THE SERVICEABILITY OF COTTON SHEETINGS AS INDICATED BY MEASUREMENTS OF ABRASION RESISTANCE

by

Judieth Elizabeth Mock

7078

A Thesis Submitted to
the Faculty of the Graduate School at
The University of North Carolina at Greensboro
in Partial Fulfillment
of the Requirements for the Degree
Master of Science

Greensboro
June, 1965

Approved by

Pauline E. Keeney
Director

APPROVAL SHEET

This thesis has been approved by the following committee of the Faculty of the Graduate School at the University of North Carolina at Greensboro, Greensboro, North Carolina.

Thesis Director: Pauline E. Keeney

Oral Examination Committee Members:

Helen C. Magee

Eunice M. Deemer

Marguerite N. Felton

May 3, 1965
Date of Examination

280061

MOCK, JUDIETH ELIZABETH. The Serviceability of Cotton Sheetings as Indicated by Measurements of Abrasion Resistance. (1965) Directed by: Dr. Pauline E. Keeney. pp. 74

The objectives of the study were to determine the effect of the fiber properties, staple length, and strength, on abrasion resistance; and to compare three methods of measuring abrasion resistance as an indication of their value in predicting wearing quality.

Data were collected from two methods of testing abrasion resistance used in the Southern Regional Textile Project SM-18, the flexing and abrasion method using the Stoll Weartester, and the strength difference method using the Taber Abraser. Abrasion resistance measurements were made using the occurrence of yarn breakdown method with the Taber Abraser.

The sample of this study consisted of the experimental sheetings used at the North Carolina station in the regional project. The sheetings were classified into four fiber property groups. They were divided into two treatment groups; use and laundering, and laundering only. Measurements were made prior to treatment, and after five, and fifteen launderings for each treatment group.

An analysis of variance was made to determine the effect of the fiber properties on abrasion resistance. Correlation coefficients were computed comparing results of each abrasion resistance method with results of tear resistance tests to indicate the effectiveness of the methods.

The results indicated that (1) the three methods of measuring abrasion resistance produced varied results, from laundering interval to laundering interval and within each laundering interval, (2) the occurrence of yarn

breakdown method was the most sensitive test in detecting differences in abrasion resistance among cottons varying in staple length and strength, (3) the flexing and abrasion method, and the occurrence of yarn breakdown method revealed differences in abrasion resistance between treatment groups, and (4) the measurements produced by the three methods of testing abrasion resistance were not closely related to tear resistance measurements.

ACKNOWLEDGMENT

The writer would like to express her gratitude to those who have contributed to the preparation of this thesis through their encouragement, interest, and time.

Appreciation is expressed to Dr. Pauline E. Keeney, director of the thesis, for her invaluable guidance and contributions; and to Miss Eunice Deemer, Miss Marguerite Felton, and Dr. Aden Magee, members of the graduate committee, for their helpful suggestions.

TABLE OF CONTENTS

CHAPTER PAGE

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Despite the increasingly keen competition between natural and synthetic fibers in the textile market, cotton continues to maintain a position of dominance. It is one of the cheapest and most versatile of all fibers, and accounts for approximately two-thirds of the world's total fiber consumption.[1] In view of its importance and extensive usage, investigation of cotton fiber properties and fabric performance is of interest and value to cotton growers, manufacturers, and consumers.

There has been extensive research dealing with cotton fiber properties in the raw state, and dealing with fabric quality; however, there has been little research dealing with the relationship between fiber properties and serviceability of the end-product. To aid in meeting this need, the Southern Regional Textile Project of the Agricultural Research Service of the United States Department of Agriculture was undertaken. This regional project was designated as SM-18.[2] The Home Economics Research Personnel of the agricultural experi-

---

[1] Textile Fibers and Their Properties, Prepared by Burlington Industries, Inc. (Greensboro, North Carolina: Burlington Industries, Inc., 1963), p. 15.

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

ment stations in six southern states are participating cooperatively in this study.

Under investigation at the present time is the relationship of the fiber properties staple length, and strength, to end-product performance.

This thesis was related to the regional project in that one aspect of the project, abrasion resistance, was considered in detail. One of the tests included in measurements of serviceability was that of abrasion resistance. Good resistance to abrasion is one of the distinguishing features of cotton, and is a primary factor to be considered in the textile market.

> . . . 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, particularly nylon, has made reappraisal of cotton's abrasion performance desirable. Moreover, increasing use of chemical finishes to enhance such qualities as mildew, soil, and wrinkle resistance intensifies the need for good abrasion resistance in cotton textiles.[3]

Two methods of measuring abrasion resistance were used in the Regional Project. They were (1) the strength difference method using the Taber Abraser, and (2) the flexing and abrasion method using the Stoll Weartester. Each test produced results of considerable variation; thus, there appeared to be a need for further study of methods of measuring abrasion resistance. It was thought that a third test, the yarn breakdown method using the Taber Abraser, might measure more accurately the abrasion resistance of the selected cotton

---

[3]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.

sheetings. This test might also be of value as an indication of the effectiveness of the three methods.

The specific objectives of this study were:

1. To determine the effect of fiber strength and fiber length on abrasion resistance of selected cotton sheetings by the occurrence of yarn breakdown method using the Taber Abraser.

2. To compile the data of the abrasion resistance of selected cotton sheetings as measured by the strength difference method using the Taber Abraser, and by the Stoll Weartester.

3. To compare these three methods of abrasion resistance, as an indication of their value in predicting the wearing quality of selected cotton sheetings.

The sheetings used in this study were those under experimentation at the University of North Carolina at Greensboro. Data compiled from abrasion measures made at the zero, fifth, and fifteenth laundering intervals were used to indicate the abrasion resistance by each of the three test methods.

Chapter II is a review of the literature pertaining to the measurements of abrasion resistance, and to studies involving serviceability and wear of cotton fabrics. Chapter III describes the procedure for the use of the sheets, the measurements of abrasion resistance, and the statistical procedures used. The compilation and results of the abrasion resistance measurements, are presented in Chapter IV. Chapter V includes the summary, conclusions and recommendations for further study.

CHAPTER II

REVIEW OF LITERATURE

One of the major factors determining the degree of serviceability obtained in textile products is that of abrasion resistance. Although the mechanism of abrasion, and the evaluation of its effects are complex processes, research concerning abrasion indicates its importance, both from the producer and consumer viewpoint. The essence of abrasion resistance is not easily recognizable, and John P. McNally and Frank A. McCord state that:

> Abrasion resistance is a textile quality which is perhaps taken for granted by the consumer, especially in apparel uses. Unlike color or luster, it is not easily evaluated at the time of purchase. Nevertheless, resistance to abrasion is a consideration in a sizeable portion of cotton textile markets.[1]

I. METHODS OF DETERMINING ABRASION RESISTANCE

From the standpoint of those involved in textile research there is disagreement on matters concerning abrasion resistance; the reliability of test methods, the methods of evaluation, and the value of laboratory tests in prediction of actual service life, or wear life. As an aid in communication, and a framework for research, certain definitions have been generally accepted.

---

[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.

Definitions of "Serviceability," "Wear," and "Abrasion"

To aid in clarifying the terminology, and limiting the meaning for research purposes, attempts have been made to define objectively the terms "serviceability," "wear," and "abrasion." Ernest Kaswell gives the following definition for "serviceability."

> A fabric which serves the functions 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 permits [permit] a fabric to be accepted or rejected for use.[2]

He treats "wear" as a more limited term which "describes the ability of a fabric to withstand the effects of abrasion . . . concomitant with stressing, straining, laundering, dry cleaning, pressing, creasing, etc."[3] W. J. Hamburger and H. N. Lee have differentiated between "wear" and "abrasion" in the following manner.

> The terminology as is the case in so many phases of textile technology, is badly confused. "Wear" and "Abrasion" are used inter-changeably whereas actually they are not synonymous, Ball comments as follows: "Abrasion derived from the verb to abrade very distinctly suggests "rubbing off" . . . . It is suggested, therefore, that the term 'wear' be considered as of broader scope than 'abrasion,' and be used to apply wherever other important destructive actions, with or without abrasion are existant.[4]

Most of the persons involved in research in this area accept the de-

---

[2]Ernest R. Kaswell, Textile Fibers, Yarns, and Fabrics, (New York: Reinhold Publishing Corporation, 1953), p. 298.

[3]Ibid.

[4]W. J. Hamburger and H. N. Lee, "A Study of Lining Fabric Abrasion," Rayon Textile Monthly, Vol. 26, No. 7, (July, 1945), p. 93, citing H. J. Ball, "Problems Which Abrasion and Wear Testing Present," Textile Research Journal, Vol. 8, 1938, p. 134.

finition of abrasion given by Hamburger and Lee as "rubbing off or wearing away by attrition, and excludes all other destructive influences."[5] The definition employed by the ASTM Standards on Textile Materials[6] is similar.

Machines for Testing Abrasion Resistance

The problem of measuring and evaluating abrasion resistance in relation to the wear life of a textile fabric is of great importance. McNally and McCord comment that probably more attempts have been made to produce uniform, constant, and reproducible machines which simulate or correlate with actual wear, than any other textile testing device.[7]

Since the first recorded description of a weartester in 1858,[8] more than 50 have been described.[9]

In the United States textile authorities differ in opinion on the merits of various machines; however, Meredith states that most recognize the following five methods of testing abrasion resistance.

---

[5]W. J. Hamburger and H. N. Lee, "A Study of Lining Fabric Abrasion," Rayon Textile Monthly, Vol. 26, No. 7, (July, 1945), p. 93.

[6]ASTM Committee D-13 on Textile Materials, ASTM Standards on Textile Materials, (Philadelphia: American Society for Testing and Materials, October, 1962).

[7]McNally and McCord, op. cit., p. 738.

[8]D. L. C. Jackson, "Wear Testing," Textile Journal of Australia, Vol. 25, No. 5, (July 20, 1950), p. 435.

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

1. Inflated diaphragm method (Stoll)

2. Flexing and abrasion method (Stoll)

3. Oscillatory cylinder method (Wyzenbeek)

4. Rotary platform, double head method (Taber)

5. Uniform abrasion method (Scheifer)[10]

The scope of each of these five methods is outlined in the ASTM Standards on Textile Materials.

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.[11]

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.[12]

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.[13]

---

[10]Ed R. Meredith and J. W. S. Hearle, Physical Methods of Investigating Textiles, New York: Textile Book Publishers, Inc., 1959.

[11]ASTM, op. cit., p. 462.

[12]Ibid., p. 465.

[13]Ibid., p. 470.

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.[14]

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.[15]

These descriptions, representing only five of the numerous types of machines in use, reveal basic differences in testing. Because several types of machines are used, and because they are used in determining various types of abrasion damage, or abrasion resistance, differences need to be analyzed, and comparisons of the different types of machines are necessary. Such comparisons are important in determining similarities and differences, and in evaluating the results obtained on different types of machines.

Jackson classifies the main differences in the various methods under three major headings: "(1) The nature of the abrading surface. (2) The direction and type of motion. (3) The method of determination of the end-point of the test."[16] Such differences between machines make accurate comparisons

---

[14] Ibid., p. 473.

[15] Ibid., p. 478.

[16] Jackson, op. cit., p. 436.

difficult. McNally comments on other variables within testing on a single machine, which further impede such scientific comparisons.

> . . . 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.[17]

Methods of Evaluation of Abrasion Tests

The method of determination of an end-point is pertinent to this study. It appears that selection of criteria for evaluating laboratory abrasion performance is a critical feature in the validity of the test. In general, the end-point, or method of evaluation depends somewhat on the actual use for which the fabric is intended, and should relate to the actual use. Authorities differ in opinion of the value of various methods of evaluation, and the sensitivity of the specific evaluations to types of abrasion. Kaswell comments on the criteria selected for judging abrasion.

> . . . 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.[18]

Many laboratory tests are evaluated in terms of a visual end-point

---

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

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

determined by the laboratory and estimated by the operator of the abrasion machine. This type of evaluation is the subject of criticism due to the factor of personal variation.

Hamburger and Lee propose and discuss eight properties in which measurable changes are produced by abrasion. These properties are:

> (1)--Tensile Strength, (2)--Thickness, (3)--Weight, (4)--Surface lustre, (5)--Air permeability, (6)--Color, (7)--Character of abrader material and, (8)--Appearance of surface. Of these, only 4 indicate possibilities of dependable quantitative results for the entire fabric structure--namely: strength, thickness, weight and air permeability.[19]

Hamburger and Lee dismiss weight and thickness changes on grounds that differences are so small, they would be difficult to measure with precision and reproducibility of results. Air permeability is questioned because debris deposits in the fabric reduce permeability with longer testing periods.[20]

Although the formation of a hole is not considered in the list of criteria just described, and is subject to criticism on the basis of personal judgment and variation involved, it is often used as a practical end-point. Gagliardi, in his abrasion study, for example, reports, "All the tests we have performed have been carried out to complete destruction, ie, [i.e.] until a complete hole has been formed in the specimen."[21]

Hamburger and Lee question the use of this criterion on the grounds

---

[19]Hamburger and Lee, Vol. 26, No. 7, op. cit., p. 93.

[20]Ibid.

[21]D. D. Gagliardi and A. C. Nuessle, "The Relation between Fiber Properties and Apparent Abrasion Resistance," American Dyestuff Reporter, Vol. 40, No. 13, (June 25, 1951), p. 410.

that:

> . . . The selection of an end point is undesirable in that it precludes a study of the rate at which the sample is proceeding to destruction, coupled with the fact that the end point is usually impossible quantitatively to define and reproduce.[22]

He suggests instead the use of strength as a criterion. Although strength "is not all that could be desired as a criteria for evaluation of damage, it appears to offer the least objectionable features."[23] This method of evaluation enables an examination of rate of destruction of the fabric also.

The Significance of Rate of Abrasive Destruction

In 1945, Hamburger and Lee acknowledged the significance of the rate of abrasion in practical evaluation.

> . . . It is justifiably claimed that an end point alone expressed as the number of cycles to cause any given extent of destruction is not a satisfactory criterion of resistance to abrasion. The rate at which the sample proceeds to destruction must also be considered.[24]

Since then, particularly in recent years, it has been decided that "A very critical factor in the establishment of this relationship [laboratory tests and service tests] is the influence of the rate and type of abrasion involved in such tests."[25]

Gagliardi, who has conducted a study involving the concept of rate of

---

[22] Hamburger and Lee, Vol. 26, No. 7, loc. cit.

[23] Ibid.

[24] W. J. Hamburger and H. N. Lee, "A Study of Lining Fabric Abrasion," Rayon Textile Monthly, Vol. 26, No. 8, (August, 1945), p. 64.

[25] Herbert F. Scheifer and Carl W. Werntz, "Interpretation of Tests for Resistance to Abrasion of Textiles," Textile Research Journal, Vol. 22, No. 1, (January, 1952), pp. 1-2.

destruction, explains its importance in this way.

> . . . In the actual life of a garment in practical use, a fabric is subjected to relatively low abrasive forces, ie, [i.e.] low stresses and strains, the cycles of which are, on the average, far apart, so that there is always time available for stress-and-strain relaxation. In spite of the precision and accuracy of laboratory abrasion machines, the general criticism that can be made against them is the rapid rate at which a specimen is destroyed by application of repeated stresses more severe than those commonly encountered in the normal wearing of garments.[26]

In his study of the dependence of abrasion resistance on rate of destruction, viscose rayon dresses, blouses, and shirts were worn by 30 Rohm and Haas Company personnel for a year. The garments underwent an average of 30 commercial or home launderings with periodic checks for signs of actual abrasion damage in use.[27] The results of the study implied the following:

> . . . These results point sternly to the fallacy of making rapid abrasion tests simply because it is convenient for routine laboratory operations. The laboratory abrasion values obtained by testing at low applied stresses and strains, which approach those encountered in normal use, give a more correct picture of performance in practice.[28]

Studies Showing Correlations of Results among Different Laboratories and Machines

In a study conducted by the Standing Consultative Conference on Textile Research, the objectives were to determine the degree of agreement between different wear or abrasion tests, and at the same time to pinpoint the sources of disagreement. The tests were carried out in six different laboratories, using

---

[26] Gagliardi, loc. cit.

[27] Ibid., p. 413.

[28] Ibid., p. 414.

various machines. The types of testing machines used included the Accelerotor, Courtaulds BFT, Lester Ring-wear, Linra, Martindale, Schiefer, Shirley Boss, and Stoll.[29]

A survey indicated that the results produced by different laboratories using the same type of machines sometimes differed substantially. One cause for the difference lay in estimation of the end-point.

> . . . These observations suggest that, for a visually estimated end-point, the differences between laboratories arise from the difficulty in standardising the end-point, and that this may affect not only the general level of results but comparisons between cloths, even at the same laboratory.[30]

However, use of an automatically determined end-point, not dependent on operator judgment, was not free from differences. "Inspection of the results obtained on both the tests made on the BFT tester . . . shows both systematic and random differences between laboratories."[31] These differences between laboratories are not unusual.

> . . . It is common experience that close agreement between laboratories using the same physical tests for textiles cannot be expected unless there has been a detailed study of the variables that affect the result and, usually, experience of inter-laboratory comparisons. Few 'wear' tests have been subjected to this kind of development. The differences observed between laboratories are, however, important in that they illustrate that, at the

---

[29]Standing Consultative Conference on Textile Research: Committee of Directors of Textile Research Associations, "Final Report on Inter-Laboratory Abrasion Tests," Journal of the Textile Institute (Proceedings), Vol. 55, No. 1, (April, 1964), pp. P1 - P2.

[30]Ibid., p. P5.

[31]Ibid., p. P8.

present stage of development of wear tests, it is not possible to expect reproducibility of absolute test results, even in laboratories that may be expected to exercise a high degree of control.[32]

Comparison of the machines themselves, provided a division into three groups according to similarity of results. Group I consisted of the Linra, Schiefer using wool abrasive, Stoll bar, and Martindale using visually estimated end-point. Group II consisted of the Boss, using loomstate abrasive, Stoll bar, and Martindale using weight loss evaluation. Group III included the Stoll Blade, BFT flex, BFT ball, Schiefer using steel abrasive, Boss using mineral-khaki-dyed abrasive, and Accelerotor. Agreement between machines in the first group was very satisfactory, and general agreement was obtained within each of the three groups. However, the rank-order of fabrics tested differed from group to group.[33]

The conclusions of the study are the following:

There are important differences between the various types of abrasion tests in comparison between the cloths that have been examined. These differences appear to be associated with the operating conditions of the machine, and particularly with the pressure between the abrasive and the sample. The differences are such that it cannot be assumed, without independent evidence, that the results obtained from a particular abrasion test are necessarily a reliable guide to behaviour in a particular practical situation.

Agreement between laboratories using the same abrasion test under nominally the same conditions is likely to be very poor.[34]

In a study reported by Louis I. Weiner and Clarance J. Pope, the Stoll,

---

[32] Ibid., p. P8.

[33] Ibid., pp. P8-P9.

[34] Ibid., p. P9.

Bocking (BFT), Sand, and Taber abraders were used in fabric evaluation. The Stoll and BFT abraders were recognized as producing an "adhesive" action of abrasion, while the Taber and the Sand abraders were considered to produce "abrasive" action. When the data were statistically analyzed, and correlation coefficients obtained, the R value between the BFT and Stoll was 0.95, and between the Sand and the Taber an R value of 0.86 was obtained.

> The results of this study suggest that differences 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. For example, the BFT abrader produces a much more rapid rate of abrasion than does the Stoll; it is therefore more efficient and economical to use the BFT when it is desired to obtain an indication of the specific type of wear action characteristic of these two abraders.[35]

Despite the varying of abrasion resistance measurements with the types of abrasive action, the measurements represent characteristics constituting wear. Jackson comments that:

> . . . Although such measurements have been adversely critised, they can provide much useful information regarding the wearing properties of the test piece, provided that the characteristic measured by the machine is the major factor involved in the actual service wear of the test piece . . . . The ultimate criterion is always the actual wearing of the particular fabric or garment, and so all accelerated tests such as are carried out on a machine should be correlated with field trials.[36]

Relation of Laboratory Abrasion Tests to Service Tests

According to Zook two philosophies have developed concerning abrasion

---

[35]Louis I. Weiner and Clarence J. Pope, "Correlation of Laboratory Abrasion Testers," Textile Research Journal, Vol. 33, (September, 1963), p. 763.

[36]Jackson, op. cit., p. 436.

and wear testing. The first philosophy requires reproduction or duplication of actual wear conditions for a specific fabric use insofar as is possible. The second philosophy recommends selection of the most influential factors in wear, as plane abrasion, or flex abrasion, for use in evaluation. In connection with the second philosophy, rank orders of fabrics relative to their abrasion resistance is possible.[37]

Authorities disagree on the relative merits of laboratory abrasion tests, and some hold the viewpoint that service tests are more valid.

> The problem of wear-resistance cannot be solved simply by subjecting a fabric to simulated wear in the laboratory, as has been demonstrated in the research of progressive commerical laboratories. The type of wear which the material is going to meet in actual service must be known, as well as the physical and chemical characteristics which contribute to the ability of the fabric to withstand the type of wear met in the field.[38]

McNally and McCord point out several pitfalls encountered in laboratory abrasion tests that might be overcome in service tests. The danger of generalized conclusions based on laboratory tests is revealed when laboratory abrasion is compared with abrasion encountered in actual use. The laboratory machine destroys or abrades the fabric at a much more rapid rate than that found in wear. The nature of the abrading action may not characterize actual wear action. Abrasion is only one of a set of variables causing wear, and in the actual wear process the extent of wear due to abrasion is not known. To

---

[37]Zook, *loc. cit.*

[38]E. Pollitt, "Factors Affecting the Performance in Use of Cotton Fabrics," *The Textile Weekly*, Vol. 59, No. 1645, (September 25, 1959), p. 586.

understand the process, service tests and salvage studies are in order.[39]

The main mechanical factors constituting wear agreed upon by most investigators include plane abrasion, edge abrasion, flex abrasion, force in tension (tearing), snagging, and impact forces.

> From an examination of a large number of U. S. Army uniforms Stoll has reported that in the normal wear of such uniforms these mechanical factors can be divided approximately as follows:
>
> 30% plane abrasion.
> 20% edge abrasion.
> 20% flex abrasion.
> 20% tear
> 10% other actions.
>
> These proportions will vary for different materials and for different garments.[40]

To expect the results of one machine to reflect the effects of all the mechanical forces described, or in the amounts described would hardly be possible. It would appear more feasible or worthwhile to determine the major factor or factors for a specific use, and conduct testing on the appropriate machine, recognizing and interpreting results in view of the limitations imposed by the use of the specific machine, and the specific type of abrasive action.

Dr. H. Sulser advocates this stand in his article in the Textile Journal of Australia.

---

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

[40]Jackson, op. cit., p. 435.

In view of the fact that different abrasion test methods give greatly varying results and that great variations can be obtained in testing the wear properties of fabrics by different methods, it is important to urge that the abrasion test conditions should correspond as closely as possible to abrasion conditions obtaining in wear. All other factors, such as keeping abrasion values constant; accuracy; objective evaluation of wear; constant wear in both directions of the specimen, etc., however important in themselves, are only of secondary significance.[41]

In a study conducted in actual service use by the Quartermaster Corps, contradictions between laboratory tests and service tests were found.

Evaluation of the original serge fabrics on the laboratory instruments used in the M. I. T. project did not rank the fabrics in the order of wear-resistance reported from the combat course. An even more complete reversal of the laboratory results by a field test occurred in evaluating wear-resistance of 10.5 ounce shirting flannel . . . .

It should be noted that none of these laboratory evaluations takes account of the effect of impact, tension, bending, flexing, torsion, and internal abrasion caused by dirt, not to mention the complex action incurred during laundering--all of which are part of field wear.[42]

Interpretation of results obtained from laboratory tests appears to be one of the most troublesome factors in accuracy and reliability of measurement when related to service use. The conclusions derived from the same Quartermaster study, however, recognized the value and potential of laboratory tests with proper interpretations.

Restricted as it was to this one phase, the work of the combined laboratories uncovered considerations . . . and illustrated clearly the

---

[41]Dr. H. Sulser, "Abrasion Tests for Textiles," Textile Journal of Australia, Vol. 30, No. 9, (November 21, 1955), p. 1090, from "Textile Rundschau," Vol. 9, pp. 572-579.

[42]Captain Stanley Backer, QMC, "Increasing the Wear Life of Army Textiles Through Research," Proceedings of the Conference on Quartermaster Textile Research, (New York: Textile Research Institute, 1945), p. 51.

> possibility of using standard laboratory abrasion machines, with proper interpretation of their results, to predict the wear-resistance of certain textile fabrics.[43]

With precautions such as those just described, laboratory abrasion tests can potentially predict wear performance with much less expenditure of time, money, and energy than is possible in service tests. If the major abrasive factor or factors in use are identifiable, reliable laboratory abrasion tests utilizing this factor could be used to advantage in predicting wear. Jackson states that:

> . . . The factors involved in wearing . . . are many and not constant. They differ from wearer to wearer, from garment to garment, and even between different parts of the same garment. So we can hardly expect one machine to assess accurately the wearing properties of all fabrics under all conditions of use.[44]

Factors involved in wearing are variables which complicate the development of accurate, standard measuring devices. Since these factors vary in both amount and intensity the problem is a complex one. Authorities have repeatedly sought to identify and define the factors of the wearing process to aid in solutions of the measurement problem.

II. FACTORS CONTRIBUTING TO ABRASIVE WEAR

The factors contributing to textile wear can be classified as either mechanical or chemical in nature. Mechanical wear includes both the gradual deterioration resulting from abrasion and tensile stressing as well as the accidental causes of failure such as rips or cuts. Chemical wear

---

[43] *Ibid.*, p. 50.

[44] Jackson, *op. cit.*, p. 435.

results from such actions or microbial attack, chlorine damage during laundering, sunlight degradation, and effects of strong acids. Abrasion is, therefore only one of several factors contributing to wear.

Wear life of textiles is complicated not only by the many different factors involved but also because the relative importance of each differs greatly with end use. In apparel items, additional complications arise as a result of the occupation and habits of the wearer.[45]

Although abrasion is recognized as only one of the factors contributing to wear, salvage studies have shown that abrasion is one of the major causes of failure of textile fabrics.[46]

Abrasive damage depends on the properties of the fiber, yarn, and fabric. McNally and McCord discuss various properties contributing to abrasion resistance under the following main divisions.

1. Fiber Mechanical Properties
   - Tensile properties
   - Shear properties
   - Flexural properties
2. Construction
   - Fiber shape
   - Yarn structure--diameter
   - Twist
   - Fabric structure
   - Crimp
   - Threads per inch
   - Weave
3. Finishes
   - Finishes additive
     - Binding agents
     - Lubricants
     - Coatings

---

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

[46] Ibid., p. 721. Citing G. C. Clegg, "Microscopical Examination of Worn Textile Articles," Journal of the Textile Institute, Vol. 40, Transactions, 1949, pp. T449-T480.

Finishes chemical
Finishes for wrinkle-resistance
Mercerization
Cyanoethylation and acetylation[47]

Fiber Damage

The first of these divisions is that of fiber properties. Pollitt, in his discussion of the relation between fiber properties and fabric abrasion performance states that there is:

> . . . Comparative scarcity of data dealing directly with the relations between the variables of the cotton fibres and the performance of the textile fabrics in service. . . . and although much is known about the effects of these factors [variables of cotton fibers, yarn, and cloth construction] on the performance of fabrics in laboratory tests, the link between these tests and performance in service is often not well established and is a matter for speculation.[48]

Resistance to abrasion and flexing is considered to be one of the most important fiber properties.

> Among the destructive mechanical actions which a fabric must withstand during use the most important are resistance to abrasion and resistance to flexing. . . . Resistance to abrasion and resistance to flexing are probably the two most disputed and intractable subjects in textile testing.[49]

Fiber breakdown is a complicated process dependent on many factors which vary with type of wear.

> . . . For instance, it may be pure abrasion, that is, the wearing through of the fibre, layer by layer, by rubbing against another surface

---

[47]McNally and McCord, op. cit., p. 586.

[48]Pollitt, op. cit., p. 586.

[49]Ibid., pp. 587-588.

> under either wet or dry conditions. Also, flexing of the fibre must set up repeated bending stresses. Again, there may be fatigue effects with the occurrence of a large number of tensile stresses--and so on.[50]

Stanley Backer suggests three types of abrasive action which cause fiber damage, the importance of which is dependent upon the composition of the abradant, the fiber behavior in the fabric, and the conditions of abrading. The three elements consist of friction, surface 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.[51]

These destructive forces acting on the fibers cause damage of several types, such as fibrillation, cuticle damage, and transverse cracking. These forms of damage are typical of cotton fibers. Fibrillation involves "the longitudinal disintegration of the fiber into a series of elements revealing the fibrillar structure,"[52] while cuticle damage, consists of a bruising of the fiber, and is thought to be caused by a "loosening, tearing, and partial or complete removal of the cuticle,"[53] from a gentler abrasion. Transverse cracking is the "development

---

[50] 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. T445.

[51] 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.

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

[53] Ibid., p. 729.

of cracks at right angles to the fiber axis."[54]

Microscopic Evaluations

Studies of the abrasion mechanism in fibers have sometimes included microscopic evaluations. A recent study conducted by Ines deGruy and others involved the use of electron microscopy in investigating fiber damage due to laboratory abrasion. The fabrics used in the study were gray, scoured, bleached, mercerized, mercerized and resin treated, and bleached and resin treated cottons. The Stoll tester was the abrasion machine, using both flat and flex abrasion methods.[55]

The results showed that the typical characteristic of dry flex abrasion was longitudinal splitting of the fiber. Fibrillation occurred also under these conditions. Compression marks were found at right angles to the fiber axis. Changes in surface and internal fiber structures were observed.[56] The damage from flat abrasion was quite different from that of flex abrasion. "Fiber surfaces were seen to be snagged and cut, not only at the fiber ends where breaks occurred, but throughout the length of the fiber."[57] Staining of the fibers showed no lengthwise splitting of the fiber or fibrillation in flex abrasion. A

---

[54] Ibid.

[55] Ines V. deGruy, Jarrell H. Carra, Verne W. Tripp, and Mary L. Rollins, "Microscopical Observations of Abrasion Phenomena in Cotton," Textile Research Journal, Vol. 32, No. 11, (November, 1962), pp. 873-882.

[56] Ibid., pp. 875-876.

[57] Ibid., p. 877.

great deal of mashing of the fibers, and deep cuts into the sides of fibers occurred instead.[58]

A study by Chippindale comparing cotton fabrics after use, and cotton fabrics subjected to laboratory abrasion, in both the wet and dry states produced results similar to those of deGruy and others. The results when compared with the used fabrics presented an analysis of similarities and differences between laboratory and service abrasion.

Chippindale found that fiber breakdown proceeded quite differently in the wet and dry states. This was true of laboratory abraded fabrics, and those subjected to normal wear and laundering.

> In the dry state, abrasion of cotton fibres gives no indication of the fibrillar structure of the fibres. In every case, the surface layers are rubbed and eroded away and the surface has a relatively smooth appearance. The characteristic ridge structure is removed in the early stages and erosion of the fibre then proceeds as though it had a homogeneous structure.[59]

Flexing led to the appearance of cracks in the fiber surface. With high-load, there were a few large cracks, while low-loads caused smaller but more frequent cracking. With continued wear, the cracks began to link up until breaks occurred, producing fiber ends.[60] This damage is not identical to that observed in actual wear.

---

[58] Ibid., pp. 877-878.

[59] 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.

[60] Ibid.

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.

In the wet state, the fibres swell and the fibrillar structure is loosened. On the application of external forces, the fibrils can be torn out from the fibre surface. In untreated fibres, the fibrils are usually torn out as individuals, and this is observed both in fabrics laundered in washing machines and in those wet-abraded on laboratory test machines.[61]

Chippindale stresses the importance of including wet abrasion in laboratory testing. A textile fabric in use is subject to both wear and laundering alternately, which he equates with dry and wet abrasion. Therefore, he reasons, laboratory tests should also consist of wet and dry abrasion alternately, to more closely simulate service conditions and exposure to abrasion.[62]

The use of the microscope in evaluation of abrasion appears to be a recent development which seems to embody great potential in describing the abrasion process, and in comparing the results of laboratory tests with those of actual service tests.

The main criteria in judging the relationship of wear obtained by abrasion tests and that obtained in use are the following: the appearance of the abraded surface, and the microscopic picture of the fibres taken from it. In the latter case, the appearance of the fibre ends is specially significant for judging the type of wear. If the ends of fibres taken from abrasion test specimens correspond to those taken from worn garments, then that is a sure sign of compatibility of testing and practical experience. If,

---

[61] Ibid., pp. T462-463.

[62] 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.

however, flexing breakages appear only infrequently, but broken or sheared ends in abundance, the test results do not conform to reality.[63]

Specific Fiber Properties: Staple Length and Strength

The specific fiber properties with which this thesis is concerned are fiber staple length, and fiber strength, as they relate to fabric abrasion performance. It is difficult to isolate the influence of particular properties on abrasion resistance, or on general performance. One reason for this difficulty is, Platt contends, that laboratory investigations of fiber friction and relation to "mechanical considerations such as pressure, strength, staple length, etc., have never been fully undertaken or successfully carried out."[64] He comments, however, that, disregarding twist, the longer staple length fibers contribute better elastic characteristics[65] which are important to good abrasion resistance.

McNally and McCord indicate fiber staple length is important to abrasion resistance because "longer fibers are generally more difficult to remove or displace from yarns than shorter ones."[66] They further explain the significance of long staple length in stating that "improved fiber cohesion and stronger yarns

---

[63] Sulser, op. cit., p. 1088.

[64] Milton M. Platt, "Mechanics of Elastic Performance of Textile Materials, Part IV: Some Aspects of Stress Analysis of Textile Structures--Staple-Fiber Yarns," Textile Research Journal, Vol. 20, No. 8, (August, 1950), p. 520.

[65] Ibid., p. 538.

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

and fabrics can be expected with increased staple length."[67]

Fiber staple length, and fiber strength, although different properties, both appear to contribute to total strength in the yarn and fabric stage. However, fiber strength constitutes a separate factor in fabric durability.

> A discussion of strength in relation to suitability and durability must begin by putting this property into proper perspective. It is easy to believe that because a fabric is strong, it must be durable, but there are few examples of textile materials that are called upon to withstand loads which are more than a small fraction of the initial tensile strength of the material. Textile materials lose strength during use because of the various mechanical and chemical actions to which they are subjected, and they finally fail under low loads, often by tearing from a damaged place. . . . From the point of view of cloth strength, greater emphasis should be placed on fibre strength than is indicated by yarn strength prediction formulae.[68]

Fabric Structure

As has been previously indicated, fabric structure is another determinant of abrasion resistance. A study of the influence of type of weave on the abrasion properties of cotton fabrics was conducted by Witold Zurek and Halena Szemik. Plain, satin, left-hand twill, and filling rib weave fabrics were used, and all fabrics underwent testing on the Kovo abrader. The criteria of evaluation consisted of bursting strength, loss of weight, and decrease in thickness. The effect of abrasion was found to vary with type of weave, with the plain weave

---

[67] Ibid., p. 744.

[68] Pollitt, op. cit., p. 744.

most resistant to abrasion.[69]

Although the plain weave cotton was the weakest fabric when evaluated in terms of bursting strength, it proved to be the most acceptable in the other aspects of evaluation. When changes in mass, or weight, were examined, the plain weave cotton showed the least weight change, quite different from the other fabrics.

> . . . 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.[70]

When the fabrics were evaluated in terms of thickness, the thickness of the plain weave fabric increased, whereas that of the others decreased. Length of float again provides the explanation since the cut fibers remain in the fabric, forming a brush which increases thickness. This was found to be especially marked in the vicinity of a hole. The cut fibers near the hole distinctly increased thickness.[71]

With respect to areas of abrasion damage, the observation was made that:

> . . . In the plain weave fabric, the cross-over of the yarns is especially sensitive to abrasion, and, although the change in yarn mass as a whole is not great, the loss in the area of the cross-overs is considerable.[72]

---

[69]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.

[70]Ibid., p. 145.

[71]Ibid.

[72]Ibid., p. 146.

III. THE TABER ABRASER AS A LABORATORY ABRASION INSTRUMENT

Use of the Taber Abraser and literature concerning this instrument is particularly pertinent to this study.

Hamburger and Lee, respected authorities in the field of abrasion research selected the Taber Abraser as the laboratory instrument for indicating abrasive destruction.

> . . . 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.[73]

The Taber Abraser method affects the fabric in both warp and filling directions simultaneously, giving it an advantage over some machines which do not. According to Sulser, the action in both directions simultaneously is to be preferred over separate testing of warp and filling directions.[74]

Methods of evaluating results obtained with the Taber Abraser vary with the material tested. Changes in weight, thickness, appearance, breaking strength, or destruction of yarns are criteria which may be applied to evaluation with this test method.

In studies conducted by the Quartermaster Corps, using the Taber Abraser, it was found that:

---

[73]Hamburger and Lee, Vol. 26, No. 7, op. cit., p. 93.

[74]Sulser, op. cit., p. 1088.

> . . . Subjecting fabrics to one cycle of wear on the back for every five cycles on the face provided the same relative loss of strength in both warp and filling directions as was noted in the actual service test.[75]

Hayes, who conducted a study using the change in appearance, and the formation of a hole criteria for the Taber Abraser, and the breaking strength criterion for the Wyzenbeek tester found the following to be true.

> There was no correlation between the number of cycles required to produce a hole with the Taber machine and either the percentage loss in breaking strength or the actual breaking strength after abrading on the Wyzenbeek . . . . Laboratory ratings based on the Taber and Wyzenbeek abrasion machines may serve to evaluate work clothing fabrics until serviceability tests determine the required minimum for such properties as breaking strength and count.[76]

Zook, who has done intensive research with the Taber Abraser, has been concerned with the reproducibility of test results on this instrument. She listed the following factors as possible causes of inconsistencies in results.

(1) Use of an insufficient number of samples
(2) Variable tension resulting from the mounting of 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, particularly where the abrasive path was not clearly visible.[77]

She developed a tensioning device to insure standardization in sample

---

[75]Backer, "Increasing the Wear Life of Army Textiles Through Research," op. cit., p. 48.

[76]Margaret B. Hayes, "Physical Properties of 26 Work Garment Fabrics," Rayon Textile Monthly, Vol. 25, No. 1, (January, 1944), p. 74.

[77]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.

mounting. After testing, the use of this device provided more uniform results than those obtained by hand mounting.[78] She also developed a testing technique involving the use of three pairs of wheels. The results indicated that combined with the uniform tension mounting of samples, "The use of three selected pairs of wheels tended to reduce variations which existed within wheels so that more consistent results were obtained."[79]

IV. SUMMARY

A review of the literature indicated the importance of good abrasion resistance properties in fabric performance. The amount of research completed in this area substantiates this conclusion. Individual pieces of research, however, have often produced results which seem to contradict each other. The complex process of abrasion damage, and the numerous factors influencing this process are not fully understood. A more adequate and precise picture of the area of abrasion resistance, and the relation of laboratory results and actual wear performance can be expected to emerge with continued research and attention to the specific variables involved.

---

[78] Margaret Harris Zook, "A Tensioning Device for Use with the Taber Abraser," American Dyestuff Reporter, Vol. 30, (November 12, 1941), p. 745.

[79] Zook, "The Development of a Reproducible Testing Technique Using the Taber Abraser on Rayon Fabrics," op. cit., p. 685.

CHAPTER III

PROCEDURE

I. EXPLANATION OF PROCEDURE FOR REGIONAL PROJECT SM-18

The regional project, "The Relation of Fiber Properties to End-Product Performance,"[1] is concerned with the physical properties of raw cotton and end-product performance of fabrics made from raw cottons having a range for the properties of length and strength. For experimentation purposes, the cottons were manufactured into sheets of Type 140 muslin, produced according to specifications established for the regional project.

The eight different bales of cotton used in manufacturing the sheetings were selected for their differences in fiber length and fiber strength. The sheeting fabrics were classified according to the bales from which they were woven, and according to fiber properties as follows:

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

---

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

The sheets were divided into two major treatment groups. One group was used in women's dormitories and laundered weekly by a commercial laundry. The second group was subjected to laundering only, in order to give an indication of the effect of wear on fabric performance.

The groups of sheets which were used and laundered were used weekly as bottom sheets in women's dormitories. The number of nights and number of hours of use was recorded for each sheet, with a minimum of four nights constituting a week of wear. The sheets being laundered only were laundered on a regular schedule with those receiving wear and laundering treatment.

Three sheets of each cotton type were withdrawn before use or laundering and sampled to obtain control data, or that which was referred to as the 0 (zero) interval. The remainder of the sheets then underwent two treatments: (1) use and laundering (WW), or (2) laundering only (W). Samples were withdrawn for testing after five and fifteen intervals of each treatment. The samples consisted of three sheets from each of the eight cotton groups undergoing wear and laundering, and two sheets from each of the eight groups undergoing laundering only. The testing area of each sample sheet was marked by means of a standard template, and laboratory tests were then performed.

II. SAMPLING PLAN

The sheetings manufactured for the regional project and used at the North Carolina Station were the samples used in this study.

Four samples for abrasion tests were taken from each sheet in the groups withdrawn for testing before treatment, and following the fifth and fifteenth intervals of wear and laundering, and of laundering only.

The standard testing area of each sheet was designated and marked by a template, then removed for testing. The samples for this study were taken from the areas of the sheet adjacent to, or partially within the standard testing area, since this area represented those parts of the sheets which received the greatest amount of wear in use. The approximate positions of the samples taken for this study are indicated in Figure 1.

Provision was made in the procedure of the regional project for testing abrasion resistance by two other methods: the flexing and abrasion method using the Stoll Weartester, and the Taber strength difference abrasion method. The positions of these samples are also indicated on Figure 1.

The sampling plan for this study was similar to that used in sampling for the previous abrasion tests[2] conducted in the regional project, although the number of samples taken from each sheet varied according to the test.

III. REVIEW OF PROCEDURES FOR ABRASION TESTS

Each of the three abrasion tests were based on procedures established by the American Society for Testing Materials.[3]

---

[2] Ibid., pp. 30, 38-42.

[3] ASTM Committee D-13 on Textile Materials, ASTM Standards on Textile Materials, (Philadelphia: American Society for Testing and Materials, October, 1962).

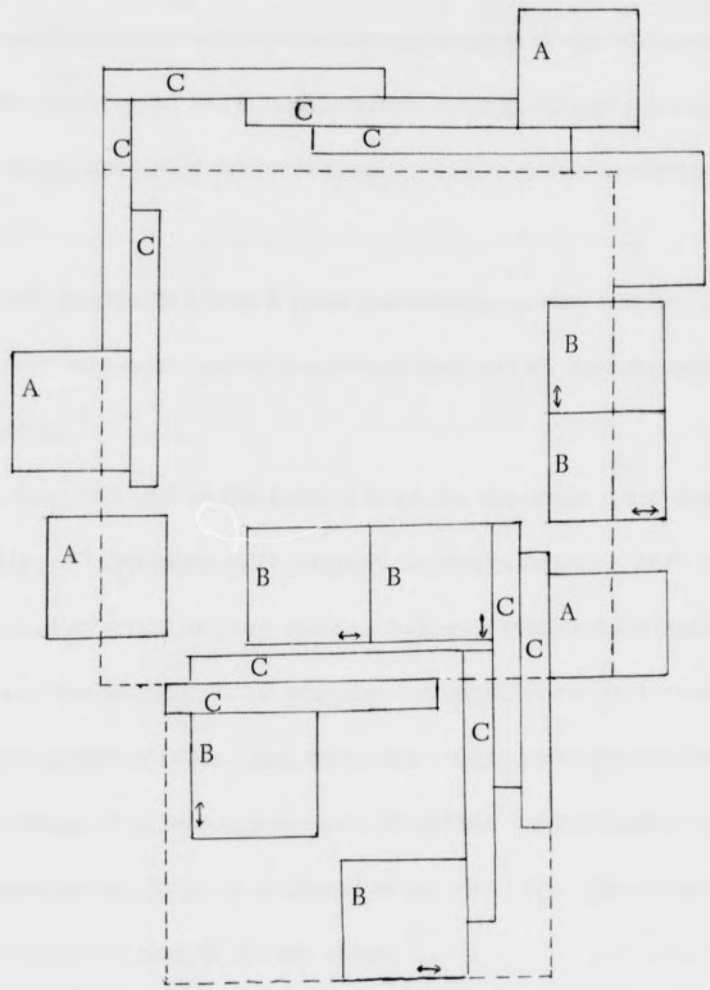


FIGURE 1.

SAMPLING PLAN FOR ABRASION TESTS
TAKEN FROM CENTER OF EACH SHEET

Key:

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

Method I. Flexing and Abrasion with the Stoll Weartester

The scope of this test was the determination of resistance to flexing and abrasion when specimens were "subjected to unidirectional folding and rubbing over a bar having specified characteristics, under known conditions of pressure and tension."[4]

A Stoll weartester with a yoke positioning device was used in testing. This instrument was equipped with a fabric load of two pounds, and a head load of one half pound.[5]

Selection and use of the folding bars for the tests were determined systematically. Three bars calibrated by the manufacturer were used. Two bars were used for actual testing and one bar was retained for calibration purposes. Each of the working bars was checked against the calibration bar before and after each series of tests. All three bars were pre-checked by means of calibration ribbon. The average number of cycles for rupture of ten strips of ribbon represented the level of calibration for that bar. The same two working bars were used for all testing in this study.[6]

The preparation and testing of all sheeting samples was completed at the Alabama station according to the following procedure:

> 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

---

[4]Ibid., p. 457.

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

[6]Ibid.

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.[7]

Method II. Rotary Platform Double Head; Strength Difference Evaluation

The Taber Abraser, standard research Model E-4010, with vacuum pick-up attachment Model 100-108 was used in this test method. The abraser arms applied a load of 500 grams per wheel against the test specimen. The wheels used were two pairs of vitrified base wheels, of calibrade H-38 type. The pairs were alternated in use so that one half of each set of specimens was abraded with one pair of wheels, and the remaining half was abraded with the other pair. Wheels were brushed periodically to remove lint.[8]

Three 6 inch square test specimens were taken from each sheet, from areas not representing the same warp or filling yarns. The warp and filling directions were marked. A 3/16 inch hole was cut in the center of each specimen by means of a template, and a die. Test specimens were mounted on the rubber mat of the specimen holder and excess fabric was not trimmed away from the bottom of the ring clamp. The face surface of each specimen was abraded for ten cycles at the rate of 70 revolutions per minute.[9]

After the ten revolutions of abrasion were completed the specimens

---

[7]Ibid.

[8]Ibid., pp. 38-39.

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

were marked as illustrated in Figure 2 for the succeeding step in the test procedure. The breaking strength was determined by the procedure described in the Manual of Procedures of the regional project 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 6 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.[10]

Determination of the percent loss in breaking strength was calculated by the following formula:

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

Where O = breaking strength before abrasion, and

A = breaking strength after abrasion

The residual breaking strength was determined from the average of the results obtained from the specimen tested in each of the warp and filling directions and was reported separately to the nearest 0.1 pound.[11]

Method III. Rotary Platform Double Head; Occurrence of Yarn Breakdown Evaluation

This test method employed the same type of instrument, load, and abrasive surface used in the preceding strength difference test method.

---

[10] Ibid., p. 42.

[11] Ibid., p. 41.

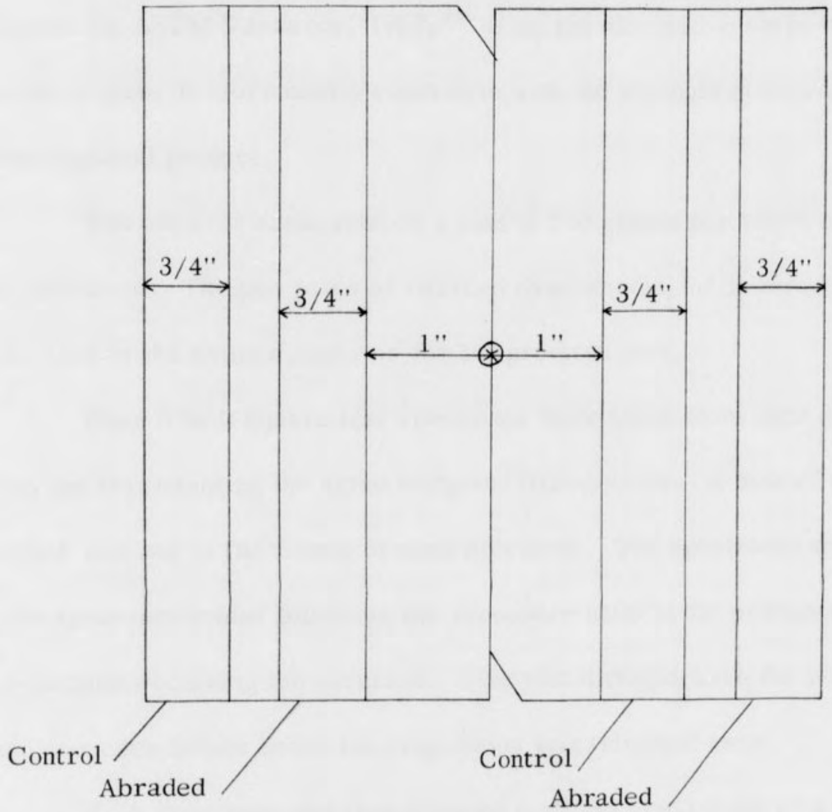


FIGURE 2.

PLACEMENT OF TEST SPECIMENS FOR
STRENGTH DIFFERENCE EVALUATION
OF TABER ABRASION

The Taber Abraser standard research model E-4010 with vacuum pick-up attachment was used in this test method. The procedure for this test followed the ASTM Standards, 1962,[12] using the alternative steps which appeared to make it more nearly consistent with the strength difference test used in the regional project.

The abraser arms applied a load of 500 grams per wheel against the test specimen. The two pairs of vitrified base wheels, of calibrade H-38 type were used in the same manner as for the previous test.

Four 6 inch square test specimens were taken from each sheet, from areas not representing the same warp and filling yarns. A hole of approximately 1/4 inch was cut in the center of each specimen. The specimens were mounted on the specimen holder following the procedure used in the previous test, the face surface receiving the abrasion. This test differed from the previous one in that the excess fabric below the ring clamp was trimmed away.

Each specimen was then abraded until the appearance of a hole was detected. The specimens were examined at intervals during the test for the appearance of a hole. The test results were reported in terms of the number of cycles of abrasion necessary to produce a hole in the specimen. A hole was defined as the occurrence of a break in both a warp yarn and a filling yarn at the point where they crossed.

---

[12] ASTM, *op. cit.*, pp. 473-478.

IV. ANALYSIS OF DATA

The data used in analyzing the effects of treatment on the different cotton types were obtained from the program used for the regional project.

An analysis of variance was the statistical procedure used to indicate the significance of differences in the cottons of long and short staple length, and of low and high strength. Two levels of significance, the five per cent level and the one per cent level, were used.

Correlation coefficients between abrasion tests and the corresponding tear resistance tests were calculated by means of the formula

$$r_{x_1x_2} = \frac{\Sigma\, x_1x_2}{\sqrt{\Sigma\, x_1 \Sigma x_2}}$$

Tests of significance of the correlation coefficients were determined using the t statistic. The formula for this statistic is

$$t = \frac{r_{x_1x_2}\sqrt{N - 2}}{\sqrt{1 - r^2{x_1x_2}}}$$

CHAPTER IV

PRESENTATION OF DATA

The major objective of this thesis was to determine the effect of two fiber properties, staple length and strength, on the abrasion resistance of selected cotton sheetings. Three methods of abrasion testing, (1) flexing and abrasion, (2) strength difference, and (3) occurrence of yarn breakdown, were used to evaluate the abrasion resistance. A second objective of the thesis was to compare these three methods of measuring abrasion resistance as an indication of their value in predicting the wearing quality of selected cotton sheetings.

I. DISCUSSION OF RESULTS FOR THE EIGHT COTTONS

Three sheets from each of the eight cotton types which underwent use and laundering treatment were withdrawn for testing following the control, fifth, and fifteenth laundering intervals. Two sheets from each cotton type which underwent the laundering only treatment were withdrawn for testing at the control, fifth, and fifteenth laundering intervals. Data were compiled for the abrasion resistance measurements on North Carolina sheets using the flexing and abrasion, and the strength difference methods. These measurements were made at other experiment stations. For this study abrasion resistance measurements were made on the North Carolina sheets using the occurrence of yarn breakdown method. The means of each of the abrasion resistance tests for each cotton type undergoing use and laundering are presented in Table I. The means for the laundered only sheets are compiled in Table II.

Warp and filling measurements were obtained by the flexing and abrasion method, and the strength difference method. The occurrence of yarn breakdown method resulted in single measurements which represented the destruction of yarns in both warp and filling directions.

Control Interval

Prior to laundering or use, the cottons were tested by each abrasion test method. The results indicated substantial differences among test methods. No one cotton was most resistant or least resistant at several intervals, or in different tests.

The results of the flexing and abrasion method, reported in number of flexings required to produce a break, indicated that cotton 4 was least resistant in both warp and filling directions. Cotton 2 was most resistant in the warp direction, and cotton 1 in the filling. In general the filling direction results were slightly higher than results for the warp direction.

Results of the strength difference method indicated small unpredictable changes. These results were reported as the per cent difference in breaking strength between an unabraded and an abraded sample. Warp direction yarns exhibited general increases in breaking strength, indicating increased abrasion resistance. The increases of the filling yarns were smaller.

Results of the occurrence of yarn breakdown method were reported in number of cycles required to produce a hole. Cotton 5 was lowest in abrasion

TABLE I

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)		Occurrence of yarn breakdown (Cycles)
	Warp	Filling	Warp	Filling	
Control interval					
1	672	1095	+3.4	-2.6	1374
2	1097	994	-1.8	-1.1	1441
3	864	868	+1.4	+0.4	1434
4	637	682	+3.2	-1.4	1465
5	644	695	+3.5	-1.4	1327
6	880	980	+1.9	+2.6	1409
7	726	741	+1.9	+0.6	1765
8	753	821	-1.9	+2.6	1666
Fifth interval					
1	2126	3534	+0.5	-0.5	960
2	2217	3201	+0.7	+1.1	1035
3	1389	2216	+0.9	+2.4	1015
4	1720	2062	+4.0	+0.6	984
5	1014	1944	-0.2	-1.3	1215
6	1755	2152	+2.4	-0.1	1221
7	1823	2691	-1.9	-1.0	1204
8	1742	2355	+1.0	-1.5	1155
Fifteenth interval					
1	1799	2718	-2.0	-3.0	1088
2	1783	3023	+3.8	+2.3	1110
3	1179	1776	-3.0	-0.8	1184
4	1350	2013	-1.4	-0.2	1216
5	1678	2513	-0.7	-0.6	1472
6	853	1482	+4.1	-0.5	1531
7	878	1280	-1.5	-2.0	1747
8	1120	1928	+2.0	+2.2	1789

TABLE II

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

Cottons	Stoll abrasion (Flexings)		Strength difference (Per cent change)		Occurrence of yarn breakdown (Cycles)
	Warp	Filling	Warp	Filling	
Control interval					
1	672	1095	+3.4	-2.6	1374
2	1097	994	-1.8	-1.1	1441
3	864	868	+1.4	+0.4	1434
4	637	682	+3.2	-1.4	1465
5	644	695	+3.5	-1.4	1327
6	880	980	+1.9	+2.6	1409
7	726	741	+1.9	+0.6	1765
8	753	821	-1.9	+2.6	1666
Fifth interval					
1	830	798	-0.4	-0.8	1516
2	814	896	-2.8	-4.4	1677
3	717	804	-1.8	-0.3	1793
4	668	638	-1.4	+1.9	1856
5	1276	1596	-0.5	-0.2	1954
6	1568	1260	-2.7	-2.8	1769
7	870	1056	-2.6	-2.4	1856
8	1121	1071	+1.4	-3.2	1867
Fifteenth interval					
1	712	708	+1.0	-4.8	1416
2	596	636	+3.4	+1.5	1528
3	576	683	-4.0	+3.6	1648
4	533	602	-4.1	+0.9	1658
5	623	1052	-2.8	+0.3	1722
6	580	712	-0.2	-4.0	1769
7	628	712	-7.6	-2.7	1856
8	532	606	-1.4	-5.1	1867

resistance, while cotton 7 was highest.

Fifth Interval

The used and laundered cottons showed increased abrasion resistance after five launderings using the flexing and abrasion method. General results for filling direction tests were higher than those for warp direction tests. The laundered only cotton increased slightly in abrasion resistance at the fifth interval, but the changes were not as great as those for the use and laundering treatment.

Results of the strength difference method again produced varied results. The majority of the used and laundered cottons increased in abrasion resistance at the fifth interval. Almost all the laundered only cottons decreased in abrasion resistance, and only cottons 4 and 8 showed increases.

The results of the occurrence of yarn breakdown method generally indicated that abrasion resistance increased from cotton 1 through cotton 8. Measurements of used and laundered cottons showed a decrease in abrasion resistance. The laundered only cottons showed a marked increase in resistance.

Fifteenth Interval

There was a general decrease from the fifth interval in the abrasion resistance of both used and laundered, and laundered only cottons using the flexing and abrasion method. The trend appeared to indicate an initial increase after five launderings, and gradual decreases afterward. The laundered only cotton measurements were generally lower than those obtained at the control interval. In the warp direction the results indicated that cotton 8 was least abrasion resistant, and cotton 1 was most resistant.

The results of the strength difference method followed no apparent trend at the fifteenth interval. The range of measurements at the fifteenth interval encompassed both the most resistance and the least resistance obtained using this test method. The -7.6 per cent difference of cotton 7 undergoing the laundering only treatment was the least resistant measure obtained. The +4.1 per cent difference of cotton 6 undergoing the use and laundering treatment was the most resistant.

Using the occurrence of yarn breakdown method, the used and laundered cottons increased in abrasion resistance over the measures obtained at the fifth interval, but generally were still below those obtained at the control interval. The laundered only cottons decreased in abrasion resistance from the measurements at the fifth interval, but were still generally higher than the control interval measurements. For both groups the resistance increased steadily from cotton 1 through cotton 8.

II. DISCUSSION OF RESULTS FOR FIBER PROPERTY GROUPS

The means of the eight cotton types were classified into the following fiber property groups for the analysis of data pertaining to this study:

1. Short staple: Cottons 1, 2, 3, and 4.
2. Long staple: Cottons 5, 6, 7, and 8.
3. Low strength: Cottons 1, 2, 5, and 6.
4. High strength: Cottons 3, 4, 7, and 8.

Flexing and Abrasion Method

The results of the flexing and abrasion method indicated a general increase in abrasion resistance after five launderings, with those undergoing use and laundering exhibiting the sharpest increase. The abrasion resistance decreased after fifteen launderings. The cottons which were most resistant to abrasion originally, generally maintained their superior resistance at all intervals. The property group means, and the per cent changes are presented in Table III. A graphic presentation of the per cent changes for used and laundered cottons is found in Figure 3, and a similar presentation of the laundered only cottons is found in Figure 4.

At the control, or 0 interval, the long staple warp yarns and the high strength warp yarns were least resistant to abrasion. The most resistance to abrasion was shown by the short staple filling yarns and the low strength filling yarns.

After five launderings, the results ranged from a +111 per cent to a +203 per cent change for used and laundered cottons. The long staple warp yarns and the low strength warp yarns were least resistant; the short staple filling yarns and the high strength filling yarns were most resistant to abrasion. The laundered only cottons ranged in abrasion resistance from a -14 per cent decrease to a +54 per cent increase. The short staple filling yarns were least abrasion resistant, while the long staple filling yarns and the low strength warp yarns were most resistant.

There was a decline in the abrasion resistance of all cotton at the

TABLE III

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

	0 Interval		5th Interval		15th Interval	
	W	F	W	F	W	F
USED AND LAUNDERED						
Length						
Short staple	818	910	1863	2754	1528	2382
Per cent change			+128	+203	+87	+161
Long staple	751	809	1584	2285	1132	1801
Per cent change			+111	+182	+51	+123
Strength						
Low strength	823	941	1778	2708	1528	2434
Per cent change			+116	+188	+86	+159
High strength	745	778	1669	2331	1132	1749
Per cent change			+124	+200	+52	+125
LAUNDERED ONLY						
Length						
Short staple	818	910	757	784	604	657
Per cent change			-7	-14	-26	-28
Long staple	751	809	1029	1246	591	771
Per cent change			+37	+54	-21	-5
Strength						
Low strength	823	941	1122	1138	628	777
Per cent change			+36	+21	-24	-17
High strength	745	778	844	892	567	651
Per cent change			+13	+15	-24	-16

[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

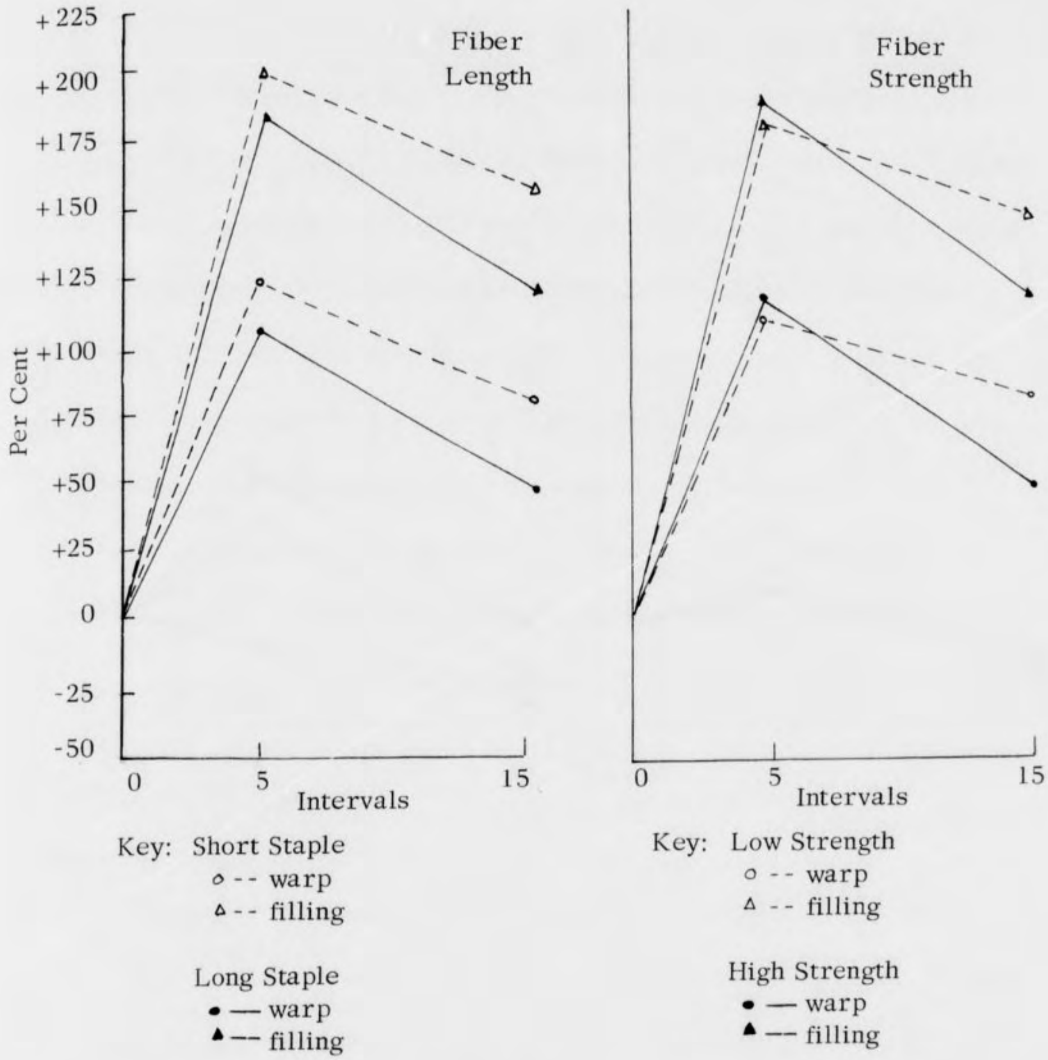


FIGURE 3

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

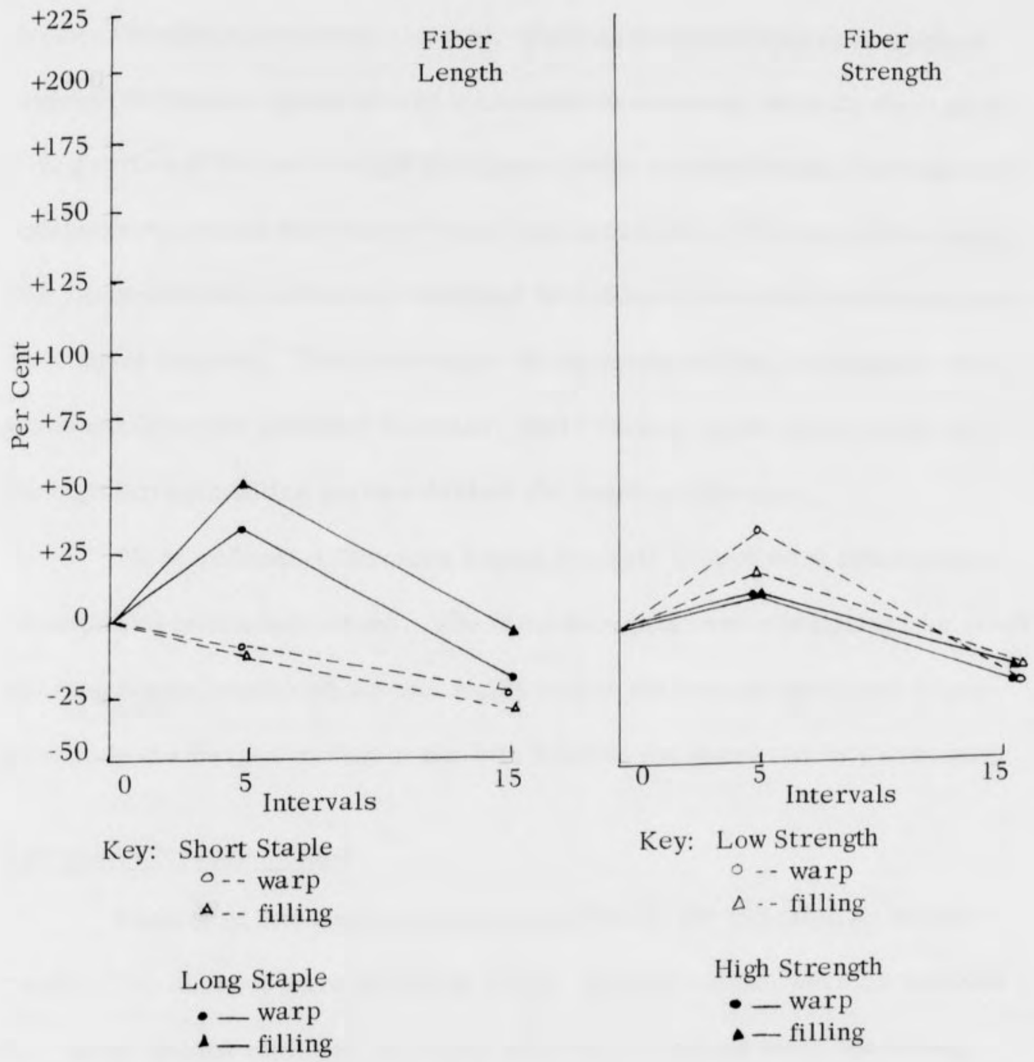


FIGURE 4

MEAN PER CENT CHANGES IN STOLL FLEX ABRASION RESISTANCE OF LAUNDERED ONLY COTTONS GROUPED ACCORDING TO FIBER PROPERTIES fifteenth laundering interval. The resistance for used and laundered cottons was greater than that at the control interval. The long staple warp yarns and the high strength warp yarns appeared to be least abrasion resistant, while the short staple filling yarns and the low strength filling yarns were most resistant. The range for both property groups was from a +51 per cent increase to a +162 per cent increase. The laundered only cottons all exhibited decreases in abrasion resistance from the control interval. The short staple filling yarns and the low strength warp yarns exhibited the greatest decrease, while the long staple filling yarns and the high strength filling yarns exhibited the smallest decrease.

No significant differences among property groups were indicated for the used and laundered cottons. The difference in abrasion resistance for short and long staple length cottons was significant at the five per cent level of probability in the warp direction at the fifth interval for laundered only cottons.

Strength Difference Method

Results of this method varied considerably and indicated no definite trends. The changes were generally slight, and fluctuations were not systematic. Some cottons exhibited increased abrasion resistance after laundering, while others exhibited decreases. The property group means are presented in Table IV. A graphic presentation of the per cent differences is shown in Figure 5 for used and laundered cottons, and in Figure 6 for laundered only cottons.

The changes in the control interval samples were small. The short staple filling yarns as well as the low strength filling yarns were least abrasion resistant, while the short staple warp yarns and the low strength warp yarns

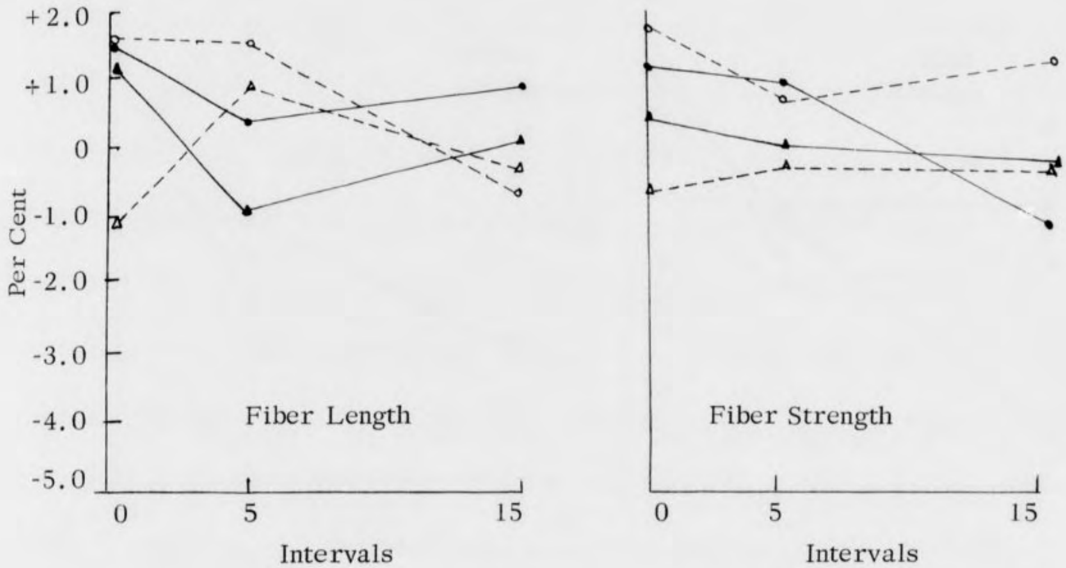
TABLE IV

MEAN PER CENT STRENGTH DIFFERENCE EVALUATION OF ABRASION RESISTANCE AFTER LAUNDERING GROUPED ACCORDING TO FIBER PROPERTIES[a]

	0 interval		5th interval		15th interval	
	Warp	Filling	Warp	Filling	Warp	Filling
USED AND LAUNDERED						
Length						
Short staple	+1.5	-1.2	+ 1.5	+0.9	-0.6	-0.3
Long staple	+1.4	+1.1	+ 0.3	-1.0	+1.0	+0.1
Strength						
Low strength	+1.7	-0.6	+ 0.8	-0.2	+1.3	-0.1
High strength	+1.2	+0.5	+ 1.0	+0.1	-1.0	-0.1
LAUNDERED ONLY						
Length						
Short staple	+1.5	-1.2	-1.6	-0.9	-0.9	+0.3
Long staple	+1.4	+1.1	-1.1	-2.2	-3.0	-2.9
Strength						
Low strength	+1.7	-0.6	-1.6	-2.0	+0.3	-1.7
High strength	+1.2	+0.5	-1.1	-1.0	-4.3	-0.8

[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



Key: Short Staple
- ○ -- warp
- △ -- filling

Long Staple
- ● — warp
- ▲ — filling

Key: Low Strength
- ○ -- warp
- △ -- filling

High Strength
- ● — warp
- ▲ — filling

FIGURE 5

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

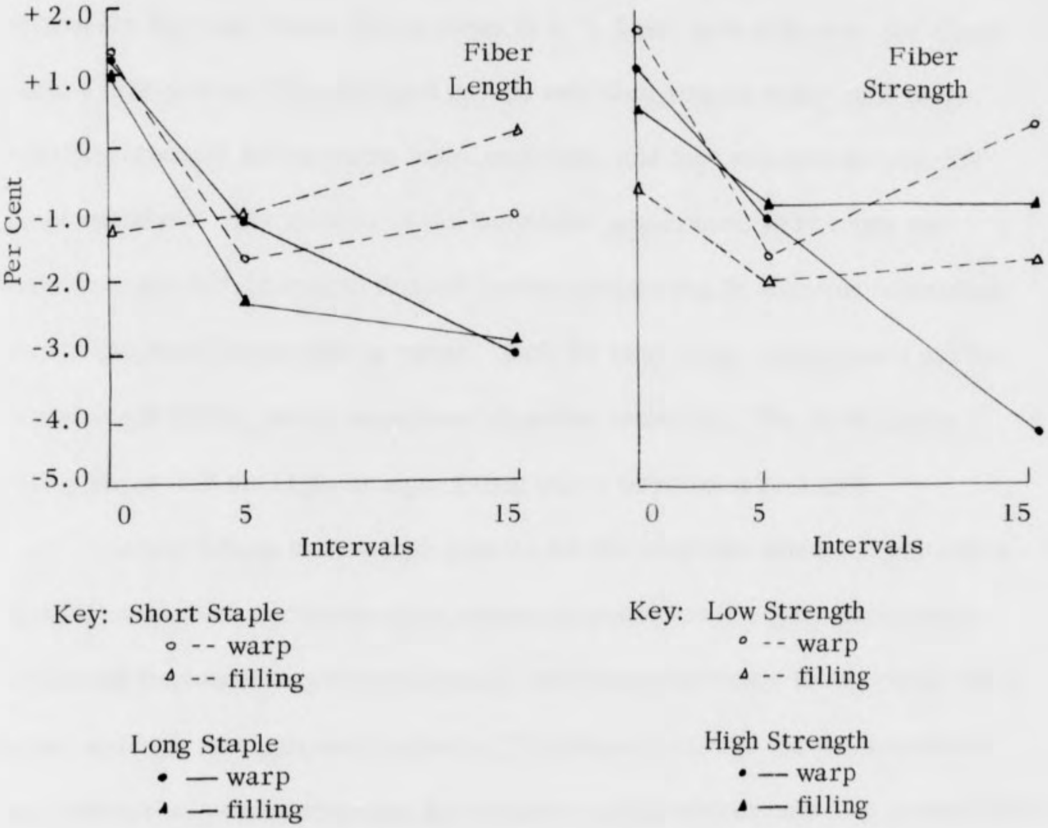


FIGURE 6

MEAN PER CENT DIFFERENCES IN STRENGTH DIFFERENCE EVALUATION OF ABRASION RESISTANCE OF LAUNDERED ONLY COTTONS GROUPED ACCORDING TO FIBER PROPERTIES were the most resistant.

At the fifth laundering interval, results ranged from a -1.0 per cent difference for long staple filling yarns to a +1.5 per cent difference for short staple warp yarns. The strength groups exhibited results within this range, with low strength filling yarns least resistant, and high strength warp yarns most resistant. The results of the laundered only cottons were more consistent at the fifth interval, with all cottons decreasing in abrasion resistance except the short staple filling yarns. Both the long staple filling yarns and the low strength filling yarns were least abrasion resistant. The short staple filling yarns and the high strength filling yarns were most resistant.

After fifteen launderings results for the used and laundered cottons indicated some distinct increases in abrasion resistance (the long staple warp yarns and the low strength warp yarns), and some decreases (short staple warp yarns and high strength warp yarns). The range of results for the laundered only cottons was wider than that for the used and laundered ones. In general the short staple cottons and the low strength cottons increased in abrasion resistance, while the long staple cottons and the high strength cottons decreased.

The strength difference method produced no significant differences in the abrasion performance of different property groups of cottons.

Occurrence of Yarn Breakdown Method

The test results of the yarn breakdown method of evaluating abrasion resistance were more consistent than those of the previous test. The trend of the used and laundered cottons differed from that of the laundered only cottons distinctly at the fifth interval. The used and laundered cottons decreased in abrasion resistance at the fifth laundering interval and increased sharply at the fifteenth interval. The laundered only cottons increased in abrasion resistance after five launderings, and maintained the general increase after fifteen launderings. In Table V the property group means and per cent changes are presented. The per cent changes for the used and laundered, and laundered only cottons are presented in graphs in Figure 7.

The control interval results indicated that the short staple cottons were least resistant to abrasion. The high strength cottons were most resistant.

The used and laundered cottons decreased in abrasion resistance after five launderings. The short staple cottons and the high strength cottons were least resistant. The long staple cottons and the low strength cottons were most resistant. The per cent changes ranged from -31 per cent to -20 per cent. The laundered only cottons increased in resistance. Both low and high strength cottons increased in resistance more than the staple length groups.

The used and laundered cottons increased in abrasion resistance at the fifteenth interval over the fifth interval. The results ranged from a -20 per cent change to a +6 per cent change. The greatest increase was shown by the long staple cottons. The least resistance was shown by the short staple cottons. Results for both strength groups fell in the middle of the range. The laundered only cottons decreased slightly in abrasion resistance from the fifth interval. The range at the fifteenth interval was smaller than that for the used and

TABLE V

MEAN OF TABER ABRASION RESISTANCE USING OCCURRENCE OF YARN BREAKDOWN METHOD AND PER CENT CHANGES AFTER LAUNDERING GROUPED ACCORDING TO FIBER PROPERTIES[a]

	0 interval	5th interval	15th interval
USED AND LAUNDERED			
Length			
Short staple	1429	998	1149
Per cent change		-30	-20
Long staple	1542	1199	1634
Per cent change		-22	+6
Strength			
Low strength	1388	1108	1300
Per cent change		-20	-6
High strength	1583	1089	1484
Per cent change		-31	-6
LAUNDERED ONLY			
Length			
Short staple	1429	1711	1563
Per cent change		+20	+9
Long staple	1542	1862	1803
Per cent change		+21	+17
Strength			
Low strength	1388	1729	1609
Per cent change		+25	+16
High strength	1583	1843	1757
Per cent change		+16	+11

[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

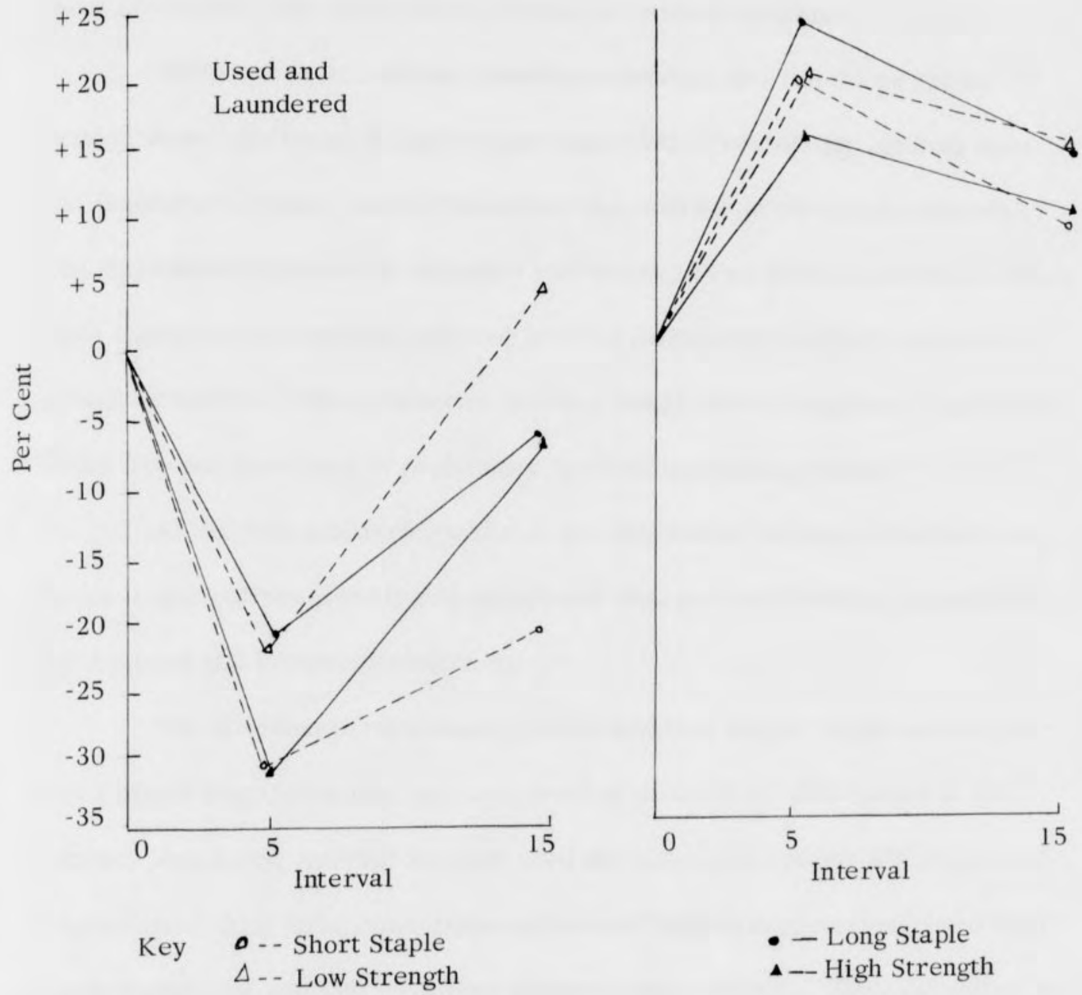


FIGURE 7

MEAN PER CENT CHANGES IN OCCURRENCE OF YARN BREAKDOWN
EVALUATION OF ABRASION RESISTANCE OF ALL COTTONS
GROUPED ACCORDING TO FIBER PROPERTIES

laundered cottons. The long staple cottons and the high strength cottons were most resistant. The short staple cottons were least resistant.

Differences in abrasion resistance between short and long staple cottons were significant at the five per cent level of probability for both used and laundered cottons, and for laundered only cottons at the control interval. The differences between the abrasion resistance of low and high strength cottons were highly significant (one per cent level of probability) for both treatment groups of cottons. The interaction between length and strength was significant at the five per cent level of probability for both treatment groups.

At the fifth laundering interval the differences between short and long staple length cottons were highly significant (one per cent level of probability) for the used and laundered treatment.

The abrasion performance of short and long staple length cottons produced highly significant (one per cent level of probability) differences at the fifteenth laundering interval for both used and laundered cottons and laundered only cottons. The differences between low and high strength cottons were also highly significant for both treatment groups at this interval. The interaction between length and strength was significant at the five per cent level of probability for the used and laundered cottons at the fifteenth interval.

III. COMPARISON OF THE THREE METHODS

The previous discussion indicates differences in the results of the three methods of testing abrasion resistance. These differences were detected in over-all measurements from laundering interval to laundering interval, and in the different evaluations of fiber property groups at each testing interval. The flexing and abrasion method and the occurrence of yarn breakdown method appeared to be the most related methods. Although results of these methods indicated the same general trend, a difference between the two methods was noted at the fifth interval for the used and laundered cottons. At this interval the results of the occurrence of yarn breakdown method indicated a considerable decrease in the abrasion resistance. The results of the flexing and abrasion method indicated a sizeable increase in resistance for the same cottons. The results of the two methods were more comparable for the laundered only cottons at the fifth interval. The similarities were not evident when comparing the effects of the two methods on fiber property groups.

The results of the strength difference method were not similar to the other two test methods.

The results of each method were compared with the results of tear resistance tests. The tear resistance test was chosen since, as a form of tensile strength test, it might be related to abrasion resistance. Also, this test was sufficiently sensitive to indicate significant differences in performance among fiber property groups. The comparison revealed the same increase in test results for used and laundered cottons after five intervals of laundering, then gradual decreases at the fifteenth interval. The sequence of fiber groups in resistance to tearing was similar to the sequence in abrasion resistance in some few instances.

The results of each test at each laundering interval in both used and laundered and laundered only treatments were compared to the corresponding tear resistance test results in a product moment correlation coefficient. When a test of significance was performed for each correlation coefficient, there were no significant correlations.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

I. SUMMARY

Cotton is one of the most versatile and extensively used fibers known. Investigation and research of cotton fiber properties, and the relationship of these properties to fabric performance are important to cotton growers, manufacturers, and consumers. Since little research has been conducted in this area, the Home Economics Research Personnel in six southern states undertook the Southern Regional Textile Project of the Agricultural Research Service of the United States Department of Agriculture, to aid in meeting the need for information. Under investigation at the time of this study was the relationship of the fiber properties, staple length and strength, to end-product performance.

To investigate the effect of the fiber properties cotton sheetings were manufactured for the regional project. There were two treatments, (1) use and laundering, and (2) laundering only. Three sheets of each cotton type were withdrawn and laboratory tests were performed before treatment was applied. These sheets were designated as the control interval. Three sheets of each cotton type undergoing use and laundering were withdrawn, and two sheets of each cotton type undergoing laundering only were withdrawn for testing after the fifth and fifteenth laundering 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 flexing and abrasion method using the Stoll Weartester, and (2) the strength difference method using the Taber Abraser. Each test produced results of considerable variation. It was thought that a third test, the yarn breakdown method using the Taber Abraser, might measure more effectively the abrasion resistance of the cotton sheetings. This method was selected for its simple operation and for its probable similarity of abrasive action to the abrasive action incurred in the normal usage of sheets.

The objectives of this study were:

1. To determine the effect of fiber strength and fiber length on abrasion resistance of selected cotton sheetings by the occurrence of yarn breakdown method using the Taber Abraser.

2. To compile the data of the abrasion resistance of selected cotton sheetings as measured by the strength difference method using the Taber Abraser, and by the Stoll Weartester, as indicated by previous research.

3. To compare these three methods of abrasion resistance, as an indication of their value in predicting the wearing quality of selected cotton sheetings.

The sample used in this study consisted of the cotton sheetings used at the North Carolina station. Data were compiled from the measurements of the flexing and abrasion completed at the Alabama station, and the strength difference method completed at the Louisiana station. Abrasion resistance measurements were made for this study using a third method, the occurrence of yarn breakdown. Four samples from each sheet were tested. The number of cycles required to produce a hole was used as the measure to determine abrasion resistance.

An analysis of variance was made to determine the effect of the fiber properties, staple length and strength, on abrasion resistance as measured by each of the three methods. Correlation coefficients were computed comparing results of each abrasion resistance method with results of tear resistance tests. This was used to indicate the effectiveness of the methods.

The Effect of Fiber Properties Staple Length and Strength on Abrasion Resistance

There were wide and unpredictable fluctuations in the results compiled using the strength difference method. This may have been due in part to the small number of cycles of abrasion (ten) used in the test. The amount of abrasion damage thus produced was small, making evaluation of abrasion performance difficult. Different fiber property groups were superior in abrasion resistance at different intervals. There were no significant differences in the abrasion resistance of the fiber properties.

The results of the flexing and abrasion method were more consistent than the results of the strength difference method. Short staple filling yarns, and low strength filling yarns were most resistant at almost all intervals for the used and laundered cottons. Long staple yarns and low strength yarns were most resistant for the laundered only cottons. Differences between fiber properties were significant only for staple length of laundered only cottons in the warp direction at the fifth laundering interval.

The occurrence of yarn breakdown method also produced more consistent results than the strength difference method. The long staple length cottons were more resistant than the short staple length cottons for both treatment groups at all intervals. The high strength cottons were more resistant than low strength cottons for both treatment groups at all intervals except for used and laundered cottons at the fifth interval.

The results of the occurrence of yarn breakdown method indicated several significant differences, whereas results for the other test methods were not generally significant. Highly significant differences (one per cent level of probability) were noted as follows:

1. Between low and high strength cottons at the control interval.
2. Between short and long staple length cottons at the fifth interval for used and laundered cottons.
3. Between short and long staple length cottons at the fifteenth interval for both treatment groups.
4. Between low and high strength cottons at the fifteenth interval for both treatment groups.

Significant differences (five per cent level of probability) were noted as follows:

1. Between short and long staple length cottons at the control interval.
2. For the interaction between strength and length at the control interval.
3. For the interaction between strength and length at the fifteenth interval for the used and laundered cottons.

Comparison of the Three Methods of Measuring Abrasion Resistance

Although the strength difference method of evaluating abrasion resistance did not produce results similar to the other methods, the flexing and abrasion method and the occurrence of yarn breakdown method did show some relationship. Results of these tests indicated the same general trend except at the fifth interval in the used and laundered cottons. These increased in resistance when tested by the flexing and abrasion method, and decreased when tested by the occurrence of yarn breakdown method.

The rise in abrasion resistance after five launderings using the flexing and abrasion method may be related to the observations noted by the research reviewed. Zurek and Szemik[1] found that the abraded fibers formed a brush or mat which deterred further abrasion damage. Chippindale[2] also mentioned fiber ends which appeared with abrasion and tended to increase abrasion resistance as long as they remained in the fabric.

Differences in the treatment is another factor influencing abrasion resistance. The used and laundered cottons showed more increase in resistance than the laundered only cottons. Apparently use contributed to initial abrasion resistance. This too may have been due to the loosening of fibers incurred in

---

[1]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.

[2]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. 445-463.

use which would result in the formation of a brush or a matting of fibers. The decrease in abrasion resistance after fifteen launderings may have been due to more pronounced fabric destruction and to the removal of fibers from the fabric.

The results obtained using the occurrence of yarn breakdown method may have been due to several factors. The trend of the results for laundered only cottons was similar to that of the flexing and abrasion method. Chippindale reported differences in the abrasion performance encountered in use and that encountered in laundering. The swelling and loosening he described as characteristic of laundering abrasion may account for the initial increase of the laundered only cottons after the fifth interval, with gradual decreases after the fifteenth interval. The decrease in abrasion resistance of the used and laundered cottons after the fifth interval may be related to the observations of Chippindale also. He reported that in the dry state the fiber surfaces were rubbed and eroded away in the early stages of abrasive destruction. It is likely that the initial abrasive action caused eroding of fiber surfaces. This may have led to the decrease which was later (after fifteen launderings) offset somewhat by formation of a brush or mat of fibers.

Results obtained from each abrasion test method were compared to the corresponding tear resistance test results to determine the existence of a relationship between various abrasion tests and other serviceability tests.

II. CONCLUSIONS

The results of this study indicated the following conclusions:

1. The three methods of measuring abrasion resistance produced varied results, from laundering interval to laundering interval and within each laundering interval.

2. The occurrence of yarn breakdown method was the most sensitive test in detecting differences in abrasion resistance among cottons varying in staple length and strength.

3. The flexing and abrasion method, and the occurrence of yarn breakdown method revealed differences in abrasion resistance between treatment groups.

4. The measurements produced by the three methods of testing abrasion resistance were not closely related to tear resistance measurements.

III. RECOMMENDATIONS FOR FURTHER STUDY

Further investigation of the effect of fiber length and strength on abrasion resistance, and of the methods of measuring abrasion resistance would be desirable in establishing better understanding of the wearing performance of textile fabrics. It would also be desirable in establishing the criteria involved in laboratory evaluation of abrasion resistance. The following recommendations are made for further study:

1. A study be conducted of the abrasion resistance of the cotton sheetings through the sixtieth laundering interval. This would aid in establishing trends more definitely and in revealing differences in cotton types throughout their wear life.

2. A study be conducted using the microscopic techniques for evaluating abrasion resistance and extent of abrasion damage of the cotton sheetings. This would indicate similarities and differences in wear test abrasion and in laboratory abrasion.

3. A study be conducted to determine the correlation of abrasion resistance measurements with several other test measurements, such as fabric weight, breaking strength, and viscosity, since serviceability is recognized to be a composite of many factors.

BIBLIOGRAPHY

BIBLIOGRAPHY

A. BOOKS

ASTM Committee D-13. ASTM Standards on Textile Materials. Philadelphia: American Society for Testing Materials, 1963.

Kaswell, Ernest R. Textile Fibers, Yarns, and Fabrics. New York: Reinhold Publishing Corporation, 1953.

__________. Wellington Sears Handbook of Industrial Textiles. New York: Wellington Sears Company, Inc., 1963.

Meredith, Ed. R., and J. W. S. Hearle. Physical Methods of Investigating Textiles. New York: Textile Book Publishers, Inc., 1959.

B. PUBLICATIONS OF THE GOVERNMENT AND OTHER ORGANIZATIONS

Backer, Captain Stanley, QMC. "Increasing the Wear Life of Army Textiles Through Research," Proceedings of the Conference on Quartermaster Textile Research. New York: Textile Research Institute, 1945.

Textile Fibers and Their Properties. Prepared by Burlington Industries, Inc. Greensboro, North Carolina: Burlington Industries, Inc., 1963.

C. PERIODICALS

Backer, Stanley. "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. 7:453-468, July, 1951.

Chippindale, P. "Wear, Abrasion, and Laundering of Cotton Fabrics. Part I: Wear of Fabrics During Actual Service and Laundering," Journal of the Textile Institute, Vol. 54:T445-T448, November, 1963.

__________. "Wear, Abrasion, and Laundering of Cotton Fabrics. Part II: Wear of Fabrics on Laboratory Test Machines," Journal of the Textile Institute, Vol. 54:T460-T463, November, 1963.

deGruy, Ines V., Jarrell H. Carra, Verne W. Tripp, and Mary L. Rollins. "Microscopical Observations of Abrasion Phenomena in Cotton," Textile Research Journal, Vol. 32, No. 11:873-882, November, 1962.

Gabliardi, D. D., and A. C. Nuessle. "The Relation between Fiber Properties and Apparent Abrasion Resistance," American Dyestuff Reporter, Vol. 40, No. 13:409-415, June 25, 1951.

Hamburger, W. G., and H. N. Lee. "A Study of Lining Fabric Abrasion," Rayon Textile Monthly, Vol. 26, No. 7:93-96, July, 1945.

__________. "A Study of Lining Fabric Abrasion," Rayon Textile Monthly, Vol. 26, No. 8:61-64, August, 1945.

Hayes, Margaret B. "Physical Properties of 26 Work Fabrics," Rayon Textile Monthly, Vol. 25, No. 1:73-74, January, 1944.

Jackson, D. L. C. "Wear Testing," Textile Journal of Australia, Vol. 25, No. 5:435-438, July 20, 1950.

McNally, John P., and Frank A. McCord. "Cotton Quality Study, Part V: Resistance to Abrasion," Textile Research Journal, Vol. 30, No. 10:715-751, October, 1960.

Platt, Milton M. "Mechanics of Elastic Performance of Textile Materials, Part IV: Some Aspects of Stress Analysis of Textile Structures--Staple-Fiber Yarns," Textile Research Journal, Vol. 20, No. 8:519-538, August, 1950.

Pollitt, E. "Factors Affecting the Performance in Use of Cotton Fabrics," The Textile Weekly, Vol. 59, No. 1645:583-588, September 25, 1959.

Schiefer, Herbert F., and Carl W. Werntz. "Interpretation of Tests for Resistance to Abrasion of Textiles," Textile Research Journal, Vol. 22, No. 1:1-12, January, 1952.

Sluser, Dr. H. "Abrasion Tests for Textiles," Textile Journal of Australia, Vol. 30, No. 9:1086-1090, November 21, 1955, from "Textil Rundschau," Vol. 9:572-579.

Standing Consultative Conference on Textile Research Associations. "Final Report on Inter-Laboratory Abrasion Tests," Journal of the Textile Institute (Proceedings), Vol. 55, No. 1:P1-P12, April, 1964.

Weiner, Louis I., and Clarence J. Pope. "Correlation of Laboratory Abrasion Testers," Textile Research Journal, Vol. 33:761-764, September, 1963.

Zook, Margaret Harris. "The Development of a Reproducible Testing Technique Using the Taber Abraser on Rayon Fabrics," American Dyestuff Reporter, Vo. 39, No. 21:679-685, October 16, 1950.

__________. "Historical Background of Abrasion Testing," American Dyestuff Reporter, Vol. 39, No. 19:625-627, September 18, 1950.

__________. "A Tensioning Device for Use with the Taber Abraser," American Dyestuff Reporter, Vol. 30:745, November 12, 1951.

Zurek, Witold, and Halemn Szemik. "Some Aspects of Abrasion Properties of Cotton Fabrics," Textile Research Journal, Vol. 34, No. 2:143-152, February, 1964.

D. UNPUBLISHED MATERIALS

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