wear is the result of

[29] McNally and McCord, op. cit., p. 720.

"microbial attack, chlorine damage during laundering, sunlight degradation, and effects of strong acids."[30]

Salvage studies have shown that abrasion is a major cause of fabric failure, but the importance of the various factors contributing to mechanical wear have not been determined. Under a given set of conditions, the abrasion damage of textiles depends upon "fiber mechanical properties, yarn and fabric construction, and finish."[31]

> All three factors significantly affect abrasion performance, but it is extremely difficult to assign a relative order of importance. Through faulty construction or improper application of finish, fibers with excellent mechanical properties can be made into fabrics with poor abrasion resistance. On the other hand, fibers with poor mechanical properties can be made into fabrics with adequate abrasion resistance through proper construction or choice of finish.[32]

Fiber Mechanical Properties

> While the textile literature is replete with articles on empirical evaluation of abrasion resistance, little has been reported toward explaining the inherent physical properties of fibers which contribute to good or poor abrasion resistance.[33]

During the course of wear, fibers undergo changes in physical properties and eventually breakdown, but much remains to be learned about the basic mechanism of abrasion. Abrasion damage proceeds through the gross mechanism of "direct fiber damage and the untwisting, displacement, or

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[30] Ibid. [31] Ibid.

[32] Ibid., p. 729.

[33] Ernest R. Kaswell, Textile Fibers, Yarns, and Fabrics, (New York: Reinhold Publishing Corporation, 1953), p. 305.

removal of fibers in the yarn, but the detailed processes involved are extremely complex and not well understood."[34]

Damage to fabrics in actual service probably results from a combination of direct rubbing, or "flat" abrasion, and bending, generally termed "flex" abrasion. This results in a weakening of the textile structure due to the removal of, or damage to, individual fibers.[35] Stanley Backer suggests that three mechanisms contributing to fiber breakdown include frictional wear, cutting, and fiber plucking.

> . . . Friction and surface cutting cause direct damage to the fiber at local points of contact with abrasive particles. Plucking may cause immediate or dynamic fatigue rupture of the fiber at that point along the fiber length where maximum stress concentration is built up.[36]

<u>Microscopic evaluation of fiber damage</u>. Microscopic examination of fibers taken from worn fabrics aid in understanding the mechanical breakdown of fibers during service. Depending upon the nature and intensity of abrasive action during use, typical forms of cotton fiber damage observed includes fibrillation, cuticle damage, and transverse cracking.

Fibrillation, which is the result of intensive abrasive action, involves "the longitudinal disintegration of the fiber into a series of elements revealing

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[34]McNally and McCord, op. cit., p. 743.

[35]Ibid., p. 724.

[36]Stanley Backer, "The Relationship Between the Structural Geometry of a Textile Fabric and Its Physical Properties, Part II: The Mechanics of Fabric Abrasion," Textile Research Journal, Vol. 21, No. 7, (July, 1951), p. 466.

the fibrillar structure."[37] Cuticle damage is due to gentler abrasion and consists of a bruising of the fiber. It is thought to be caused by a "loosening, tearing, and partial or complete removal of the cuticle,"[38] the outermost portion of the fiber. Transverse cracking is the "development of cracks at right angles to the fiber axis."[39]

Microscopic evaluation has revealed that there is a fundamentally different mechanism occurring during the wet and dry abrasion of a fabric. Chippindale, by means of the electron microscope, compared the effects of wear upon cotton fabrics in actual performance and laboratory abrasion, while in both the wet and dry state.

Fabrics which had been worn and dry cleaned were compared with fabrics which had been laundered only. The fibers from the worn fabrics appeared to have suffered erosion while there was no evidence of breakdown into fibrils.[40] Fabrics which were subjected to wet abrasion during laundering had no broken yarns, but the microscope revealed considerable fibrillation had taken place, and individual fibrils had been torn from the fiber surface.[41]

Fiber breakdown observed during wet and dry laboratory abrasion

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[37] McNally and McCord, op. cit., p. 728.

[38] Ibid., p. 729. [39] Ibid.

[40] P. Chippindale, "Wear, Abrasion, and Laundering of Cotton Fabrics, Part I: Wear of Fabrics During Actual Service and Laundering," Journal of the Textile Institute, Vol. 54, (November, 1963), p. T447.

[41] Ibid., p. T448.

tests was similiar to that observed during the wet and dry abrasion of laundering and wear. During the wet machine abrasion, the fibers swelled and fibrils were torn from the fiber surface, just as was observed in the laundered fabrics.[42] Dry flexing led to the appearance of cracks in the fiber surface which, with continued wear, led to breaks and the appearance of fiber ends.[43] This type of damage was not identical to that observed in actual wear.

> Although fibre ends have not been observed in fabrics that have suffered abrasion in normal wear, fibre surfaces from these fabrics show a similar eroded appearance. Cracks have not been found in these fibres and it may be that erosion rather than fibre stressing plays a greater part in breakdown than is the case with laboratory machines whose action is relatively severe.[44]

Since a cotton textile fabric is exposed to alternate wear and laundering during use, Chippindale contends that laboratory abrasion tests should also consist of alternate wet and dry abrasion. This method of testing would more closely simulate service conditions and exposure to abrasion.[45]

The electron microscope is invaluable in research concerning fiber breakdown, and its continued use should lead to a more thorough understanding of the complex mechanism of abrasion and fabric failure.

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[42]P. Chippindale, "Wear, Abrasion, and Laundering of Cotton Fabrics, Part II: Wear of Fabrics on Laboratory Test Machines," Journal of the Textile Institute, Vol. 54, (November, 1963), p. T462.

[43]Ibid. [44]Ibid.

[45]Chippindale, "Wear, Abrasion, and Laundering of Cotton Fabrics, Part I," p. T447.

Specific Fiber Properties: Staple Length and Strength

Cotton is bred for specific fiber properties, but it is difficult to isolate the influence of a particular property and to determine its effect upon desired qualities such as abrasion resistance. This study is concerned with the fiber properties of length and strength, as they relate to service performance.

Since fiber length, fineness, and strength tend to vary together, it is obvious why the relative importance of each of these fiber properties is unclear. However, it is generally accepted that cottons of long staple tend to be stronger than short staple varieties.[46]

Fiber length and fineness influence abrasion resistance by their effects upon fiber cohesion in yarns. McNally and McCord contend that "longer fibers are generally more difficult to remove or displace from yarns than shorter ones,"[47] thereby improving abrasion resistance. They maintain that breeding practices which produce longer cotton fibers are desirable since "improved fiber cohesion and stronger yarns and fabrics can be expected with increased staple length."[48]

A study to determine the strength of single cotton fibers and the corresponding property of the resultant textile structure was undertaken by

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[46] K. L. Hertel, "Fiber Strength as a Function of Fiber Length and Gauge Length," Textile Research Journal, Vol. 27, No. 7, (July, 1957), p. 571.

[47] McNally and McCord, op. cit., p. 733.

[48] Ibid., p. 744.

Rebenfeld. He concluded that the "transmission of single fiber strength to the strength of textile structures such as bundles, yarns and fabrics does not appear to be a perfect one."[49] He attributed these findings to the fact that steps in the manufacturing process tend to reduce the differences among cottons in their single fiber state. Thus, the basic differences in strength among cottons are not as large in the textile structure as they are in the single fiber state.[50]

Numerous factors of fabric geometry can be introduced into a fabric so that it does not behave mechanically in the same manner as the bulk material of which it is made. However, these geometrical elements assume a major role in the abrasion mechanism.[51]

Fabric Construction

As indicated previously, fabric construction is another factor related to the abrasion resistance of a fabric. To elucidate the influence of types of weaves on the abrasion properties of cotton fabrics, Witold Zurek and Halena Szemik conducted a study using plain, satin, left-hand twill, and filling rib weave fabrics. The criteria used to evaluate the fabrics, which were abraded on the Kovo abrader, included bursting strength, loss of weight, and decrease in

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[49] L. Rebenfeld, "Transmission of Cotton Fiber Strength and Extensibility," Textile Research Journal, Vol. 28, No. 7, (July, 1958), p. 588.

[50] Ibid., p. 592.

[51] Backer, op. cit., p. 454.

thickness.[52]

The effect of abrasion was found to vary with the type of weave, with the plain weave being the most resistant to abrasion. Although the plain weave fabric was the weakest in terms of bursting strength, it showed a small change in weight as compared to the other weaves.

> . . . This can be explained by the fact that the plain weave fabric has short floats and the other weaves have long floats. When the short floats are cut by the abrasive, the short pieces are still locked in the fabric of the plain weave, whereas they are removed from the other weaves.[53]

In terms of thickness, the plain weave showed an increase, whereas the others showed a decrease. Again, length of the float provided the explanation, for the cut fibers remained in the plain weave to form a brush and increase thickness.[54]

III. THE TABER ABRASER AS A LABORATORY ABRASION INSTRUMENT

Of particular importance to this study is information concerning the Taber Abraser and its use in the laboratory.

W. J. Hamburger, an authority in the field of abrasion research, indicated the following reasons for selecting the Taber Abraser as a laboratory

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[52] Witold Zurek and Halena Szemik, "Some Aspects of Abrasion Properties of Cotton Fabrics," Textile Research Journal, Vol. 34, No. 2, (February, 1964), pp. 143-152.

[53] Ibid., p. 145.

[54] Ibid.

abrasion machine.

> . . . This selection was made because of the simple operation of the instrument, the fact that it abrades multi-directionally to the specimen as a whole, but essentially uni-directionally to any given point on the specimen; and because the abradant, while not absolutely constant, may be reasonably controlled, and essentially nothing other than plane abrasion takes place upon the specimen.[55]

Since the Taber Abraser abrades a specimen multidirectionally, it affects both the warp and filling yarns simultaneously, as does actual wear. In order to evaluate the extent of damage which occurs in either direction, strength difference tests may be performed on the abraded portions of the fabric in both warp and filling directions.[56]

The methods used for evaluating results obtained from the Taber Abraser vary according to the material tested and its expected end uses. Various criteria which may be applied in the evaluation of this test method include changes in weight, breaking strength, thickness, and appearance, as well as destruction of yarns.

Zook, who has done extensive research with the Taber Abraser, has been concerned with inconsistencies in results obtained from tests on this instrument. She listed the following factors as possible causes of inconsistencies in results:

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[55]Kaswell, Textile Fibers, Yarns, and Fabrics, p. 306. Citing W. J. Hamburger, "Mechanics of Abrasion of Textile Materials," Textile Research Journal, Vol. 15, (1945), pp. 169-177.

[56]Kaswell, "Tests of Military Fabrics on Quartermaster Combat Course," p. 417.

1. Use of an insufficient number of samples
2. Variable tension of the mounted test swatches
3. Lack of uniformity throughout the abradant wheels
4. Differences between pairs of the wheels
5. Inadequate refacing of the wheels
6. Inaccurate marking and cutting of the strength strips[57]

To reduce the amount of variation in results due to differences in sets of wheels, she developed a testing procedure using three pairs of wheels instead of only one. Results indicated that "the use of three pairs of wheels tended to counteract the variation existing within wheels and between pairs of wheels"[58] so that results were more consistent. She also developed a device to insure uniform tension of mounted specimens, for this is another factor contributing to inconsistent results. Test results indicated that the use of this device provided more uniform results than in the case of samples mounted by hand.[59]

IV. SUMMARY

A review of the literature revealed a substantial amount of research has been devoted to the study of abrasion resistance. The consensus was that good abrasion resistance contributes to improved fabric performance, but individual pieces of research often produced results which seem to contradict each other.

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[57]Margaret Harris Zook, "The Development of a Reproducible Testing Technique Using the Taber Abraser on Rayon Fabrics," American Dyestuff Reporter, Vol. 39, No. 21, (October 16, 1950), p. 682.

[58]Ibid., p. 684.

[59]Margaret Harris Zook, "A Tensioning Device for Use With the Taber Abraser," American Dyestuff Reporter, Vol. 30, No. 23, (November 12, 1951), p. 745.

Continued study of the complex process of abrasion, and the numerous factors involved in the wearing process of a textile, can be expected to establish a relationship between laboratory abrasion results and the performance in use of fabrics.

CHAPTER III

PROCEDURE

The purpose of Regional Project SM-18 was to investigate the physical properties of selected types of raw cotton and to determine product quality and end-product performance of sheetings made from cottons varying in the fiber properties of length and strength.[1] This study related to the regional project in that one aspect of the project, abrasion resistance, was considered in detail.

Eight bales of raw cotton, having a specified range of fiber length and fiber strength, as illustrated in Table I, were selected for the project and manufactured into type 140 sheeting fabric, 72 inches in width. The fabrics were classified according to the bales from which they were woven and according to the following fiber properties:

Bales 1-2. Short staple, low strength

Bales 3-4. Short staple, high strength

Bales 5-6. Long staple, low strength

Bales 7-8. Long staple, high strength

The sheets were distributed to four states participating in the experiment and were divided into two treatment groups. One group was used as

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[1]Technical Committee Project SM-18, "The Relation of Fiber Properties to End-Product Performance, " (Manual of Procedures, Southern Regional Research Project SM-18).

TABLE I

LENGTH AND STRENGTH OF RAW STOCK OF SELECTED BALES OF COTTON[a]

Cotton Code Number	Length (Inches) U. H. M.[b]	Length (Inches) Mean	Strength Pressley PI[c]	Strength "O" Gauge PSI[d]
1	.88	.72	6.46	69.7
2	.92	.73	6.63	71.7
3	1.00	.79	7.54	81.4
4	.99	.80	7.48	80.8
5	1.06	.87	7.92	85.5
6	1.08	.86	7.79	84.1
7	1.07	.82	8.35	90.2
8	1.09	.92	8.60	92.9

[a]Manual of Procedures, Southern Regional Research Project SM-18, op. cit., p. 6.

[b]Upper half mean.

[c]Pressley Index.

[d]Pounds per square inch.

bottom sheets in women's dormitories and laundered weekly by a commercial laundry. The second group was subjected to laundering only on a regular schedule with those receiving both wear and laundering.

I. SAMPLING PLAN

All specimens for this study were taken from those sheetings distributed to the University of North Carolina at Greensboro for experimentation under conditions specified in the regional project. The samples were obtained from three sheets in each of the eight cotton types undergoing use and laundering, and from two sheets in the eight types undergoing laundering only. To obtain control data for each of the three test methods, three sheets of each of the eight cotton types were withdrawn for sampling before use or laundering. Samples were again withdrawn for testing following the completion of thirty and sixty intervals of the two treatments: (1) use and laundering or (2) laundering only.

A standard testing area, which was the area receiving the most wear in use, was designated and marked on each sheet by means of a standard template. Three 6 inch square specimens for the yarn breakdown abrasion test were taken from the area of the sheet partially within, or adjacent to the standard testing area. Figure 1 indicates the approximate positions of the three samples.

Three 6 inch square specimens for the strength difference tests were taken from each sheet. As specified in the regional project, tests were carried out at Louisianna State University.

The Alabama station performed the flexing and abrasion tests on five

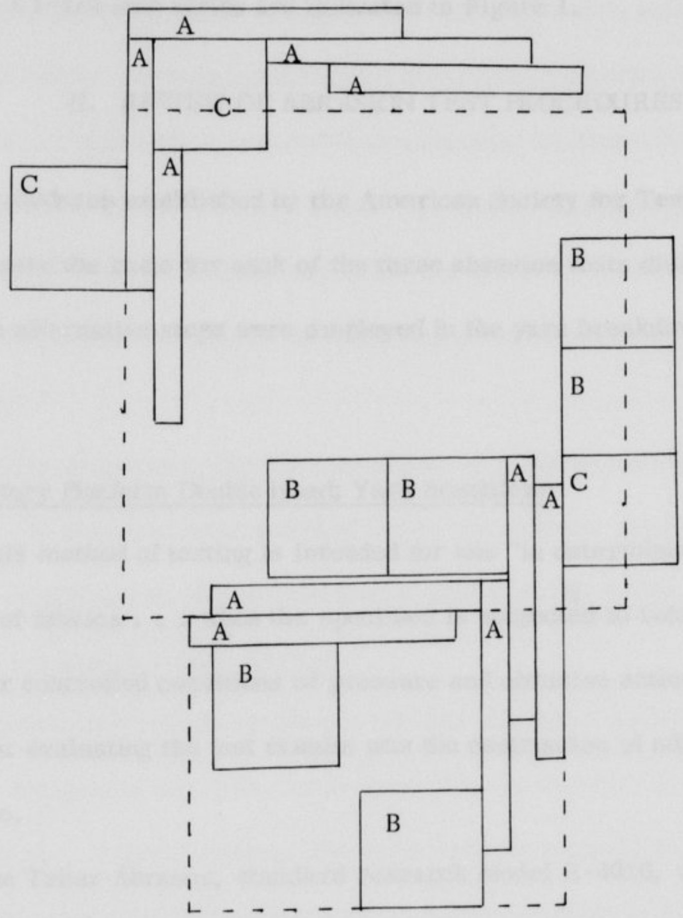

FIGURE 1.

SAMPLING PLAN FOR ABRASION TESTS
TAKEN FROM CENTER OF EACH SHEET

Key:

- - - Standard testing area
A Stoll specimens
B Taber strength difference specimens
C Taber yarn breakdown specimens

strips from both the warp and the filling directions of the fabric. The positions of these 15 x 1-1/4 inch strips are indicated in Figure 1.

II. REVIEW OF ABRASION TEST PROCEDURES

Procedures established by the American Society for Testing and Materials were the basis for each of the three abrasion tests discussed in this study. The alternative steps were employed in the yarn breakdown test procedure.

Test I. Rotary Platform Double Head; Yarn Breakdown

This method of testing is intended for use "in determining the abrasion resistance of fabrics . . . when the specimen is subjected to rotary rubbing action under controlled conditions of pressure and abrasive action."[2] The criterion for evaluating the test results was the destruction of adjacent yarns in the fabric.

The Taber Abraser, standard research Model E-4010, with vacuum pick-up attachment, was used in this test method. The abraser incorporates the rotary rub-wear principle of abrasion in which dual abrading wheels crisscross their abrasion paths. The right wheel rubs the specimen from the center outward, and the left wheel rubs the specimen from the outside in toward the

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[2]ASTM Committee D-13 on Textile Materials, ASTM Standards on Textile Materials, (Philadelphia: American Society for Testing and Materials, September, 1963), p. 480.

center. The action is continuous throughout the 360 degree rotation of the specimen and closely parallels abrasive wear encountered in actual use.[3]

The rotary platform, double head abraser is a machine of compact design which is comprised of a removable flat circular specimen holder, a pair of pivoted arms to which the abrasive wheels are attached, a motor for rotating the platform and specimen, a counter for indicating the revolutions of the specimen holder, and a vacuum attachment for removing abraded particles from the abrasion path.[4]

The abraser arms exerted a pressure of 500 grams each upon the test specimens. To the arms were attached a pair of resilient, medium abrasive wheels, CS-10 Calibrase, which produced a mild abrading action ordinarily recommended for testing textile fabrics.[5]

Three 6 inch square specimens for this test were taken from each sheet at the designated intervals, from areas not representing the same warp and filling yarns. Prior to testing, the specimens were conditioned for twenty-four hours in a controlled atmosphere at a relative humidity of 65% ± 2 and a temperature of $70^{o} \pm 2^{o}$ Fahrenheit.

A one-fourth inch hole was cut in the center of each specimen. The specimens were then mounted, face up, on the specimen holder and secured by the ring clamp. The excess fabric below the clamp was trimmed away.

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[3]*Taber Abraser Manual*, (New York: Taber Instrument Corp., 1953), p. 3.

[4]ASTM, *loc. cit.*

[5]*Taber Abraser Manual*, *op. cit.*, p. 15.

Each specimen was then placed on the machine and abraded at seventy revolutions per minute to the occurrence of a break in adjacent warp and filling yarns. Specimens were examined periodically for the appearance of a break, and the surface of the fabric was brushed to remove debris. The wheels were resurfaced, using S-11 resurfacing disks, following each five hundred cycles of abrasion and prior to each new test.

The number of cycles of abrasion required to produce a break in both a warp and filling yarn at the point where they crossed was recorded for each of the specimens for each sheet. The average of the three specimens was considered the test results for that sheet.

Test II. Rotary Platform Double Head; Strength Difference

This test method employed the same type of instrument as the preceding yarn breakdown method. Two sets of vitrified base wheels, Calibrade H-38, which were similar in abrasive character were alternated during the testing. One half of each set of specimens were abraded with one pair of wheels, while the remaining half was abraded with the other pair. No resurfacing of the wheels was necessary, but they were brushed periodically to remove debris.[6]

Three test specimens, 6 inches square, were taken from each sheet from areas of the fabric not representing the same warp or filling yarns. The

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[6] Manual of Procedures, Southern Regional Research Project SM-18, op. cit., pp. 38-39.

warp and filling directions were marked on the face of the fabric, and a three-sixteenth inch hole was cut in the center of the specimen using a template and a die. Specimens were mounted on the specimen holder and secured by a ring clamp, leaving excess fabric extending below the clamp. Each specimen was subjected to ten revolutions of abrasion at the rate of 70 revolutions per minute.[7]

Following the completion of ten cycles of abrasion, the specimens were marked, as illustrated in Figure 2, for tests to determine breaking strength. This procedure, carried out at Louisianna State University, was as follows:

> Mark a strip 3/4" wide, beginning on line of perforations and in direction away from center of the specimen. Mark a second strip 3/4" wide, beginning at edge of fabric and marking toward the center of specimen. The outside strips are "control" strips and the inside strips are "abraded" strips. Each of the six specimens, 3 warp and 3 filling, provide 2 abraded and 2 control strips. The 3/4" strips are further prepared by raveling to 1/2" and tested on a Scott tensile strength tester of 1025.5 lb. capacities with a 3 inch distance between clamps.[8]

The difference in breaking strength between abraded and unabraded strips was determined by calculating the per cent loss in breaking strength. The formula used was as follows:

$$\text{Per cent loss} = \frac{O-A}{O} \times 100$$

Where O = breaking strength before abrasion, and

A = breaking strength after abrasion

The residual breaking strength was the average of the results obtained from the

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[7] Ibid., pp. 39-40.

[8] Ibid., p. 42.

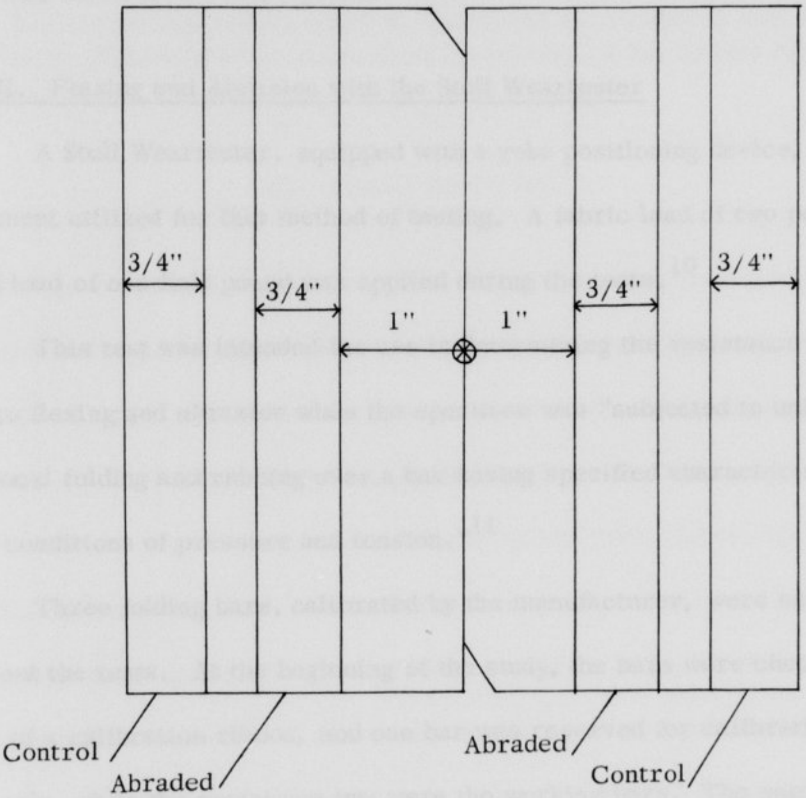

FIGURE 2.

PLACEMENT OF TEST SPECIMENS FOR
STRENGTH DIFFERENCE EVALUATION
OF TABER ABRASION

specimens tested in each of the warp and filling directions and was reported separately to the nearest 0.1 pound.[9]

Test III. Flexing and Abrasion with the Stoll Weartester

A Stoll Weartester, equipped with a yoke positioning device, was the instrument utilized for this method of testing. A fabric load of two pounds and a head load of one-half pound was applied during the tests.[10]

This test was intended for use in determining the resistance of specimens to flexing and abrasion when the specimen was "subjected to unidirectional reciprocal folding and rubbing over a bar having specified characteristics, under known conditions of pressure and tension."[11]

Three folding bars, calibrated by the manufacturer, were necessary to carry out the tests. At the beginning of the study, the bars were checked by means of a calibration ribbon, and one bar was reserved for calibration purposes only, while the remaining two were the working bars. The same two bars were retained for the testing in the regional project and were checked against the calibration bar before and after each series of tests.[12]

All flexing and abrasion tests were completed at the Alabama station according to the following procedure:

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[9] Ibid., p. 41

[10] Ibid., p. 30.

[11] ASTM, op. cit., p. 472.

[12] Manual of Procedures, Southern Regional Research Project SM-18, op. cit., p. 30.

> There shall be 5 strips each of warp and filling from each sheet. Each strip will be cut 1-1/4 inches wide and 15 inches long and shall be ravelled to one inch in width. Two breaks shall be made on each strip and the average cycles for the two breaks shall be considered the result for that strip. The average of these five averages shall be considered the results for this sheet.[13]

III. ANALYSIS OF DATA

The statistical treatment of data included an analysis of variance to determine the significance of differences in abrasion resistance of cottons having two levels of length and two levels of strength as measured by the yarn breakdown, strength difference, and flexing and abrasion test methods after zero, thirty, and sixty intervals of use and laundering and zero, thirty, and sixty intervals of laundering only. An analysis of variance was also used to determine the significance of differences in abrasion resistance of those cottons which underwent laundering only and those cottons which underwent both use and laundering. Findings were considered significant at the .05 level and highly significant at the .01 level.

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[13] *Ibid.*

CHAPTER IV

PRESENTATION OF DATA

The major objective of this thesis was to study the abrasion characteristics of selected cotton sheetings made from cottons of varying properties of fiber length and strength. Three methods of testing abrasion resistance, (1) yarn breakdown, (2) strength difference, and (3) flexing and abrasion were used to evaluate the abrasion resistance. A second objective of the thesis was to compare the effectiveness of these three test methods in predicting the performance of selected cotton sheetings.

I. THE EFFECT OF THREE METHODS OF ABRASION ON EIGHT TYPES OF COTTON SHEETING

Eight bales of raw cotton, having a specified range of fiber length and fiber strength, were selected for Southern Regional Research Project SM-18 and manufactured into eight groups of type 140 muslin sheeting fabric, 72 inches in width.[1] Sheets made from each of the eight groups of fabric were divided into two treatment groups, (1) laundered only and (2) used and laundered. Only those sheets which underwent experimental treatment at the University of North

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[1] Technical Committee Project SM-18, "The Relation of Fiber Properties to End-Product Performance," (Manual of Procedures, Southern Regional Research Project SM-18).

Carolina at Greensboro were used in this study. Two sheets from each of the eight cotton types of the laundered only treatment group and three sheets from the used and laundered group were tested at the control, or zero, interval and following thirty and sixty launderings. All data reported represent the abrasion resistance of the eight groups of cotton sheetings. However, this study was concerned primarily with the relationship of the specific fiber properties of the selected cottons to each of the three methods of testing abrasion.

The strength difference abrasion tests were performed by Louisiana State University, while the flexing and abrasion tests were made at the Alabama testing station. These data were compiled for comparison with the yarn breakdown test measurements made for this study. The means of each of the abrasion tests for the eight cotton types undergoing use and laundering are presented in Table II. The means for the laundered only cottons are compiled in Table III.

The yarn breakdown test, which was performed at the University of North Carolina at Greensboro for this study, provided a single measurement which represented the destruction of yarns in both the warp and filling directions. The flexing and abrasion test and the strength difference test provided two measurements, one for the warp and one for the filling direction.

Control Interval

Prior to laundering or use, each of the eight cotton types were tested by the three abrasion methods, and substantial differences among test results were indicated. No one of the eight cotton types was most resistant or least resistant

TABLE II

MEAN ABRASION RESISTANCE OF USED AND LAUNDERED SHEETS OF EIGHT COTTON TYPES COMPARING THREE METHODS OF ABRASION

Cottons	Stoll abrasion (Flexings)		Strength difference (Per cent change)		Yarn breakdown (Cycles)
	Warp	Filling	Warp	Filling	
Control Interval					
1	672	1095	+ 3.4	- 2.6	665
2	1097	994	- 1.8	- 1.1	745
3	864	868	+ 1.4	+ 0.4	825
4	637	682	+ 3.2	+ 1.4	739
5	644	695	+ 3.5	- 1.4	758
6	880	980	+ 1.9	+ 2.6	778
7	726	741	+ 1.9	+ 0.6	786
8	753	821	- 1.9	+ 2.6	714
Thirtieth Interval					
1	678	1127	+ 4.8	+ 1.5	696
2	889	1291	- 0.3	- 1.1	695
3	674	898	- 2.3	- 4.4	737
4	696	1420	- 2.4	+ 2.3	636
5	740	1284	- 2.4	- 0.4	927
6	865	1199	- 1.1	- 0.8	807
7	861	1134	+ 1.6	- 2.6	842
8	944	1596	- 4.1	- 3.9	677
Sixtieth Interval					
1	507	531	- 9.0	- 6.8	487
2	581	667	-11.8	- 4.9	408
3	476	580	- 9.3	- 6.4	391
4	452	578	-16.0	-10.0	397
5	632	715	- 7.4	+ 0.3	558
6	831	837	- 7.0	- 1.4	485
7	397	324	- 7.9	- 2.7	505
8	270	353	- 8.9	- 8.2	432

TABLE III

MEAN ABRASION RESISTANCE OF LAUNDERED ONLY SHEETS OF EIGHT COTTON TYPES COMPARING THREE METHODS OF ABRASION

Cottons	Stoll abrasion (Flexings) Warp	Stoll abrasion (Flexings) Filling	Strength difference (Per cent change) Warp	Strength difference (Per cent change) Filling	Yarn breakdown (Cycles)
Control Interval					
1	672	1095	+3.4	-2.6	665
2	1097	994	-1.8	-1.1	745
3	864	868	+1.4	+0.4	825
4	637	682	+3.2	-1.4	739
5	644	695	+3.5	-1.4	758
6	880	980	+1.9	+2.6	778
7	726	741	+1.9	+0.6	786
8	753	821	-1.9	+2.6	714
Thirtieth Interval					
1	700	739	+1.4	-0.6	806
2	568	672	-0.6	+3.1	837
3	668	910	+2.8	-2.6	842
4	632	768	-1.8	0.0	699
5	618	735	+4.4	+0.6	844
6	630	682	-0.6	0.0	780
7	574	682	-4.0	-2.4	832
8	586	682	+2.7	+5.8	732
Sixtieth Interval					
1	285	370	-4.3	-5.2	412
2	311	382	-7.7	-8.2	588
3	329	406	-5.5	+4.2	540
4	315	364	-6.8	+0.3	518
5	374	406	-6.9	-4.2	736
6	355	440	+1.9	-4.0	646
7	363	444	-2.4	0.0	610
8	338	398	-7.5	-3.7	534

to abrasion produced by the different methods.

Yarn breakdown method. Results of the yarn breakdown test method were reported in the number of cycles of abrasion required to produce a break in adjacent warp and filling yarns. Cotton 3 was most resistant to abrasion, while Cotton 1 was least resistant.

Strength difference method. Results of the strength difference test indicated small, unpredictable changes. These results were reported as the per cent difference in breaking strength between an unabraded and an abraded sample. General increases in breaking strength were exhibited by the warp direction measurements, indicating increased abrasion resistance. The filling direction measurements demonstrated less resistance to this method of abrasion.

Flexing and abrasion method. The results of the flexing and abrasion test were reported in the number of flexings required to produce a break in the sample. Cotton 4 was the least resistant to abrasion in both the warp and filling directions, while Cotton 2 was the most resistant in both directions. In general, the warp direction results were slightly lower than the filling direction results.

Thirtieth Interval

Yarn breakdown method. After thirty launderings, there was a general increase in abrasion resistance of the cottons, according to results of the yarn breakdown test. The laundered only cottons showed a steady increase in resistance, while the used and laundered cottons varied in their abrasion resistance.

Strength difference method. As in the control interval, the strength difference test again produced varied results. In general, both the laundered only and the used and laundered cottons showed decreases in resistance to abrasion, with the used and laundered showing the greatest decrease.

Flexing and abrasion method. The used and laundered cottons showed increased abrasion resistance using the flexing and abrasion test method. The results for the filling direction tests were higher than those for the warp direction. The laundered only cottons decreased in abrasion resistance, with the warp direction results being lower than those of the filling direction.

Sixtieth Interval

Yarn breakdown method. The results of the yarn breakdown method of testing revealed that the used and laundered cottons decreased markedly in abrasion resistance from the results obtained at the thirtieth interval. While the laundered only cottons demonstrated a sizeable increase in resistance at the thirtieth interval, they decreased measurably in abrasion resistance at the sixtieth interval. Overall, the laundered only cottons maintained a greater resistance to abrasion at both the thirtieth and sixtieth intervals than did the used and laundered.

Strength difference method. Both the warp and filling measurements of the used and laundered, as well as the laundered only cottons, generally decreased in abrasion resistance, according to the strength difference test method. The warp measurements of the used and laundered cottons were the lowest, indicating the least resistance to abrasion. The filling measurements of the laundered only cottons indicated the most resistance to abrasion at all intervals.

Flexing and abrasion method. Using the flexing and abrasion test method, the most pronounced reduction in abrasion resistance appeared in the warp measurements of the laundered only cottons at the sixtieth interval. The filling measurements of the used and laundered cottons also showed a considerable decrease at the sixtieth interval from the measurements at the thirtieth interval. The used and laundered cottons demonstrated the most resistance to abrasion at both the thirtieth and sixtieth intervals.

II. THE EFFECT OF THREE METHODS OF ABRASION ON THE COTTONS GROUPED ACCORDING TO FIBER PROPERTIES

The eight bales of cotton from which the sheets were manufactured were further classified into the following fiber property groups according to their differences in fiber length and fiber strength:

Short staple: Cottons 1, 2, 3, and 4

Long staple: Cottons 5, 6, 7, and 8

Low strength: Cottons 1, 2, 5, and 6

High strength: Cottons 3, 4, 7, and 8

The means of these fiber property groups were used for further comparison of data.

Yarn Breakdown Method

Results of the yarn breakdown test indicated a general increase in abrasion resistance at the thirtieth interval and a distinct decrease in resistance at the sixtieth interval for both laundered only and used and laundered cottons. The means of the fiber property groups and per cent changes of the results of the thirtieth and the sixtieth interval from the results of the control interval are presented in Table IV. Graphs illustrating the per cent changes in abrasion resistance of the fiber property groups for both treatments are presented in Figure 3.

Control interval. Results indicated the low strength cottons were least resistant to abrasion at the control interval. The high strength cottons demonstrated the most resistance to abrasion at this interval.

Thirtieth interval. The results for the used and laundered cottons were not consistent at the thirtieth interval. The low strength and the long staple cottons increased in abrasion resistance, while the short staple and the high strength cottons decreased in resistance. All property groups in the laundered only cottons showed an increase in abrasion resistance, with the low strength cottons being the most resistant.

Sixtieth interval. Both treatment groups decreased in abrasion resistance at the sixtieth interval, with the used and laundered cottons showing the greatest decrease. The high strength and the short staple cottons were the least resistant to abrasion in both the laundered only and the used and laundered groups. The results ranged from losses of 28 to 44 per cent with the used and laundered

TABLE IV

MEANS OF TABER ABRASER YARN BREAKDOWN TEST AND PER CENT CHANGES AFTER TREATMENT GROUPED ACCORDING TO FIBER PROPERTIES[a]

	0 interval	30th interval	60th interval
USED AND LAUNDERED			
Length			
Short staple	744	691	421
Per cent change		-7	-43
Long staple	759	813	495
Per cent change		+7	-35
Strength			
Low strength	736	781	484
Per cent change		+6	-34
High strength	766	723	431
Per cent change		-6	-44
LAUNDERED ONLY			
Length			
Short staple	744	796	514
Per cent change		+7	-31
Long staple	759	797	632
Per cent change		+5	-17
Strength			
Low strength	736	817	596
Per cent change		+11	-19
High strength	766	776	550
Per cent change		+1	-28

[a]Short staple Cottons 1, 2, 3, 4; Low strength Cottons 1, 2, 5, 6
Long staple Cottons 5, 6, 7, 8; High strength Cottons 3, 4, 7, 8

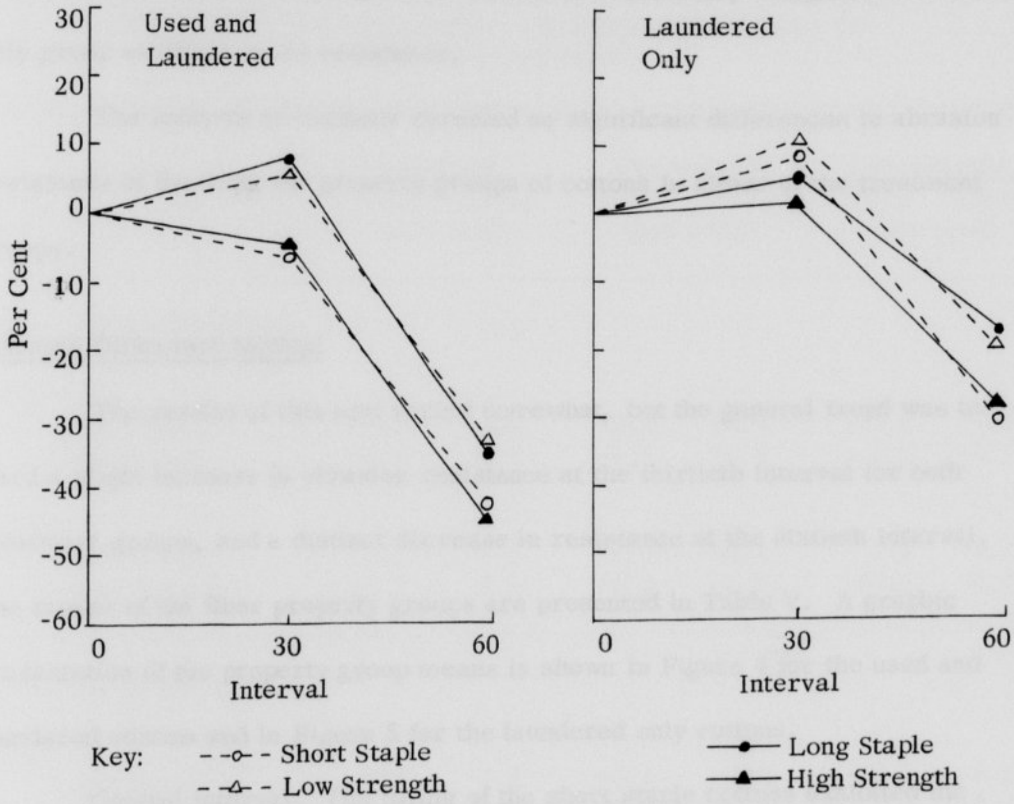

FIGURE 3

MEAN PER CENT CHANGES IN YARN BREAKDOWN EVALUATION OF ABRASION RESISTANCE OF ALL COTTONS GROUPED ACCORDING TO FIBER PROPERTIES cottons being least resistant to abrasion. The long staple and the low strength cottons in both treatment groups were resistant to abrasion, though the laundered only group exhibited more resistance.

The analysis of variance revealed no significant differences in abrasion resistance of the different property groups of cottons in either of the treatment groups.

Strength Difference Method

The results of this test varied somewhat, but the general trend was toward a slight increase in abrasion resistance at the thirtieth interval for both treatment groups, and a distinct decrease in resistance at the sixtieth interval. The means of the fiber property groups are presented in Table V. A graphic presentation of the property group means is shown in Figure 4 for the used and laundered cottons and in Figure 5 for the laundered only cottons.

Control interval. The filling of the short staple cottons exhibited the least resistance to abrasion at the control interval. The warp of the low strength cottons and the short staple cottons showed the most abrasion resistance.

Thirtieth interval. The used and laundered cottons tended to decrease somewhat more in abrasion resistance at the thirtieth interval than the laundered only cottons. The warp and filling measurements of the high strength cottons, as well as the warp and the filling of the long staple cottons of the used and laundered treatment group exhibited the largest decrease in abrasion resistance. The filling of the short staple and the low strength cottons demonstrated an

TABLE V

MEANS OF THE TABER STRENGTH DIFFERENCE TEST AND CHANGES AFTER TREATMENT GROUPED ACCORDING TO FIBER PROPERTIES[a]

	0 interval		30th interval		60th interval	
	Warp	Filling	Warp	Filling	Warp	Filling
	(per cent)		(per cent)		(per cent)	
USED AND LAUNDERED						
Length						
Short staple	+1.5	-1.2	-0.3	-0.4	-11.5	-7.0
Long staple	+1.4	+1.1	-1.5	-1.9	- 7.8	-3.1
Strength						
Low strength	+1.7	-0.6	+0.3	-0.2	- 8.8	-3.3
High strength	+1.2	+0.5	-1.8	-2.1	-10.5	-6.8
LAUNDERED ONLY						
Length						
Short staple	+1.5	-1.2	+0.4	0.0	- 6.1	-2.2
Long staple	+1.4	+1.1	+0.6	+1.0	- 3.7	-3.0
Strength						
Low strength	+1.7	-0.6	+1.1	+0.8	- 4.3	-5.4
High strength	+1.2	+0.5	-0.1	+0.2	- 5.5	+0.2

[a]Short staple Cottons 1, 2, 3, 4
Long staple Cottons 5, 6, 7, 8
Low strength Cottons 1, 2, 5, 6
High strength Cottons 3, 4, 7, 8

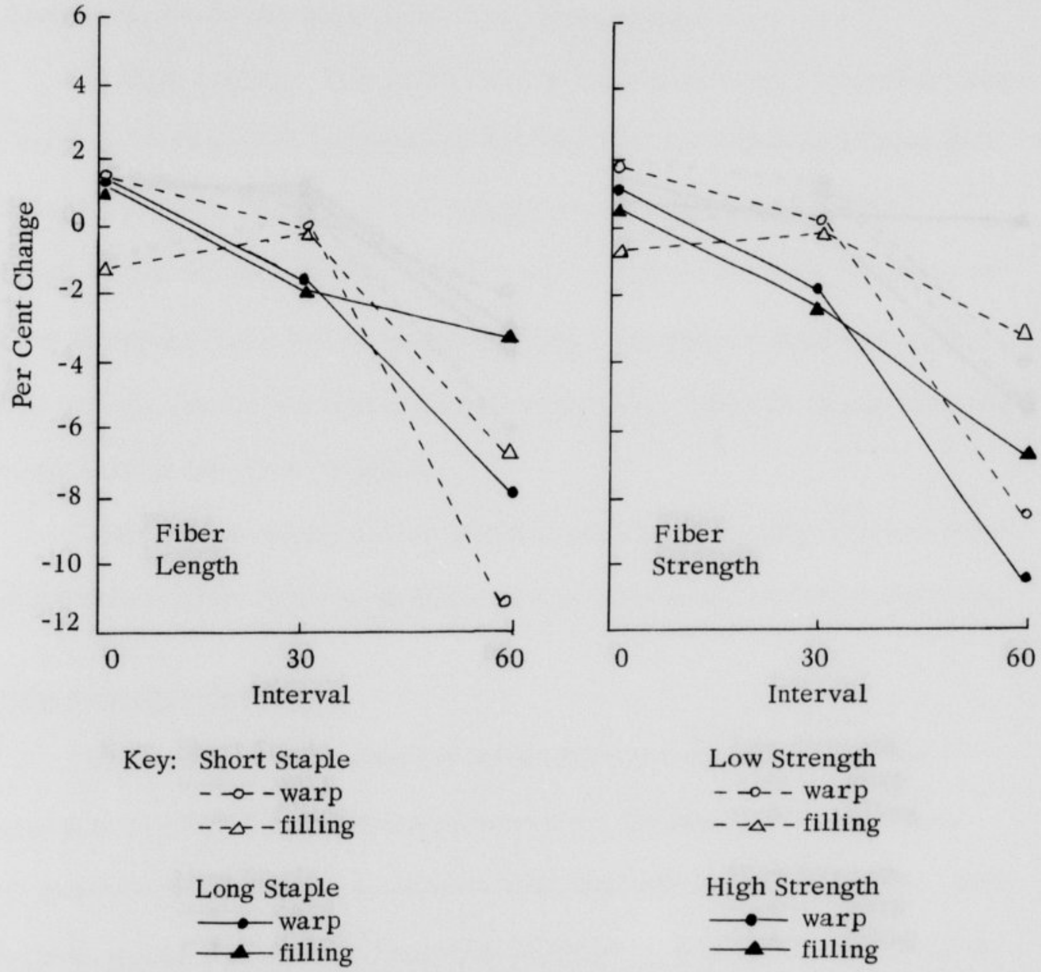

FIGURE 4

MEAN PER CENT DIFFERENCES IN STRENGTH DIFFERENCE EVALUATION OF ABRASION RESISTANCE OF LAUNDERED ONLY COTTONS GROUPED ACCORDING TO FIBER PROPERTIES

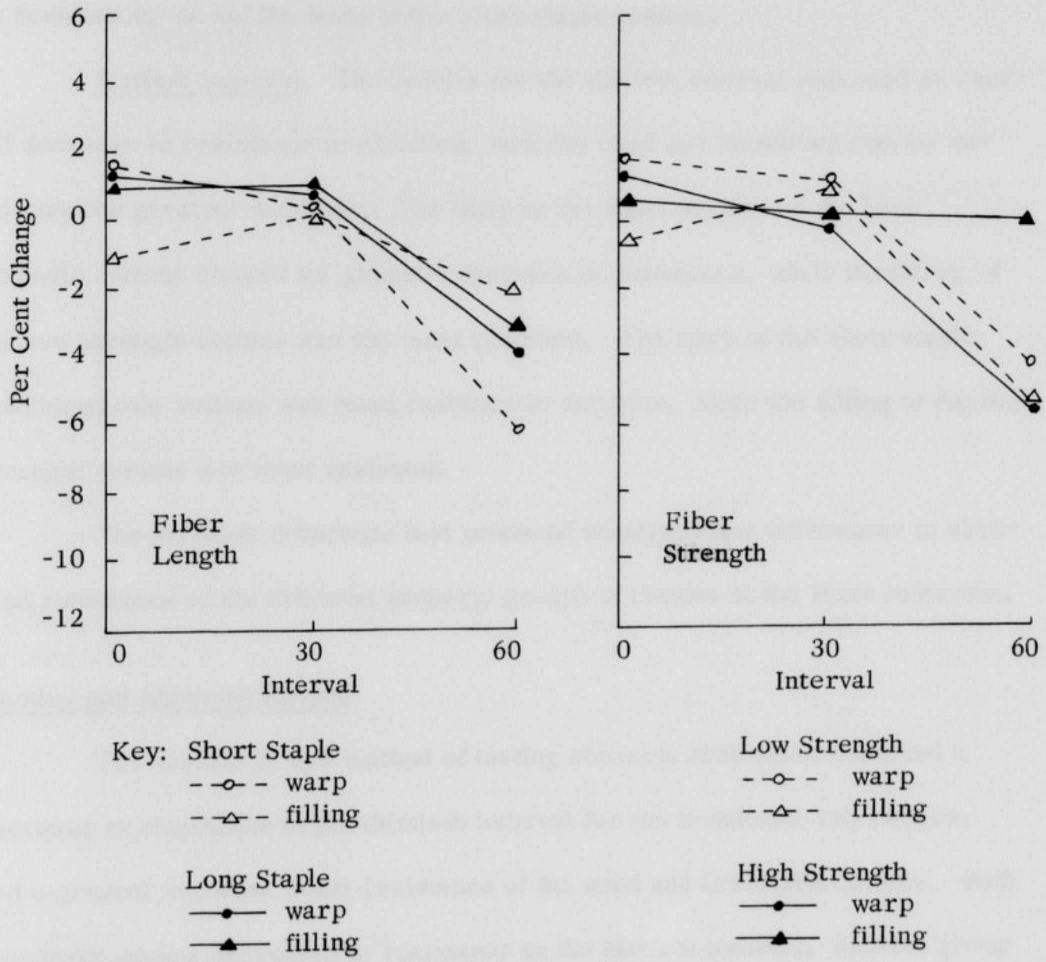

FIGURE 5

MEAN PER CENT DIFFERENCES IN STRENGTH DIFFERENCE EVALUATION OF ABRASION RESISTANCE OF LAUNDERED ONLY COTTONS GROUPED ACCORDING TO FIBER PROPERTIES increased resistance to abrasion. The warp of the high strength cottons decreased in resistance, as did the warp of the short staple cottons.

Sixtieth interval. The results for the sixtieth interval indicated an overall decrease in resistance to abrasion, with the used and laundered cottons exhibiting the greatest decrease. The warp of the short staple and the high strength cottons showed the greatest decrease in resistance, while the filling of the low strength cottons was the most resistant. The warp of the short staple laundered only cottons was least resistant to abrasion, while the filling of the high strength cottons was most resistant.

The strength difference test produced no significant differences in abrasion resistance of the different property groups of cottons at the three intervals.

Flexing and Abrasion Method

The results of this method of testing abrasion resistance indicated a decrease in resistance at the thirtieth interval for the laundered only cottons, and a general increase in the resistance of the used and laundered cottons. Both treatment groups decreased in resistance at the sixtieth interval, with the group undergoing laundering only exhibiting the greatest decrease in abrasion resistance. The means of the fiber property groups and the per cent changes in results for this test are presented in Table VI. A graphic presentation of the per cent changes for the used and laundered cotton property groups is found in Figure 6, and a similar presentation of the laundered only cottons is found in Figure 7.

Control interval. At the control interval, this test showed the filling

TABLE VI

MEANS OF STOLL FLEX ABRASION TEST AND PER CENT CHANGES AFTER TREATMENT GROUPED ACCORDING TO FIBER PROPERTIES[a]

	0 interval		30th interval		60th interval	
	Warp	Filling	Warp	Filling	Warp	Filling
USED AND LAUNDERED						
Length						
Short staple	818	910	734	1184	504	589
Per cent change			-10	+30	-38	-35
Long staple	751	809	853	1303	532	532
Per cent change			+14	+61	-29	-34
Strength						
Low strength	823	941	793	1225	638	688
Per cent change			-4	+30	-22	-27
High strength	745	778	794	1262	399	434
Per cent change			+ 7	+62	-46	-44
LAUNDERED ONLY						
Length						
Short staple	818	910	642	773	310	380
Per cent change			-22	-15	-62	-58
Long staple	751	809	602	731	357	422
Per cent change			-20	-10	-52	-48
Strength						
Low strength	823	941	629	707	331	400
Per cent change			-24	-25	-60	-57
High strength	745	778	615	796	336	403
Per cent change			-17	+ 2	-55	-48

[a]Short staple — Cottons 1, 2, 3, 4; Long staple — Cottons 5, 6, 7, 8; Low strength — Cottons 1, 2, 5, 6; High strength — Cottons 3, 4, 7, 8

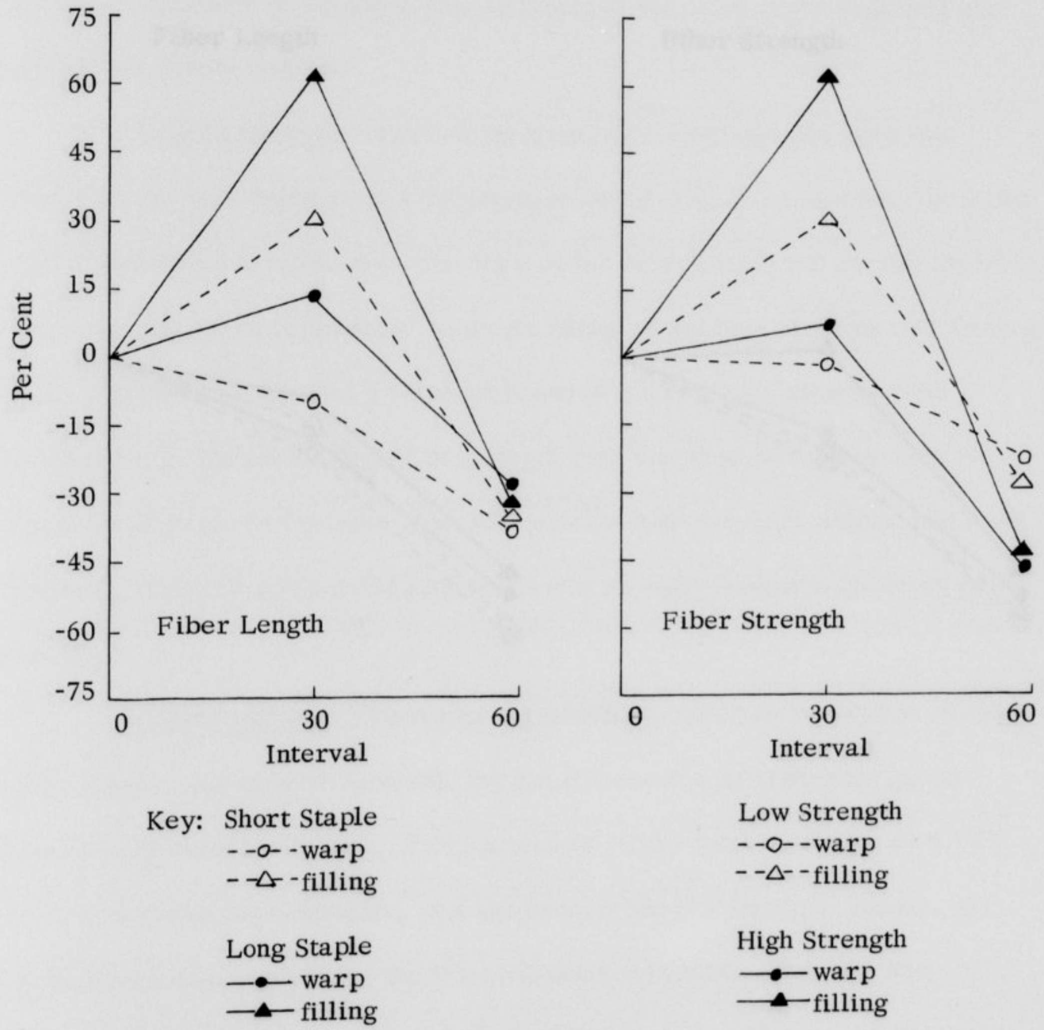

FIGURE 6

MEAN PER CENT CHANGES IN STOLL FLEX ABRASION RESISTANCE OF USED AND LAUNDERED COTTONS GROUPED ACCORDING TO FIBER PROPERTIES

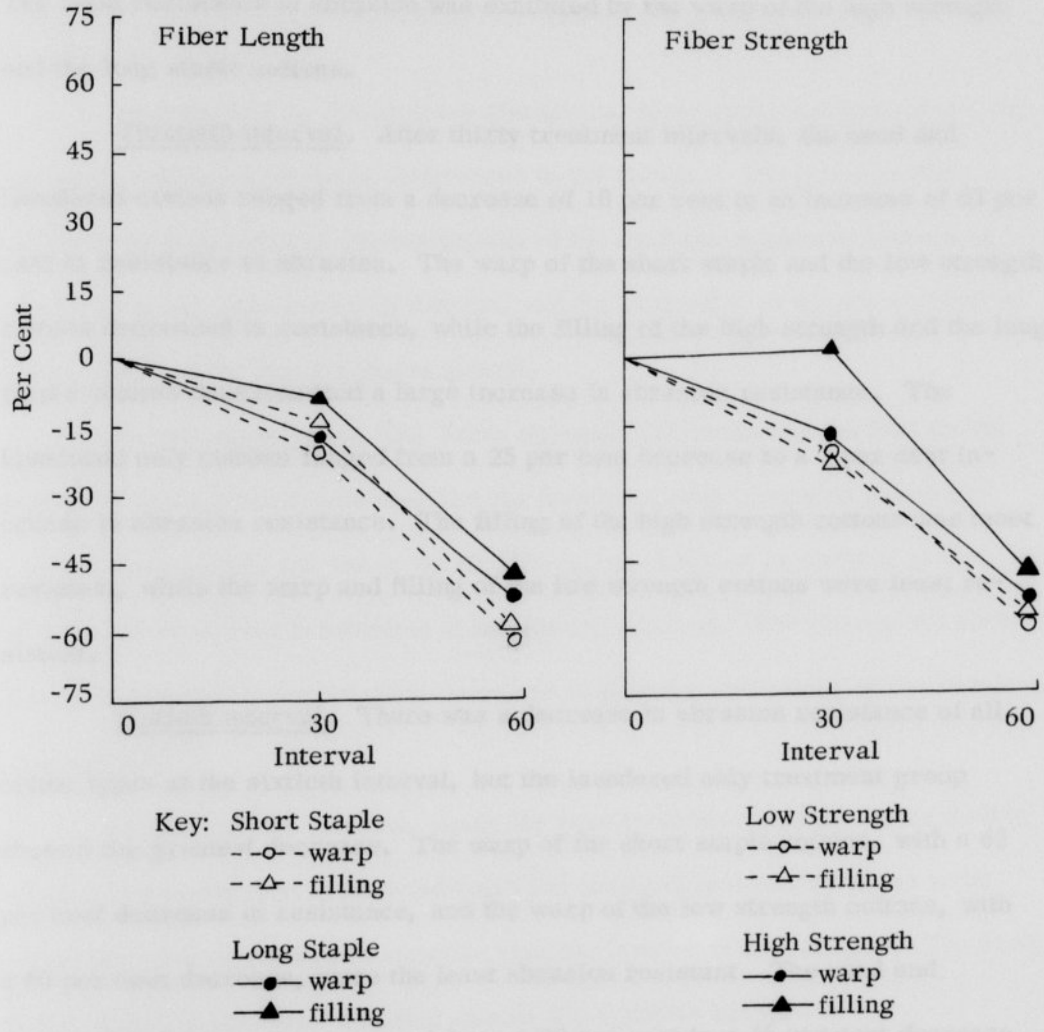

FIGURE 7

MEAN PER CENT CHANGES IN STOLL FLEX ABRASION RESISTANCE OF LAUNDERED ONLY COTTONS GROUPED ACCORDING TO FIBER PROPERTIES of the low strength and the short staple cottons to be most resistant to abrasion. The least resistance to abrasion was exhibited by the warp of the high strength and the long staple cottons.

Thirtieth interval. After thirty treatment intervals, the used and laundered cottons ranged from a decrease of 10 per cent to an increase of 62 per cent in resistance to abrasion. The warp of the short staple and the low strength cottons decreased in resistance, while the filling of the high strength and the long staple cottons demonstrated a large increase in abrasion resistance. The laundered only cottons ranged from a 25 per cent decrease to a 2 per cent increase in abrasion resistance. The filling of the high strength cottons was most resistant, while the warp and filling of the low strength cottons were least resistant.

Sixtieth interval. There was a decrease in abrasion resistance of all cotton types at the sixtieth interval, but the laundered only treatment group showed the greatest decrease. The warp of the short staple cottons, with a 62 per cent decrease in resistance, and the warp of the low strength cottons, with a 60 per cent decrease, were the least abrasion resistant. The used and laundered treatment group ranged from a 22 per cent to a 46 per cent decrease in resistance. The warp and filling of the high strength cottons exhibited the greatest decrease in resistance, while the warp and filling of the low strength cottons exhibited the smallest decrease.

No significant differences in abrasion resistance among the fiber property groups were indicated for either treatment group at the three intervals.

III. COMPARISON OF THE EFFECTIVENESS OF THE THREE METHODS OF ABRASION

As indicated by the previous discussion, these three methods of testing abrasion resistance produced differences in the results. The greatest differences were detected in the evaluations of the used and laundered cottons as compared to the laundered only cottons, and the evaluation of the fiber property groups within these two treatment groups.

Treatment groups. The Taber strength difference test method and the yarn breakdown method indicated that the laundered only treatment group retained approximately the same, or slightly more, abrasion resistance at the thirtieth interval than it exhibited at the control interval. The flexing and abrasion test indicated a considerable decrease in abrasion resistance of the laundered only cottons.

At the sixtieth interval, again the yarn breakdown and the strength difference tests coincided as they indicated the used and laundered cottons to be appreciably less resistant to abrasion than the laundered only cottons. The Stoll flexing and abrasion test indicated exactly the opposite results.

Fiber property groups. The differences in measurements at the thirtieth interval were not large enough to distinguish any differences in abrasion resistance among the cotton fiber property groups. However, the differences became much larger at the sixtieth interval, and all three test methods indicated the short staple and the high strength cottons in the used and laundered treatment group to be least resistant to abrasion. As in the used and laundered group, the yarn breakdown test revealed the short staple and the high strength cottons in the laundered only treatment group to be the least resistant to abrasion, but the strength difference method and the flexing and abrasion method indicated the short staple and the low strength cottons to be the least abrasion resistant.

Statistical summary. As stated previously, the analysis of variance did not show significant differences in resistance to abrasion among the cottons varying in levels of length and strength. Neither the yarn breakdown, strength difference, nor the flexing and abrasion methods of testing indicated any difference in abrasion resistance of the cottons at any interval for either treatment group.

However, the analysis of variance used to determine the significance of differences between those cottons which underwent laundering only and those cottons which underwent both use and laundering did point out differences. Except for the strength difference test at the thirtieth interval, all three methods of abrasion showed a significant difference in abrasion resistance between those cottons which underwent laundering only and those which underwent both use and laundering. The Stoll method of testing indicated highly significant differences for the warp measurements of the thirtieth interval and both the warp and the filling measurements for the sixtieth interval.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

I. SUMMARY

Cotton is regarded as the most versatile of all natural and synthetic fibers, and is used more extensively than any other textile raw material. Yet to maintain this position of dominance in a competitive market, those interested in the continued utilization of cotton must constantly seek new improvements in cotton fiber quality and in the serviceability of end-products. While extensive research has been directed toward the study of cotton fiber properties in the raw state, little experimentation has been directed toward the relationships between fiber properties and serviceability of cotton products in consumer use. To aid in meeting the need for this information, a research project was undertaken by the Home Economics Research Personnel of the agricultural experiment stations in six southern states in cooperation with the Agricultural Research Service of the United States Department of Agriculture.

Southern Regional Research Project SM-18 was designed to investigate the relations between the fiber properties, staple length and staple strength, and the performance characteristics of cotton sheeting. Eight bales of experimental cottons varying in length and strength were manufactured into type 140 muslin sheetings of single bed size. These sheets were distributed to four colleges participating in the research project and divided into two treatment groups. One group was used as bottom sheets in women's dormitories and laundered following each week of use for a total of sixty intervals of use and laundering. The other group was laundered only on a regular schedule with those used in the dormitory, in order to give an indication of the effect of wear on fabric performance. To obtain control data, sheets were withdrawn before use or laundering and sampled for testing. The remainder of the sheets were subjected to the two treatments and samples were withdrawn for testing following a specified number of treatment intervals.

As a study related to the regional project, this thesis was concerned with one aspect of the project, abrasion resistance. Two methods of testing abrasion resistance were used in the regional project: (1) the Taber Abraser strength difference method and (2) the Stoll Weartester flexing and abrasion method. Each test produced results of considerable variation, thus indicating a need for further investigation of methods to test abrasion resistance. This study investigated the Taber Abraser yarn breakdown test method to determine whether it might measure more consistently the abrasion resistance of cotton sheeting.

The objectives of this study were:

To study abrasion characteristics of selected sheetings made from cottons of varying properties of fiber length and fiber strength, using the Taber Abraser yarn breakdown method of testing.

a. To determine whether differences in fiber length and fiber strength influence abrasion resistance.

b. To determine the significance of differences in abrasion resistance of selected cotton sheetings that have (1) been used and laundered and (2) been laundered only.

To compare the data obtained from the above test procedure with that obtained previously from the Stoll Weartester method and the Taber Abraser strength difference method as an indication of the value of each method in predicting fabric degradation.

The test specimens used in this study were taken from those cotton sheetings which underwent experimental treatment at the University of North Carolina at Greensboro. Measurements of the flexing and abrasion test method were completed at the Alabama experiment station, and the strength difference test measurements were made at the Louisiana station. These data were compiled for comparison with abrasion measurements made for this study using the yarn breakdown test method.

An analysis of variance was used to determine the significance of differences between the cottons of varying properties of length and strength as measured by the flexing and abrasion, strength difference, and yarn breakdown test methods after zero, thirty, and sixty periods of laundering only and use and laundering. Differences were considered significant at the .05 level and highly significant at the .01 level.

The Effect of Staple Length and Strength on Abrasion Resistance

Yarn breakdown method. The yarn breakdown test method produced generally consistent results. The low strength cottons were more resistant to abrasion than the high strength cottons at all intervals for both treatment groups. The long staple cottons were more resistant than the short staple cottons for both treatment groups at all intervals except the thirtieth for the laundered only cottons. There were no significant differences in the abrasion resistance of the fiber property groups at any interval.

Strength difference method. The strength difference test method produced wide fluctuations in results. Different fiber property groups were superior in resistance to abrasion at different intervals, so that no trend in results was evident. Perhaps this was due, in part, to the fact that only ten cycles of abrasion were used in this test. Such a small amount of abrasion would not have resulted in significant damage, thus making evaluation of the damage difficult. No significant differences in the abrasion resistance of the fiber property groups were noted for either treatment group.

Flexing and abrasion method. The flexing and abrasion test produced more consistent results than the strength difference test. The filling of the long staple and the high strength cottons was more resistant to abrasion at all intervals for the laundered only treatment group. As a whole, the long staple and the high strength cottons were most resistant for the used and laundered treatment group. Differences between fiber property groups were not significant at any interval.

The Effect of Laundering Versus Use and Laundering on Abrasion Resistance

Differences in the two treatments, (1) laundering only and (2) use and laundering, was a factor influencing the abrasion resistance of the cotton sheetings. An analysis of variance was carried out on results obtained from each of the three test methods to determine the significance of differences between those cottons which underwent laundering only and those which underwent both use and laundering. Either significant or highly significant differences were indicated for the three methods at all intervals except the thirtieth for the strength difference test method.

The flexing and abrasion test revealed that the used and laundered cottons were more resistant to abrasion than the laundered only, while both the yarn breakdown and strength difference tests showed the used and laundered cottons to be less resistant to abrasion than the laundered only. The results of these two tests may be related to the observations reported by Chippindale who noted differences in abrasion resistance encountered in use and that encountered in laundering only.[1] Fabrics which suffered abrasion in normal use were progressively broken down by erosion of the fiber surface. Those fabrics which underwent laundering only suffered cracks in the fiber surfaces which resulted in breaks and the formation of fiber ends. These fiber ends subsequently formed a brush which significantly decreased the rate of abrasion.

Comparison of the Results of the Three Methods of Abrasion

The yarn breakdown and strength difference test methods produced related results, while the flexing and abrasion test results did not follow this trend. Both of the Taber test methods indicated that the used and laundered cottons were less resistant to abrasion than the laundered only cottons. The Stoll flexing and

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[1] P. Chippindale, "Wear, Abrasion, and Laundering of Cotton Fabrics, Part I: Wear of Fabrics During Actual Service and Laundering," Journal of the Textile Institute, Vol. 54, (November, 1963), pp. T445-448.

abrasion test showed the laundered only cottons to be less resistant to abrasion.

These differences in results may be related to the differences in abrasive action of the testing machines. The abrasive action of the Stoll machine is a reciprocal flexing and rubbing over a steel blade, while the action of the Taber machine is the rotary rubbing action of abrasive wheels. The nature of these two abrasive actions are basically different, and therefore, can make accurate comparison of results difficult.

II. CONCLUSIONS

The results of this study indicated the following conclusions:

1. The differences in fiber length and fiber strength did not significantly affect the abrasion resistance of the cotton sheetings as measured by the three test methods.

2. The three methods of testing abrasion resistance produced varied results among fiber property groups from laundering interval to laundering interval.

3. The yarn breakdown test method was the most consistent in detecting differences in abrasion resistance among cottons varying in staple length and strength.

4. The two treatments, (1) laundering only and (2) use and laundering, significantly affected the abrasion performance of the cotton sheetings.

III. RECOMMENDATIONS FOR FURTHER STUDY

As evidenced by this study, further investigation of the methods of testing abrasion resistance would be desirable to develop a better understanding of the wear performance of fabrics. To accomplish this objective, however, considerable study must be directed toward the investigation of the basic mechanism of abrasion. The following recommendations are made for further study:

1. A microscopic study be conducted to compare the extent of damage which results from wet laboratory abrasion tests with that which occurs during laundering of fabrics.

2. A study be conducted of the abrasion resistance of resin treated cotton sheetings for comparison with the results of untreated sheetings. This should aid in determining the effect that resin treatment has on wear performance of fabrics.

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