Thomas, Shirley Ann. Appearance and Resilience Characteristics of Selected Carpeting Following Serviceability Testing. (1970) Directed by: Dr. Pauline E. Keeney. pp. 90

The purpose of this study was to investigate the differences in compressional resilience and the changes in appearance of selected carpeting following a serviceability test. Two types of investigation were used to collect the necessary data: (1) a laboratory test to determine the compressional resilience of the carpet samples, and (2) a subjective test to evaluate changes in appearance of the carpet samples by means of visual examination.

A test carpet of six replicates of 12 selected carpets was used in the serviceability test. The 12 carpet samples were of tufted construction and included three fiber types (wool, acrylic and nylon), two pile types (cut and uncut) and two pile heights (high and low).

Carpet thickness measurements (original, compressed and recovered) were taken to determine compressional resilience of the carpets. An analysis of variance for a 3 x 2 x 2 factorial design was performed on the measurements of compressional resilience prior to and following the serviceability test. The same statistical design was applied to the data obtained in the subjective evaluation of changes in surface appearance.

Prior to serviceability testing differences in compressional resilience were statistically significant at the 0.01 level of probability: (1) between the two pile types; (2) the interaction between fibers and pile heights; and

(3) the triple interaction among fibers, pile heights and pile types. Differences in compressional resilience between pile heights and pile types were significant at the 0.05 level of probability.

Following serviceability testing differences in compressional resilience were statistically significant at the 0.01 level of probability: (1) between the pile types, (2) the interaction between pile types and pile heights, and (3) the triple interaction among fibers, pile types and pile heights. There were no significant differences in compressional resilience prior to or following serviceability testing among the fiber types and between the pile heights.

Twenty-five women participated in the subjective evaluation of changes in appearance of the carpet samples following the serviceability test by comparing visually the surface pile of each sample with control samples. Visual change effects significant at the 0.01 level of probability were: (1) between the pile types, (2) the pile heights, and (3) the interaction between fibers and pile heights. There were no significant differences in the changes in appearance of the three fiber types and the triple interaction among fibers, pile heights and pile types.

APPEARANCE AND RESILIENCE CHARACTERISTICS OF SELECTED CARPETING FOLLOWING SERVICEABILITY TESTING

by

Shirley Ann Thomas

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APPROVAL SHEET

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CHAPTER I

INTRODUCTION

The carpets and rugs currently manufactured are most attractive in appearance and economically represent better values than ever before. Due to the variety of fibers that exist and to the many colors and designs of carpeting available, it is necessary for the consumer to consider carefully the many characteristics that will be important to her in the use of the carpeting. These characteristics relate to the aesthetic or decorative features, the economic investment involved, and the physical properties that pertain to the performance of the carpet during use.

Since carpeting is a major investment in home furnishings, serviceability is a concern of the consumer. There are a number of factors associated with the serviceability of carpeting. The two factors that were given consideration in this study were: (1) fiber content, and (2) construction features that pertain to the surface yarns.

In order for fibers to be used satisfactorily in the surface yarns of a carpet, the fibers should have resilience, luster, length, and strength. Resilience, an inherent property in some fibers, is most essential because it enables carpet pile yarns to resist crushing and matting, thus contributing to the feeling of luxury when walked on and to the retention of original appearance.

A resilient fiber alone does not guarantee carpeting of high quality for the durability of a carpet is also dependent on good construction. Density, pile height, yarn structure and pile type, are all construction features which affect the serviceability and the appearance retention of a carpet. The construction features considered in this study, however, are limited to pile height and to pile type.

THE PROBLEM

Carpets are usually so durable that changes involved in completely "wearing out" require years of normal service. Changes in carpet texture, without significant fiber loss, however, occur from the initial use of the carpet.

This thesis was planned to investigate how the differences in fiber type, pile height, and pile type affected the resilience and appearance of carpeting after a serviceability test. Experimentation was performed on a "wear test carpet" which consisted of six replicates of twelve specially manufactured carpets of three fiber types: wool, acrylic, and nylon. These fibers were those sold in the greatest volume for the surface pile of carpeting for the living area at the time the study was initiated. Each fiber type was manufactured in two pile types (cut and uncut), and with two pile heights (high and low) within each pile type.

In relation to this subject, the following seven hypotheses were established and tested:

Hypothesis 1. There is no significant difference in the resilience between the test carpets made of wool, acrylic and nylon fiber after serviceability testing.

Hypothesis 2. There is no significant difference in the resilience between the carpets of cut and uncut pile after serviceability testing.

Hypothesis 3. There is no significant difference in the resilience between carpets of high and low pile height after serviceability testing.

Hypothesis 4. There is no significant difference in the appearance between the control and tested samples of carpeting made of wool, acrylic, and nylon fibers.

Hypothesis 5. There is no significant difference in the appearance between control and tested samples of cut and uncut pile carpeting.

Hypothesis 6. There is no significant difference in the appearance between control and tested carpet samples of high and low pile height.

Hypothesis 7. There is no significant interaction among the three factors; fibers, pile heights and surface finishes.

The objectives of the study were: (1) to determine the difference in resilience of selected carpeting prior to and following serviceability testing, (2) to compare the resilience of the carpets before and after the serviceability test, and (3) to evaluate the changes in appearance of the carpets after the serviceability test by visually comparing the walked-on samples with samples which received no wear.

DEFINITIONS OF TERMS USED

The following definitions have been included for clarification of terms used throughout the study.

Compression. The pressure, equivalent to 12.48 pounds per square inch, applied to the carpet samples. (In this study a 22 ounce weight plus a 3/8" pressure foot = 12.48 pounds per square inch). The measurements are reported in thousandths of an inch (0.001 inch).

Density. The closeness or compactness of the tufts or surface yarns.

Compressional Resilience. The ratio of the difference between the recovered carpet thickness (C) and the compressed carpet thickness (B), divided by the difference between the original carpet thickness (A) and the compressed carpet thickness (B), expressed as a percentage. For example: percent compressional resilience = $\frac{B-C}{A-B}$ x 100.

Carpet Thickness. The distance between the top of the surface pile and the bottom of the carpet backing.

Pile Height. High or low pile of the surface yarns of a tufted or woven pile floor covering.

Pile Types. The cut or uncut loops forming the surface yarns of a tufted or woven pile floor covering.

Recovery. The ability of the pile yarn to return to its initial configuration after being subjected to forces of distortion, such as repeated "walk-ons".

Test Carpet. The 3 1/2 foot by 15 foot carpet, made of 72 nine inch carpet squares, used in the wear test. The squares were made of (1) three fiber types, (2) two pile types, and (3) two pile heights within each pile type.

Serviceability Test. Term used to indicate the actual floor trial.

Wear. Physical changes which occur in carpet pile when it is walked on. These changes would include, matting, crushing, flattening, fuzzing and untwisting.

Walk-ons. The approximate number of people who walked across the test carpet.

CHAPTER II

REVIEW OF LITERATURE

Although a wide range of tests for assessing the properties of fibers used in the surface yarns of carpeting have been available for a long period of time, it has only been within the last 20 years that carpet research has been considered important in the United States. A logical reason for this might be that carpets were almost entirely manufactured from wool, and to a lesser extent cotton, up until the mid 1940's; thus, the variability of properties experienced was confined to only one or two types of fiber.

Following the introduction of man-made fibers into the carpet industry, it became necessary for laboratory and service tests to predict carpet performance, specifically to estimate the suitability of a particular fiber. British and American, as well as German researchers have written a great deal about the testing processes. Research by each of the three countries have been included in this chapter.

The review of literature is divided into four parts. Part I presents literature related to the tufted carpet industry, including fibers used in the surface yarns of broadloom carpeting. Part II includes literature pertaining to important properties of fibers used in surface yarns of carpeting. Part III includes literature which compares the three types of fibers used in this study. Part IV presents research pertaining to methods used to determine carpet performance.

TUFTED CARPET INDUSTRY

Despite the current slow textile market the growth of the carpet industry during the past two decades has been rapid and constant. The Carpet and Rug Institute reported that broadloom carpet sales were 8 percent higher in 1967 than in 1966.[1] In 1968 and in the first quarter in 1969 the percent gain in sales was even greater. There was a 26.5 percent gain in 1968 over 1967, and an 18 percent gain in the first quarter in 1969 over the first quarter in 1968. Of the types of carpets sold, tufted carpets headed the list in 1968 at 91 percent and were predicted to reach 95 percent by the end of 1970.[2]

The credit for the constant growth has been the success and growth of man-made fibers, in combination with the

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[1]American Carpet Institute, Basic Facts About the Carpet and Rug Industry, (New York 1968 ed.; American Carpet Institute, Inc.) p. 2.

[2]"Changes Dominate Carpet Industry," Modern Textiles Magazine, 50:33, July, 1969.

tufting process. These two technological advances have produced acceptable carpeting at a progressively lower cost thus changing carpeting from a predominantly luxury item to one of practical significance.[3] In addition, the carpet industry's ability to offer carpets in a variety of colors and styles, and to offer constructions that satisfy needs of serviceability has met with wide appeal. Therefore, the "tufted carpet industry has proved to be one of the most dynamic industries within the United States."[4]

Fibers Used in the Face of Carpeting

In 1953 the primary raw materials in the manufacture of carpets were natural fibers. Wool was the dominant fiber used for carpet surface yarns due to a balance of desirable properties.[5] A shortage of wool of carpet quality resulted in an increase in wool prices and made the introduction of man-made fibers into the carpet market a necessity. The development of new man-made fibers and improved modifications of existing fibers did not only contribute to the growth of the carpet industry but also reversed the rank order of fiber consumption within the past four years.

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[3]J. L. Nevin, and R. B. Mumford, "Carpet Fiber Evaluation," Textile Industries, 131:97, February, 1967.

[4]Reg. Burnett, "What Lies Ahead," Modern Textiles Magazine, 50:43, December, 1969.

[5]"Carpet and Rug Progress," Modern Textiles Magazine, 50:52-53, April, 1969.

As late as 1964, wool still headed the list for surface fiber consumption. However, by 1968, natural fibers represented less than 15 percent of the carpet fibers that were being used (wool, 13.2 percent; cotton and others, a total of 0.5 percent).[6] Therefore, man-made fibers, led by nylon filament yarns, comprised slightly more than 85 percent of the market. A breakdown of the fiber types used were rated as shown in Table 1.[7]

As seen by the results in Table 1, polyester fiber and nylon staple gained the most in 1968. Polyester, although not included in this study, has had an unprecedented history of growth and is predicted to reach first place in total consumption during 1970 or 1971.[8]

Nylon filament still was used in greatest quantity as it had been for the past four years. In combination with nylon staple, both types of nylon supplied nearly half the fibers needed for surface yarns of carpeting; thus, nylon emerged as the most important fiber in the carpet industry.

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[6]"Carpet and Rug Progress: Shifts in Fiber Consumption," Modern Textiles Magazine, 50:34, July, 1969.

[7]Ibid.

[8]Amos H. Griffin, "Fibers Marketing," Modern Textiles Magazine, 51:43, January, 1970.

Table 1

BROADLOOM SURFACE FIBER CONSUMPTION IN

1967 and 1968

Fiber	Million 1968	Pounds 1967	Per Cent Change	Per Cent of Total
Nylon Filament	245.0	198.0	+ 23.7	35.4
Nylon Staple	82.6	58.0	+ 42.4	12.0
Acrylics and Modacrylics	165.6	147.0	+ 12.6	24.0
Polypropylene	28.6	26.1	+ 9.5	4.1
Polyester	74.5	35.0	+112.9	10.8
Wool	91.0	84.0	+ 8.3	13.2
Cotton, Rayon, and Others	3.5	8.0	- 56.3	0.5
	690.8	556.1	+ 24.2	100.0

IMPORTANT PROPERTIES OF FIBERS USED IN THE SURFACE PILE OF CARPETING

A great deal of literature has been written stressing the many necessary properties essential for fibers used in surface yarns of carpeting. Angus, a consultant with the Federation of British Carpet Manufacturers, gave a summation of the properties which he designated as most desirable:

durability; resilience; non-soiling; non-burning; decorative value (ability to be dyed satisfactorily); warmth; moth proof;[9]

Resilience and/or crush resistance, strength, and durability were included in a number of sources and were considered to be of major significance to this study. The importance of resilience was summarized by the Monsanto Company in its 1969 book on "Carpet Technology".

Resilience in a carpet fiber is a most important characteristic, for it controls the degree to which the carpet pile will bounce or spring back to its original height after being trod on. Good resilience is a vital ingredient of lasting carpet beauty: the better a carpet can recover from pressure and retain its original thickness, the longer it keeps its brand new look and deep pile under foot.[10]

Crone emphasized the importance of the combination of fiber resilience and strength:

Apart from considerations of colour, the principal feature of a carpet from the customer's point of view is its ability to wear for a long time and reserve its appearance. This infers that the fibres used in the surface yarns must be resilient and strong. These are probably the most important properties for yarns for carpet surfaces....[11]

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[9]G. B. Angus, "Basic Structures and Fibers Used in Carpet Manufacture," Textile Institute and Industry, 3:315, December, 1965.

[10]Chemstrand, A Division of Monsanto Company, "The Manufacture, Styling and Performance Characteristics of Acrilan Carpet made with Monsanto Type 71 Bicomponent Acrylic Carpet Fiber," Carpet Technology, (Decatur, Alabama: Chemstrand, 1969), p. 13.

[11]H. R. Crone, "Fibre Blends as Carpet Surface Yarns," Textile Institute Journal, 43:533, August, 1952.

A number of studies used the words "resilience" and "crush resistance" interchangeably. Within other studies the term crush resistance was used in place of resilience. According to Richardson and Stanley, "crush resistance - one of the most critical properties of a carpet fiber is the ability to retain form under high crushing loads of traffic or furniture."[12]

COMPARISON OF THE THREE FIBER TYPES USED IN THIS STUDY

Wool Fibers

Recognized as the traditional carpet fiber for so many years, wool is still used as a basis of standards for most manufacturers. It has a balance of desirable characteristics; resiliency (natural built-in spring), abrasion resistance, warmth, comfort, styling, and easy dyeability. Due to the above characteristics, wool carpeting has long been known for its warmth, comfort, and beauty. Angus believed that, "even if man-made fibers had every property desirable, the yarns as now produced would fail to give as pleasing surface on carpets as wool."[13]

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[12]Graham Richardson, and Harry Stanley, "How DuPont Developed 501 Filament Nylon for Carpets," Modern Textile Magazine, 43:50, February, 1962.

[13]Angus, op. cit., p. 319.

On the negative side, wool is fairly expensive because the types of wool produced in the United States are not suitable for carpet yarns. Therefore, the fibers must be imported from foreign countries. Although Crone agreed with Angus concerning the many advantages of wool, he also pointed out that wool was not a completely ideal fiber.

> . . . wool, being a natural fibre, is variable in physical and chemical properties, for which allowances must continually be made in the mechanical and chemical processes through which it passes, it is subject to biological attack, being degraded by moth larvae and similar bodies; it is subject to chemical attack and has the inherent weakness that the main structural support in the molecule - the cystine linkage - is readily attacked by several agencies.[14]

Acrylic Fibers

Acrylic fibers have become the second most important fiber for the pile of carpets. They, more than any other man-made fiber, are similar to wool in hand and appearance. Press stated that these fibers are characterized by "high bulk value, good covering power, crush and abrasion resistance equal to wool, and wool-like hand."[15]

Even Angus, hesitant in accepting acrylics as a substitute for wool, pointed out that the acrylic fiber

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[14]Crone, loc. cit.

[15]J. J. Press (editor), Man-Made Textile Encyclopedia (New York: Textile Book Publishers, Inc., 1959). p. 317.

is ". . . as good a synthetic carpet fibre, used 100 percent, as has yet been produced."[16] For these reasons, along with a decline in acrylic prices, it is no wonder that the acrylics have made quite an impact on the residential carpet market.

Although many problems originally existed in regards to the dyeing of acrylics, Burnett indicated that fibers are now readily dyeable in a wide range of shades with certain acrylic fibers having the ability to be dyed different colors in a single dye bath. He also pointed out that although very popular in the residential market, the acrylic fibers will be expanding rapidly into the outdoor and contract market.[17]

Nylon Fibers

Nylon, although off to a slow start in the late 1950's, is the most widely used fiber in today's carpets. It is a very strong and tough fiber which is exceptionally resistant to abrasion and wears almost indefinitely. Present day nylon is also easily dyeable and has good colorfastness, although some problems do exist in regard to sun and atmospheric fading.[18]

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[16] Angus, op. cit., p. 317.

[17] Burnett, "What Lies Ahead?" loc. cit.

[18] George S. Wham, "Performance Requirements For New Textile Products," Modern Textiles Magazine, 48:58, July, 1967.

Due to the success of continuous filament carpet yarns nylon carpeting tends to predominate the low cost end of the market. According to Nevin and Mumford:

> Since filament nylon has the ability to provide a maximum of cover with a minimum use of face yarn, along with its outstanding properties of recovery and durability, a carpet can be produced of good serviceability with a minimum of material cost.[19]

There is discrepancy among authorities concerning resiliency. Although some sources indicate that nylon carpeting shows good crush recovery, others indicate that nylon carpeting tends to mat when heavily walked on. In agreement with the negative viewpoint, Press stated:

> Matting in service can occur in an improperly designed carpet construction because nylon is actually slightly poorer than wool with respect to compressional recovery characteristics. . . .[20]

The most severe deficiency of conventional nylon was that it appeared to soil more rapidly than other carpet fibers. In their study, Nevin and Mumford discussed this major problem:

> Soiling is usually the first factor affecting the appearance of nylon, not because it soils appreciably more, but simply because nylon retains all of its original attributes to a higher degree than the other fibers. Nylon can look soiled before the carpet looks "worn".[21]

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[19] J. L. Nevin, and R. B. Mumford, "Nylon and Prognosis," <u>Modern Textiles Magazine</u>, 48:70, May, 1967.

[20] Press, op. cit., p. 392.

[21] Nevin and Mumford, op. cit., p. 71.

With the introduction of second and third generation fibers, or in this case, low-soiling nylon, a major technical breakthrough has been made. Other improvements predicted for the near future, to make nylon even more desirable to the consumer, include: dye variants; anti-static fibers; and flame resistant nylon variants.[22]

METHODS OF DETERMINING CARPET PERFORMANCE

Within recent years carpet researchers in the United States, England, and Germany have attempted to develop objective laboratory tests capable of predicting the end-use performance of carpets. These tests were considered to be of major importance in eventually leading to better performance economy for the consumer.

During a review of the status of carpet testing in 1966, the three countries cited found that the United States emphasized in-service testing with particular attention directed to the tentative A.S.T.M. method D-2401-65T. England emphasized efforts to correlate laboratory tests with floor trials, and Germany, the most recent Carpet Research Institute, worked with the German Standards Committee on standard test methods.[23]

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[22]Burnett, "What Lies Ahead," loc. cit.

[23]Kenneth C. Laughlin and Gordon E. Cusick, "Carpet Performance Evaluation Part I: The Tetrapod Walker Test," Textile Research Journal, 37:608, July, 1967.

Since prime requirements for a carpet are that (1) it should have desirable properties when new, and (2) it should maintain these properties for considerable time, two types of laboratory tests are required. The first simply "measures the physical properties, for example, thickness and compressibility of a new or worn carpet".[24] The second, a "serviceability type test", subjects the carpet to an accelerated version of one or more of the degrading agencies, such as traffic or abrasion, which are encountered during use.[25]

Measurement of Thickness and Compressibility

The first attempts to improve carpet manufacturing in the United States took place in the early 1930's. Confusion existed due to the many definitions and test methods related to carpet thickness. General agreement on one test method and specifications for a standard thickness gauge and standard definitions were necessities.

Schiefer developed test methods and discovered vital information concerning wear-life of carpeting which are still in use today. He also introduced the compressometer,

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[24]S. L. Anderson, "Recent Developments in the Test-of Carpets," Wool Science Review, 29:1, April, 1966.

[25]Ibid.

the first instrument which enabled measurements to be made directly on carpeting instead of fiber in bulk form.[26] The compressometer was the only instrument used up to 1942, thus, maintaining its importance for more than ten years:

> The instrument measured the thickness of a carpet under a known pressure which was gradually and continuously increased or decreased. The compressional resilience of the material was computed from these data.[27]

In his research Schiefer learned:

> The change in thickness of the pile of a carpet during a test has been found to be the best measurement of the amount of wear. The thickness of the pile decreases very rapidly during the early stage of a test. Thus, rapid decrease is caused primarily by a matting of the pile. After the pile has been matted, its thickness decreases at a fairly uniform rate for the remainder of the wear test.[28]

In 1947 Beckwith and Barach published a research report in which they summarized work completed in the area of carpet resilience measurements from 1932 to 1946. The compressometer was the instrument used for all tests within their study. After calculations were made, resilience was

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[26] Peter A. Costanza, "An Instrument for Measuring the Compression and Recovery of Carpeting," Modern Textiles Magazine, 51:84, May, 1970.

[27] H. F. Schiefer, "The Compressometer," Journal of Research National Bureau of Standards, Research Paper RP561, 10:705-713, June, 1933.

[28] H. F. Schiefer, "Wear Testing of Carpets," Journal of Research National Bureau of Standards, Research Paper RP1505, 29:341, November, 1942.

expressed as ". . . the ratio of the work returned upon release of a compressional load to the total work done in compression."[29] Through the tests cited in their report, Beckwith and Barach found that although the compressometer was useful in evaluating initial carpet resilience there was a definite need for tests that more closely simulated actual wear conditions.

Accelerated Laboratory Tests

In order to devise a measuring device to simulate actual wear, it was necessary to find out how the fibers were actually bent when a person walked on a carpet. Barach found through high speed photography that:

> . . . fibers when walked on do not bend alike and that they act in groups rather than singly. This proved to be an important clue to the performance of material in the form of pile fabric, . . .--that the interfiber relationships such as surface fiber friction, fiber crimp and the energy absorption properties of groups of fibers are equal in importance to the elastic performance of single fibers."[30]

As a direct result of this photographic study a test instrument was constructed which was essentially a free falling weight.[31]

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[29] O. P. Beckwith and J. L. Barach, "Notes on the Resilience of Pile Floor Coverings," Textile Research Journal, 17:305-313.

[30] J. L. Barach, "Dynamic Studies of Carpet Resilience," Textile Research Journal, 19:355, June, 1949.

[31] Ibid.

In 1960 and 1962 two dynamic loading testers, the Tetrapod Walker and the WIRA Dynamic Loading Machine, were introduced and gained wide acceptance in the United Kingdom. Onions, in a comparative study of test methods, described the Tetrapod Walker developed by Breens and Morton of Courtaulds, Ltd. as follows:

> The specimen is fitted as the lining to the curved inner surface of a drum of 8-inch internal diameter, the pile pointing inwards. A tetrapod, weighing 950 g. is placed inside the drum, which is then rotated at about 52 rev/min, the inside of the drum. The specimens are inspected at intervals. . . .[32]

Laughlin and Cusick emphasized in a test that, prior to and following their test, measurements had to be made in the center of the carpet sample because of the tendency of the Tetrapod Walker to concentrate wear in this region. As a result of an experiment to evaluate carpet performance during use, it was found that performance was affected by the nature of the fiber, the pile weight, and whether the pile was loop or cut. It was also found that the use of the Tetrapod Walker gave results which qualitatively resembled those obtained in extended floor trials.[33]

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[32]W. J. Onions, "An Assessment of Methods of Test of Carpets for Flattening, Change of Appearance, and Long Time Wear," Journal of Textile Institute, 58:489, October, 1967.

[33]Laughlin and Cusick, op. cit., p. 609.

The WIRA Dynamic Loading Machine developed by Clegg and Anderson for the Wool Industries Research Association was described by Anderson:

> An instrument for estimating the non-recoverable compression or change in appearance of the pile . . . . a small area of the Carpet A of measured thickness is driven slowly backwards and forwards . . . . two rectanglor plates each 2 inch x 0.25 inch falls freely on the carpet every five seconds. A central compressed area is thus produced and this is measured for thickness at intervals up to 1,000 impacts and the losses in thickness calculated. Two independent corridor trials covering a wide range of carpets have shown good correlations with results obtained on this machine.[34]

The Good Housekeeping Institute has established standards and test procedures to measure essential performance characteristics of carpets and rugs. According to Wham:

> To determine the resilience of the carpet we subject a sample to a load equivalent to a 180 pound person for 360 times at the rate of six times per minute. The reduction in the thickness is measured immediately after five minutes and after one hour.[35]

This standard requires that after being subjected to the test, the carpet sample must regain 70 percent of its original thickness.[36]

The most recent instrument developed to test carpet performance was introduced by the American Cyanamid Company. Costanza related in his paper that the instrument is inexpensive and that

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[34]Anderson, op. cit., p. 7.

[35]Wham, op. cit., p. 7.

[36]Sears, op. cit., p. 16.

> . . . it can be used for both dynamic and static load testing. In addition, it separates the effect of compression from the effect of abrasion. Only compression and recovery from compression, which account for most of the loss in the pile height of a carpet, are measured.[37]

Floor Trials Evaluating Serviceability and Changes in Appearance

Considerable research has been directed towards simulated laboratory tests because of the need to produce quality control as well as to reduce the time element and the cost involved in floor trials. Authorities agreed, however, that the most satisfactory method of comparing carpets for the maintenance of properties during use was a controlled wear test.

In his research Crone emphasized the point that

> . . . the walking movements and allied movements are primarily responsible for wear, but their effects can be aggravated by other conditions. It is for this reason that we have not been in complete agreement with workers who, to estimate wear in carpets, have used machines which do not conform to the walking movement. . . .[38]

The Rug and Carpet Institute include with its 1968 literature a statement on wear testing equipment issued by The Technical Committee of The American Carpet Institute, Inc. on February 13, 1961.

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[37]Peter A. Costanza, "An Instrument for Measuring the Compression and Recovery of Carpeting," Modern Textiles Magazine, 51:84-85, May, 1970.

[38]Crone, op. cit., p. 549.

> In developmental work, carpet manufacturers compare the relative durability of their products by laboratory simulated 'wear' tests. This procedure is useful for the development, improvement and quality control of a manufacturers own products when performed under controlled laboratory conditions and where a history of past data is available for comparison.
>
> Laboratory simulated wear test machines cannot predict the relative serviceability of a group of floor covering samples, since the conditions of service are unpredictable and testing a small number of samples does not give dependable results.
>
> Carpet manufacturers, therefore, do not recommend the use of these machines and methods in competitive purchasing or selling of pile floor coverings because they do not simulate actual service conditions and cannot predict the wear life in service of any given fabric.[39]

Although a number of tests exist in the evaluation of carpeting, the Good Housekeeping Institute regards the Carpet Aisle Test more important than any other:

> Samples ranging from dark to light colors, are taped together and placed in a traffic aisle. The thickness of the carpet is measured before and after 20,000 trafflicks and vacuuming: the carpet is then cleaned and remeasured and the percent change in thickness is determined . . . .appearance . . . is noted under standard lighting conditions according to the scale: Poor, Fair, Good, Very Good and Excellent, using as standard established graded samples of known performance.[40]

From over 25,000 carpet construction evaluations, the Good Housekeeping Institute found that certain facts have been proved over and over again. A few that relate

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[39] American Carpet Institute, Statement: To Members of the Marketing and Technical Committee, "Statement on Wear Testing Equipment," American Carpet Institute, Inc., New York, February 13, 1961.

[40] Wham, op. cit., p. 58.

to this study are: (1) Density of the surface yarns, which largely determines the ability to recover from crushing and the ability to maintain texture, is the most important factor with respect to carpet quality. (2) Short twisted pile yarns show less matting than long cut pile yarns. (3) Type of construction is of major importance in carpets made of fibers of low crush resistance. (4) Generally, wool carpets of good quality retain a better overall surface appearance than man-made fiber carpets. (5) Carpets made of a man-made fiber with a low pile weight are practically impossible to revive when the pile yarns are crushed down.[41]

Anderson and Clegg, British researchers, primarily known for their work with dynamic loading machines, found that the greatest decrease in carpet thickness occurred during the first few months of wear. Then a much slower but steady fall follows until the pile is completely worn away.[42]

A year later than the research mentioned above, Cusick and Dawber determined the loss of thickness of carpts in floor trials by taking thickness measurements "in situ" at specified intervals during the trials. The findings

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[41]Ibid.

[42]Dorothy G. Clegg and S. L. Anderson, "A Test for the Assessment of Carpet Compression During Wear," Journal of the Textile Institute, 53:T347, July, 1962.

agreed with those found by Clegg and Anderson and, also maintained in their study that there was a linear relationship between loss of thickness and the logarithm of the number of treads.[43]

A number of studies have been made in which laboratory results with both the Tetrapod Walker and the WIRA Dynamic Loading Machine were correlated with corridor wearing trials. The largest test of this type was one in which six British laboratories participated in a inter-laboratory research project. The test involved 12 carpets covering a range of fiber types and constructions. Onions reported that:

> . . . the floor trial was organized to study three developments in the carpet under test: (i) flattening; (ii) change of texture; and (iii) wear to backing.[44]

The machines used included the Tetrapod Walker, the WIRA Dynamic Loading Machine, and the WIRA Carpet Abrasion Tester.

Results of the changes in appearance were noted by a panel of judges at intervals during the floor trials. In general, at the end of the floor trial, agreement between judges was satisfactory. Although most judges stated that ranking the six middle carpets was difficult, there was little difficulty in picking out the three that had changed most and the three that had changed least.

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[43] G. E. Cusick and D. K. R. Dawber, "Loss of Thickness of Carpets in Floor Trials," Journal of the Textile Institute, 55:T535, October, 1964.

[44] Onions, op. cit., p. 490.

Both the WIRA Dynamic Loading Machine and the Tetrapod Walker showed satisfactory and promising signs of agreement between laboratories. Also, there was satisfactory correlation between ranking on the floor and ranking on the instruments. The Carpet Abrasion Tester, however, showed discrepancies in correlation between laboratories and disappointing results with those made on the floor.[45]

In a subjective study in which ten judges used a scale of 1-4 to rate the carpets for change of color and change of texture the findings indicated that with the exception of three carpets,

> . . . the correspondence between the scores for colour change and those for change of texture appears strong. Among the possible implications may be:
>
> (a) that the change of colour is physically dependent on the change of texture; and
>
> (b) that the change of colour associated with flattening may influence the judgment of texture, at any rate, in early stages of service.[46]

The procedure most often followed in the United States for appearance retention is the corridor test developed by the American Society for Testing and Materials (A.S.T.M. D-2401). The carpets to be tested are placed in a corridor along with some means to count the traffic. At the end of the test two basic variations of comparison are used to show degrees of change in appearance

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[45]Ibid., pp. 514-515. [46]Ibid., p. 500.

of the carpet pile. (1) Photographs of the carpets under test are compared with reference photographs, or (2) carpet test specimens are compared directly with reference photographs.[47]

SUMMARY

During the past twenty years the carpet industry has become one of the most dynamic industries in the United States. Credit for the constant and rapid growth of the industry has primarily been attributed to two technological advances: (1) the development of the tufting process, and (2) the introduction and success of man-made fibers with properties specifically suited for this end use.

Recent literature indicates that 91 percent of all carpets sold are of tufted construction. For many years wool was the dominant fiber used for carpet surface yarns; but by the mid 1960's two man-made fiber groups, nylon and the acrylics, led in total carpet consumption. Polyester fiber, however, is predicted to reach first place in total consumption in the near future.

Resilience, strength and durability are included in most sources as properties essential for fibers used in

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[47]American Society for Testing and Materials, "Service Change of Appearance of Pile Floor Coverings," A.S.T.M. D-2401-67. 1967 Book of ASTM Standards, Part 24 (Philadelphia: American Society for Testing and Materials, October, 1967), pp. 518-528.

surface yarns of carpeting. All contribute to and are important in determining how well a carpet will wear and how well it will retain its original appearance.

Although on a decline, wool carpeting is still noted for its beauty, warmth and resilience. The acrylics have made quite an impact on the residential carpet market because they are so similar to wool in hand and appearance and yet are less expensive than wool carpets of similar construction. Nylon, known for its strength and durability, dominates the low cost end of the market. Due to deficiences such as matting and soiling, nylon carpeting has not been considered as aesthetically attractive as those made of wool or the acrylics. Modifications of the fiber, however, are predicted to make nylon more desirable.

In the 1950's and 1960's considerable time has been spent in the United States, England, and most recently Germany on the development of meaningful test methods using instrumentation that would correlate to a high degree with results of actual carpet performance. The availability of several useful accelerated tests indicates that advances have been made, but disagreement appears to exist as to which method, if any, best simulates actual wear and consistently gives the most accurate results. Controlled floor trials, although time consuming and expensive, are considered by many authorities to be the most satisfactory method of comparing maintenance and appearance properties of carpets.

CHAPTER III

EXPERIMENTAL PROCEDURE

As noted in the first two chapters, principle features of a carpet from the customer's point of view are the ability to wear for a long time and the ability to retain the original appearance.[1] For these reasons the fibers used in surface yarns of carpeting must be resilient and strong.

To test the importance of fiber resilience, a recent study was made on 12 specially manufactured carpets to determine whether fiber resilience is a factor influencing the consumer selection of carpeting and to make a comparison between laboratory evaluation and consumer reaction to fiber resilience in new carpeting.[2]

The present study was developed to compare fiber resilience and crush recovery characteristics of the same carpeting prior to and following a serviceability test. Changes in appearance of each type of carpeting following the test were also studied.

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[1]H. R. Crone, "Fiber Blends as Carpet Surface Yarns," Journal of the Textile Institute, 43:533, August, 1952.

[2]Nancy Sears, "Relation of Fiber Resilience to Consumer Selection of Carpeting," (unpublished Doctor's Dissertation, The University of North Carolina at Greensboro, 1969), p. 3.

DESCRIPTION OF CARPET SAMPLES

The carpets included three fiber types: wool, acrylic, and nylon which were the three types sold by the manufacturer as carpeting for living areas of the home. Each fiber type was manufactured in two pile types (cut and uncut) and with two pile heights (high and low) within each pile type. The carpets of low pile height were manufactured to be within 0.2 to 0.4 inches. The carpets of high pile height were manufactured to be within 0.4 to 0.6 inches.

Although each carpet met the specifications necessary for consumer use, the samples were constructed in such a way that those in each group were comparable in construction features: appearance, performance, and texture. Due to the inherent differences in the fibers, it was impossible to construct carpets of the same structure and density in terms of weight. Nylon fiber has a lower specific gravity than either wool or acrylic fibers. For this reason nylon samples were lighter in weight and required slight adjustments in the stitches and rows per inch.

All the carpets were tufted with a jute backing and bonded with latex adhesive. The color of the test samples were gold, in order to eliminate color as a variable.

Manufacturing specifications, supplied by the manufacturer, are presented in Table 2.

Table 2

MANUFACTURER'S SPECIFICATIONS FOR CONSTRUCTION OF TEST CARPETS

Fibers	Pile Weights (ounces per square yard)	Courses Per Inch	Stitches Per Inch
<u>Cut Pile</u>			
Wool			
High	44.0	5.3	8.0
Low	28.0	5.3	8.0
Acrylic			
High	42.0	5.3	9.0
Low	26.5	5.3	9.0
Nylon			
High	30.0	6.4	9.0
Low	20.0	6.4	7.0
<u>Level Loop Pile</u>			
Wool			
High	46.0	8.0	6.7
Low	30.0	8.0	6.0
Acrylic			
High	40.0	8.0	6.7
Low	26.0	8.0	6.0
Nylon			
High	23.2	8.0	6.7
Low	18.7	8.0	7.0

PREPARATION OF CARPET FOR WEAR TEST

Coding and Test Carpet Formation

The 12 carpets to be tested were coded before they were joined together into a large "test carpet". Numbers, one through six indicated the two factors, fiber type and pile height. Letters A and B indicated the third factor, pile type. The coding system is shown in detail in Appendix A.

Nine 9-inch squares were cut from each of the 12 coded carpets. Due to difficulty in cutting accurately, it was necessary to devise a specific procedure to facilitate the cutting of the samples. The 9 x 9 inch measurement lines were drawn on the jute backing with a medium felt-pointed marker. The samples were then cut with a slicing motion in the center of the line, using a specially designed carpet knife. This technique tended to reduce ragged edges. When necessary, the edges of each sample were trimmed with sharp scissors.

Of the nine squares cut from each sample, six were used in the test carpet and three were retained as control samples. Therefore, there was a total of 72 samples to be tested.

Randomization and Sampling Plan

Due to the size of the finished test carpet and to the difficulty in taking the samples apart, the samples were randomized so that the carpet would not have to be rotated or changed in any way during the testing period.

The large test carpet was made up of six replicates of each of the 12 carpets. The 12 samples were randomized in a three-factor, split-plot design with the sub-plot factor arranged in a Latin Square. The whole plot factor was the pile type and the sub-plot factor was the factorial combination of the two pile heights and the three fiber types. A table of random numbers was used for randomizing the position of the squares within a whole plot with the restriction that their position in the test carpet not be repeated.

The 72 pieces were fastened together by means of heavy-duty staples and a nylon tape covered with a carpeting adhesive. A nine inch border was attached on all four sides so as to alleviate wear occasioned on the outer edges of the carpet squares to be tested. The entire test carpet measured 3 1/2 feet by 15 feet. A master table showing the design of the carpet is included as Appendix B.

Site for Wear Test Carpeting

The test carpet was placed in a hallway in the Home Economics Building at The University of North Carolina at Greensboro for wear trials approximating moderate usage. Each end of the carpet was taped to the floor by means of double-faced tape so that the carpet would remain securely in place.

An electric counter was installed at the midpoint of the carpet to estimate the number of "walk-ons" per day.

In order to restore pile and to aid in preventing changes in appearance, the carpet was vacuum cleaned at least once a week during the testing and immediately before removal from the hallway.

DATA COLLECTION

Procedure for Laboratory Tests

Prior to all laboratory testing, samples were conditioned at 70 ± 2 degrees Fahrenheit and 65 ± 2 percent relative humidity. The pile of the new samples was brushed with a nylon brush prior to conditioning. The pile of the test carpet samples was vacuum cleaned before they were conditioned. All measurements were made under the same standard conditions--temperature and humidity.

Measurement of Carpet Thickness

Prior to and following the serviceability test, twelve readings were taken on each type of carpet to obtain measurements for (1) original carpet thickness, (2) compressed carpet thickness, and (3) recovered carpet thickness, making a total of thirty-six readings for each sample. All the readings were taken in the center section of each sample, so that a degree of consistency would be maintained.

While taking the measurements it was necessary for the specimens to be flat on the instrument base, otherwise the readings would not be consistent. The base of the instrument had previously been enlarged with pieces of wall-board which were the same thickness as the base so that the nine inch squares were flush with the base of the instrument.

The C & R Tester, an instrument designed to measure thickness, compression, and recovery, was used for taking the three measurements. Based on information received from the manufacturer, The Custom Scientific Instruments, Inc., the instrument was adapted to measure compression by combining a 3/8 inch pressure foot and a 22 ounce weight to serve as an indenting load equal to 12.48 pounds per square inch.[3] This indenting load was used since it had been indicated by Barach (1949) that compression of 12.0 pounds per square inch per second approximates the pressure of an average person walking on a carpet.[4]

"The dial indicator supplied with the instrument is graduated in .001 inches. The indicator may be raised or lowered by means of a screw and handwheel to have a range of from 0 to 1 inch thickness."[5] Since the dial registers

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[3]Sears, op. cit., p. 34.

[4]J. L. Barach, "Dynamic Studies of Carpet Resilience," Textile Research Journal, 19:355, June, 1949.

[5]Custom Scientific Instruments, Inc., C. & R. Tester Model CS-55. Whippany, New Jersey: Custom Scientific Instruments, Inc., (n.d.).

the distance the pressure foot moves from a position one inch above the base of the instrument, all readings were subtracted from one inch to obtain the exact thickness measurements.

The initial carpet thickness was determined from readings made when the pressure foot rested lightly on the pile of the carpeting. By turning the screw and handwheel as tight as possible, the indenting load was applied to the carpet to obtain the readings to determine the compressed carpet thickness. The pressure was then removed from the sample by quickly rotating the screw and handwheel. After 30 seconds the pressure foot was again lowered to the surface of the carpet and readings of the recovered carpet thickness were made.

Determination of Compressional Resilience

Since the C & R Tester is not designed to measure the compressional resilience, it must be determined from measurements of carpet thickness. The percent compressional resilience is the ratio of the difference between the recovered and the compressed thickness divided by the difference between the original and the compressed thickness multiplied by 100. The following formula was used for the calculation:

$$\text{Percent Compressional Resilience} = \frac{C - B}{A - B} \times 100$$

A = Original carpet thickness
B = Compressed carpet thickness
C = Recovered carpet thickness

Anderson and Clegg illustrate a typical thickness-pressure curve obtained during the loading-unloading cycle as shown in Figure 1.

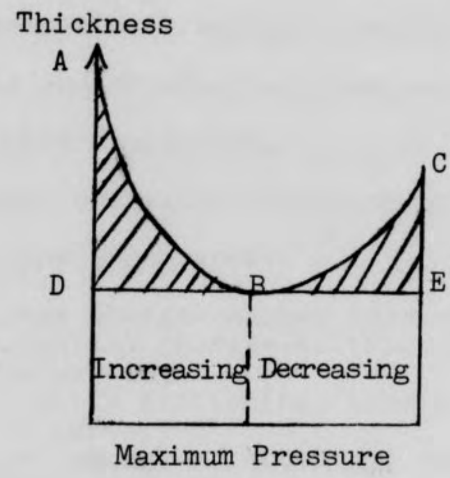

Figure 1

Typical Thickness-Pressure Curves for Carpets

The area ABD is the energy given by a foot to a carpet (compressibility) and area CEB is that given up by the carpet when the foot is removed. A measure of the resilience or recovery of the carpet is the percentage ratio of area CEB and area ABD.[6]

<u>Evaluation of Appearance and Texture of Carpet Samples Following Wear</u>

A rating scale was used to evaluate the appearance of the six replicates of each of the 12 carpet samples

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[6]S. L. Anderson and Dorothy Clegg. "Physical Test Methods for Carpets," <u>Textile Institute and Industry</u>, 1:6-8, February, 1963.

following the floor trial period. A panel of judges, 25 women, who were faculty members or graduate students in the school of Home Economics, compared visually the surface pile of each sample with control samples. Apparent changes in surface pile and/or original texture were the major consideration in this evaluation.

Appearance was rated according to the following changes in surface appearance:

5 - extreme change--marked loss of original texture.
4 - substantial change--matting, loss of tufts, untwisting.
3 - noticeable flattening, some matting, slight loss of tufts.
2 - slight change--flattening, but no matting, no loss of tufts.
1 - no change--indistinguishable from original.

The rating was similar to that advocated by AATCC for many textile tests and procedures requiring subjective evaluation.

A copy of the evaluation form used by the women to evaluate changes in surface appearance is included as Appendix C.

DATA ANALYSIS

Statistical analysis of the data included an analysis of variance of compressional resilience with variation due to the following sources obtained in the partitioning: (1) differences among three fiber types, (2) differences between two pile types, (3) differences between two pile heights, and (4) interaction among the three variables. An analysis of variance of the visual appearance of the tested carpet compared with control samples was also used with the same variations as stated on the previous page.

The statistical design used in this study was a split-plot design with the whole plot arranged according to a completely randomized design and the sub-plot treatments consisting of a 2 x 3 factorial of pile heights and fibers. The sub-plots were arranged according to a Latin Square. The whole plot treatment factor was that of pile type. The following Analysis of Variance Model was used:

SOURCE OF VARIANCE	DEGREES OF FREEDOM					
	TEST CARPET					
	Not Walked On		Walked On		Visual Rating	
Cut vs. Uncut		1		1		1
Error (a)		4		10		
Treatments		5		5		5
Pile Height	1		1		1	
Fiber	2		2		2	
P.H. x Fiber	2		2		2	
Treatment x cut vs. uncut		5		5		5
(Cut vs. Uncut) x P.H.	1		1		1	
(Cut vs. Uncut) x Fiber	2		2		2	
(Cut vs. Uncut) x P.H. x Fiber	2		2		2	
Error (b)		20		50		
Determination Error		108		72		288
Total (corr.)		143		143		299

In conjunction with tests of significance, means were tabulated and comparisons made utilizing the least significant difference. Tests of significance were made at both the 0.01 and 0.05 levels.

CHAPTER IV

RESULTS AND DISCUSSION OF FINDINGS

The results of the study will be presented in three parts:

1. Laboratory analysis of fiber resilience.
2. Comparison of the resilience of the carpeting following use with the resilience prior to serviceability test.
3. Visual evaluation of carpet samples following serviceability test.

The test carpet constructed from six replicates of the 12 carpet types was placed in a hallway in the Home Economics Building at the University of North Carolina at Greensboro where it was walked on for a total of 12 weeks. An electric counter was installed at midpoint of the carpet. It was estimated that there were approximately 1,259 footsteps per week or a total of 15,540 walk-ons.

LABORATORY ANALYSIS OF FIBER RESILIENCE

Measurement of Carpet Thickness

Preceding laboratory analysis all carpets were conditioned at 70 ± 2 degrees Fahrenheit and 65 ± 2 percent relative humidity. All testing was performed under these same conditions.

After restoring the texture by brushing and vacuum cleaning, readings were taken in the center of each carpet type to obtain the mean of 12 measurements for (1) original carpet thickness, (2) compressed carpet thickness, and (3) carpet thickness after a 30 second recovery period.

The means of the laboratory measurements of carpet thickness prior to and following the serviceability test are presented in Table 3. The original and recovered measurements showed a decrease in thickness following the serviceability test in all but one of the carpets. The difference in thickness of the uncut nylon carpet of low pile height was negligible prior to and following the test. The compressed carpet thickness measurements, however, presented no definite pattern of increase or decrease. High and low uncut nylon showed the greatest decrease in compressed thickness of all the carpeting; cut nylon of both pile heights showed a slight decrease in thickness. Differences in the measurements of the acrylic carpets of uncut high and low pile and of cut high pile decreased a small amount; whereas, the acrylic of cut low pile showed a slight increase in thickness; uncut high pile carpets, however, decreased in thickness.

Compressional Resilience of Carpeting Prior to Serviceability Testing

An analysis of variance (Appendix D) was used to determine significant differences in the compressional resilience

Table 3

MEASUREMENT OF CARPET THICKNESS PRIOR TO AND FOLLOWING SERVICEABILITY TESTING EXPRESSED IN 0.001 INCH*

	Thickness in 0.001 Inches Prior to (1) and Following (2) Serviceability Testing					
	Original		Compressed		Recovered	
	1	2	1	2	1	2
Uncut Pile						
Wool						
High	.487	.459	.103	.097	.440	.402
Low	.365	.329	.081	.092**	.326	.296
Acrylic						
High	.459	.443	.100	.098	.412	.392
Low	.322	.312	.088	.087	.282	.269
Nylon						
High	.387	.371	.089	.074	.345	.330
Low	.321	.322**	.082	.068	.288	.265
Cut Pile						
Wool						
High	.698	.645	.093	.101**	.582	.542
Low	.512	.447	.085	.092**	.431	.377
Acrylic						
High	.674	.664	.089	.087	.543	.536
Low	.482	.447	.080	.086**	.428	.379
Nylon						
High	.547	.522	.089	.082	.476	.442
Low	.454	.428	.080	.079	.374	.359

*Means based on 12 measurements.

**Compressed carpet thickness measurements which show an increase in thickness following the serviceability test.

with variation due to the following sources: (1) differences among the three fiber types, (2) differences between two pile types, (3) differences between two pile heights, and (4) interactions among fibers, pile heights, and pile types.

Compressional resilience effects significant at the 0.01 level of probability were:

1. Pile types.
2. Interaction between fibers and pile heights.
3. Interaction of fibers, pile heights, and pile types.

The mean percentages of compressional resilience of the carpets prior to the serviceability test are presented in Table 4 and plotted in Figure 2. The compressional resilience of the 12 carpets ranged from 87.84 percent resilience for the wool carpet of high uncut pile to 77.49 percent resilience for the acrylic carpet of high cut pile. Differences in compressional resilience were not statistically significant among the individual factors: (1) fiber types -- wool, acrylic and nylon, and (2) between pile heights -- high and low. Differences in compressional resilience between the pile types -- cut and uncut, however, were highly significant. The uncut pile carpeting was 4.52 percent more resilient than the cut pile carpeting.

Differences in percentage compressional resilience between the pile heights of the fibers of uncut and cut

Table 4

MEAN PERCENTAGE COMPRESSIONAL RESILIENCE OF THE CARPETS PRIOR TO SERVICEABILITY TESTING

Carpet Construction	Wool	Acrylic	Nylon	Mean
	Percent	Percent	Percent	Percent
Pile Type				
Uncut Pile				
High	87.74	86.86	86.09	86.89
Low	86.29	83.07	86.08	85.15
Mean	87.07	84.96	86.08	86.02
Cut Pile				
High	80.82	77.49	84.60	80.97
Low	81.00	86.65	78.41	82.02
Mean	80.91	82.07	81.51	81.50
Pile Height				
High Pile				
Uncut	87.74	86.86	86.09	86.89
Cut	80.82	77.49	84.60	80.97
Mean	84.28	82.17	85.34	83.93
Low Pile				
Uncut	86.29	83.07	86.08	85.15
Cut	81.00	86.65	78.41	82.02
Mean	83.64	84.86	82.24	83.58
Overall Fiber Means	83.96	83.52	83.82	

LSD	0.05 level	0.01 level	LSD	0.05 level	0.01 level
Pile Type	1.57	2.61	Pile Type x Pile Height	1.51	N.S.
Fiber x Pile	1.84	2.51	Pile Type x Fiber x Pile Height	2.61	3.56

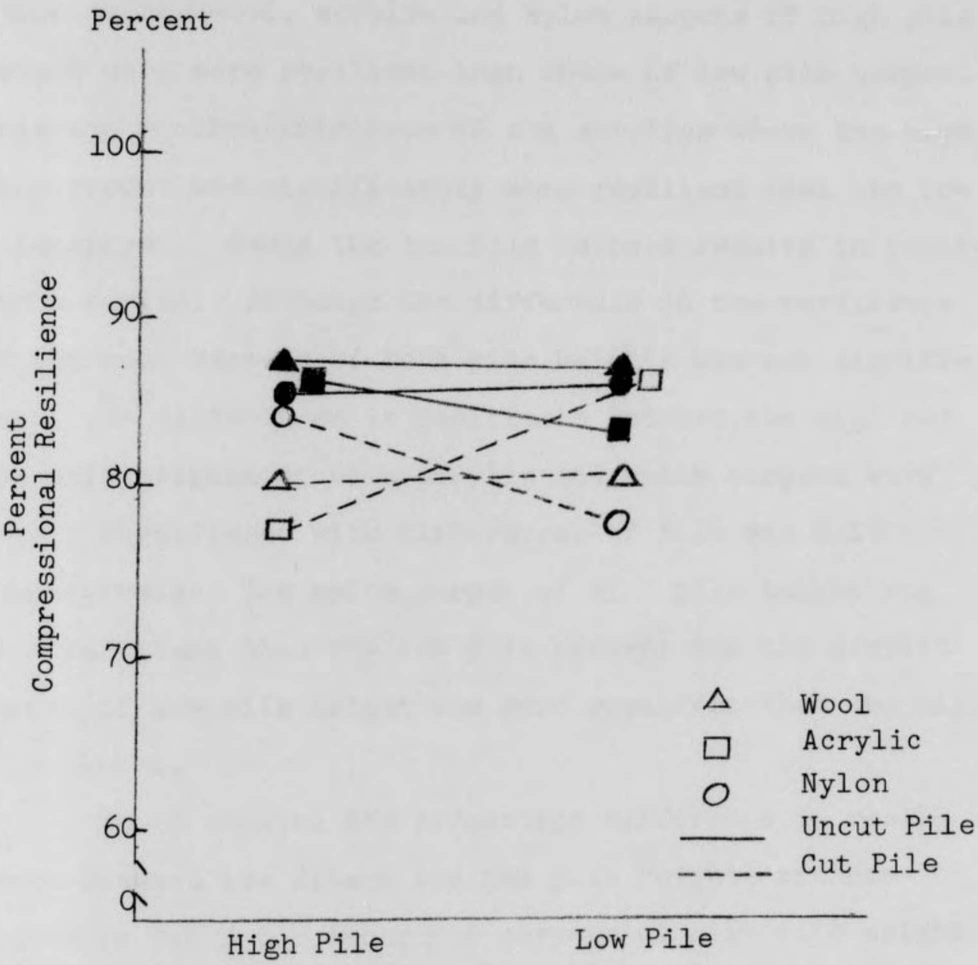

Figure 2

MEAN PERCENTAGES SHOWING THE INTERACTION BETWEEN FIBERS, PILE HEIGHTS AND PILE TYPES PRIOR TO SERVICEABILITY TESTING carpeting are presented in Table 5. Among the uncut pile carpets, the wool, acrylic and nylon carpets of high pile height were more resilient than those of low pile carpet. This was particularly true of the acrylics where the high pile carpet was significantly more resilient than the low pile carpet. Among the cut pile carpets results in resilience varied. Although the difference in the resilience of the wool carpets of both pile heights was not significant, the differences in resilience between the high and low pile heights of both acrylic and nylon carpets were highly significant with differences of 9.16 and 6.19 respectively. The nylon carpet of high pile height was more resilient than the low pile carpet; and the acrylic carpet of low pile height was more resilient than the high pile carpet.

Means showing the percentage difference in resilience between the fibers and the pile heights are presented in Table 6. Among the carpets of high pile height the nylon was the most resilient (85.35 percent). Among the carpets of low pile height and acrylic was the most resilient (84.36 percent). A difference in resilience which was significant at the 0.01 level of probability was found between the two nylon carpets. Differences in resilience between nylon and acrylic carpeting of high pile height and between acrylic and nylon of low pile height were also significant at the 0.01 level. Differences in

Table 5

DIFFERENCES IN PERCENTAGE COMPRESSIONAL RESILIENCE BETWEEN THE PILE HEIGHTS OF THE FIBERS OF UNCUT AND CUT PILE CARPETS

Fibers and Pile Types	Pile Heights		Percent Difference
	High	Low	
	(Percent)	(Percent)	
Uncut Pile			
Wool	87.74	86.26	1.48
Acrylic	86.86	83.07	3.79**
Nylon	86.09	86.08	0.01
Cut Pile			
Wool	80.82	81.00	0.18
Acrylic	77.49	86.65	9.16**
Nylon	84.60	78.41	6.19**
Uncut Pile			
Wool vs. Acrylic	87.74-86.86	----	0.88
Wool vs. Nylon	87.74-86.09	----	0.65
Acrylic vs. Nylon	86.86-86.09	----	0.77
Wool vs. Acrylic	---- ----	86.26-83.07	0.32*
Wool vs. Nylon	---- ----	86.26-86.08	0.18
Acrylic vs. Nylon	---- ----	83.07-86.08	3.01*
Cut Pile			
Wool vs. Acrylic	80.82-77.49	----	3.33*
Wool vs. Nylon	80.82-84.60	----	3.78**
Acrylic vs. Nylon	77.49-84.60	----	7.11**
Wool vs. Acrylic	---- ----	81.00-86.65	5.65**
Wool vs. Nylon	---- ----	81.00-78.41	2.59
Acrylic vs. Nylon	---- ----	86.65-78.41	8.24**

Least Significant Difference (LSD) for comparing 3 fibers and 2 pile types with 2 pile heights.
0.01 level = 3.56
0.05 level = 2.61

Table 6

MEANS SHOWING PERCENT DIFFERENCE IN RESILIENCE
BETWEEN FIBERS AND PILE HEIGHTS

Fiber Types	Pile Heights		Percent Difference
	High	Low	
	(Percent)	(Percent)	
Wool	84.28	83.65	0.63
Acrylic	82.17	84.36	0.69
Nylon	85.35	82.25	3.10**
Wool vs. Acrylic	84.28-82.17	----	2.11*
Wool vs. Nylon	84.28-85.35	----	1.07
Acrylic vs. Nylon	82.17-85.35	----	3.17**
Wool vs. Acrylic	---- ----	83.65-84.86	1.22
Wool vs. Nylon	---- ----	83.65-82.25	2.03*
Acrylic vs. Nylon	---- ----	84.86-82.25	2.62**

LSD for comparing 3 fibers within 2 pile heights.
0.01 level = 2.51
0.05 level = 1.84

resilience between wool and acrylic carpeting of high pile height and between wool and nylon of low pile height were significant at the 0.05 level.

Data pertaining to the triple interaction between fibers, pile heights, and pile types are reported in Table 4 and shown graphically in Figure 2.

Differences in compressional resilience between pile heights and pile types were significant at the 0.05 level of probability. Uncut pile carpets of both high and low pile height were more resilient than cut pile carpets of the respective pile heights. The high uncut pile carpets were slightly more resilient than the low uncut pile carpets; whereas, the low cut pile carpets were more resilient than those of high cut pile. No significant differences in compressional resilience were observed:

1. Among the fibers.
2. Between the pile heights.
3. In the interaction between fibers and pile types.

Compressional Resilience of Carpeting Following Serviceability Testing

The analysis of variance (Appendix E) showed that compressional resilience effects significant at the 0.01 level of probability were:

1. Pile types.
2. Interaction between pile types and pile heights.

3. Triple interaction among fibers, pile types and pile heights.

The mean percentages of compressional resilience of the carpets following the serviceability test are presented in Table 7 and plotted in Figure 3. The compressional resilience of the 12 carpets ranged from 86.28 percent resilience for the nylon carpet of high uncut pile to 76.82 percent resilience for the acrylic carpet of high cut pile. Significant differences were not observed among the individual factors: (1) fiber types — wool, acrylic and nylon fibers, and (2) between pile heights — high and low. Differences in compressional resilience between the pile types — cut and uncut, however, were highly significant. The uncut pile carpeting was 4.96 percent more resilient than the cut pile carpeting.

Differences in percentage of compressional resilience between the two pile heights of the three fiber types of the uncut and cut pile carpets are presented in Table 8. Among the uncut pile carpets results in resilience varied. The acrylic and nylon carpets of high pile height were both significantly more resilient than the respective carpets of low pile height. The wool carpet of low pile height, however, was only slightly more resilient than the wool carpet of high pile height. All cut pile carpets of low pile height were more resilient than the cut pile carpets of

Table 7

MEAN PERCENTAGES COMPRESSIONAL RESILIENCE OF THE CARPETS FOLLOWING THE SERVICEABILITY TEST

Carpet Construction	CARPET FIBERS Wool	Acrylic	Nylon	Mean
	Percent	Percent	Percent	Percent
Pile Type				
Uncut Pile				
High	84.29	85.25	86.28	85.27
Low	85.95	80.93	83.10	83.33
Mean	85.12	83.09	84.69	84.30
Cut Pile				
High	79.75	76.82	77.50	78.02
Low	80.16	81.17	80.64	80.66
Mean	79.96	79.00	79.07	79.34
Pile Height				
High Pile				
Uncut	84.29	85.25	86.28	85.27
Cut	79.75	76.82	77.50	78.02
Mean	82.02	81.03	81.89	81.65
Low Pile				
Uncut	85.95	80.93	83.10	83.33
Cut	80.16	81.17	80.64	80.66
Mean	83.06	81.05	81.87	81.99
Overall Fiber Means	82.54	81.04	81.88	----

LSD	0.05 level	0.01 level	LSD	0.05 level	0.01 level
Pile Type	2.62	3.48	Pile Type x Pile Height	1.85	2.46
			Pile Type x Fiber x Pile Height	3.21	4.26

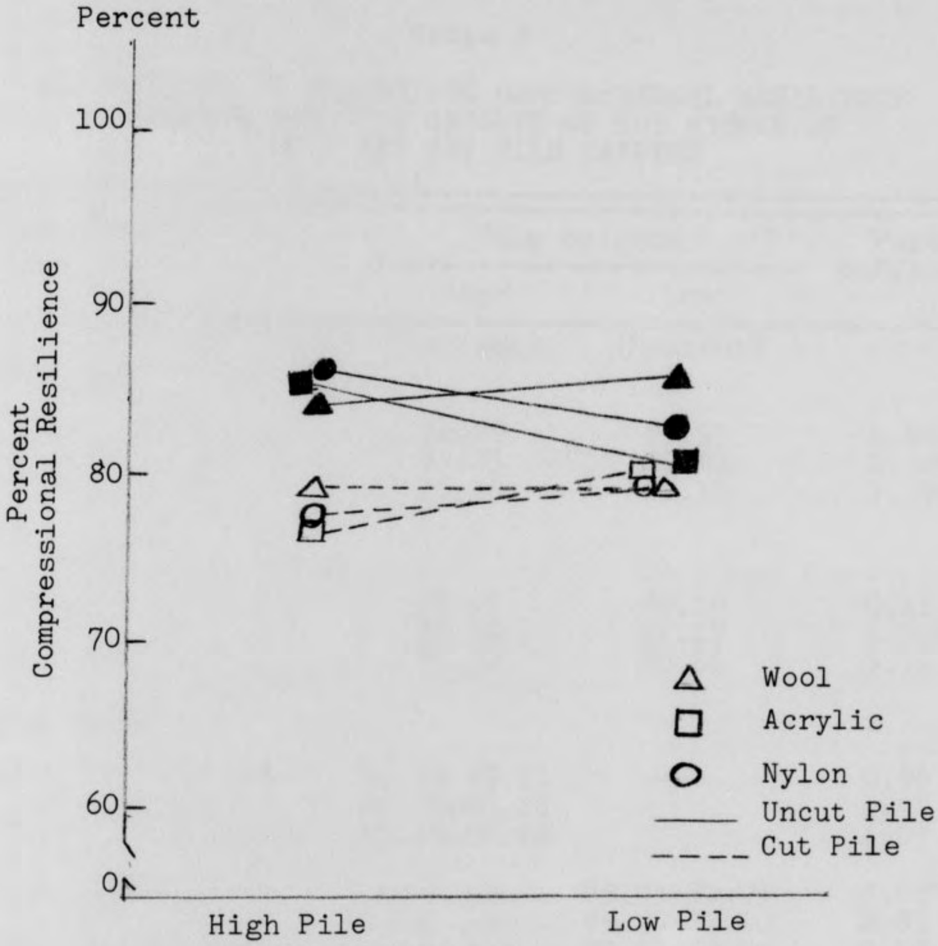

Figure 3

MEAN PERCENTAGES SHOWING THE INTERACTION BETWEEN FIBERS, PILE HEIGHTS AND PILE TYPES FOLLOWING SERVICEABILITY TESTING

Table 8

DIFFERENCES IN PERCENTAGE COMPRESSIONAL RESILIENCE BETWEEN THE PILE HEIGHTS OF THE FIBERS OF UNCUT AND CUT PILE CARPETS

Fibers and Pile Types	Pile Heights		Percent Difference
	High	Low	
	(Percent)	(Percent)	
Uncut Pile			
Wool	84.29	85.95	1.66
Acrylic	85.25	80.93	4.32**
Nylon	86.28	83.10	3.18
Cut Pile			
Wool	79.75	80.16	0.41
Acrylic	76.89	81.17	4.35**
Nylon	77.50	80.64	3.14
Uncut Pile			
Wool vs. Acrylic	84.29-85.25	----	0.96
Wool vs. Nylon	84.29-86.28		1.99
Acrylic vs. Nylon	85.25-86.28		1.03
Wool vs. Acrylic	---- ----	85.95-80.93	5.02**
Wool vs. Nylon	---- ----	85.95-83.10	2.85
Acrylic vs. Nylon	---- ----	80.93-83.10	2.17
Cut Pile			
Wool vs. Acrylic	79.75-76.89	---- ----	2.86
Wool vs. Nylon	79.75-77.50	---- ----	2.25
Acrylic vs. Nylon	76.89-77.50	---- ----	0.61
Wool vs. Acrylic	---- ----	80.16-81.17	1.01
Wool vs. Nylon	---- ----	80.16-80.64	0.48
Acrylic vs. Nylon	---- ----	81.17-80.64	0.53

LSD for comparing three fibers and two pile types within two pile heights.
0.01 level = 4.27
0.05 level = 3.21

high pile height. In particular, the low acrylic and nylon carpets were more resilient than the high pile carpets of the corresponding fibers.

The interaction between the pile heights and pile types are plotted in Figure 4. Uncut pile carpets of high and low pile height were significantly more resilient than cut pile carpets of the respective pile heights. High uncut pile were 1.94 percent (0.05 level) more resilient than carpets of low uncut pile; whereas, low cut pile carpets were 2.64 percent (0.01 level) more resilient than carpets of high cut pile.

Data pertaining to the triple interactions between fibers, pile heights, and pile types were reported in Table 7 and shown graphically in Figure 3.

No significant differences in compressional resilience were observed:

1. Among the fibers.
2. Between the pile heights.
3. Between fibers and pile heights.
4. Between fibers and pile types.

Comparison of Findings

Table 9 shows the differences in compressional resilience between the test carpets prior to and following the serviceability test. Although differences were not large, one major difference was that, with two

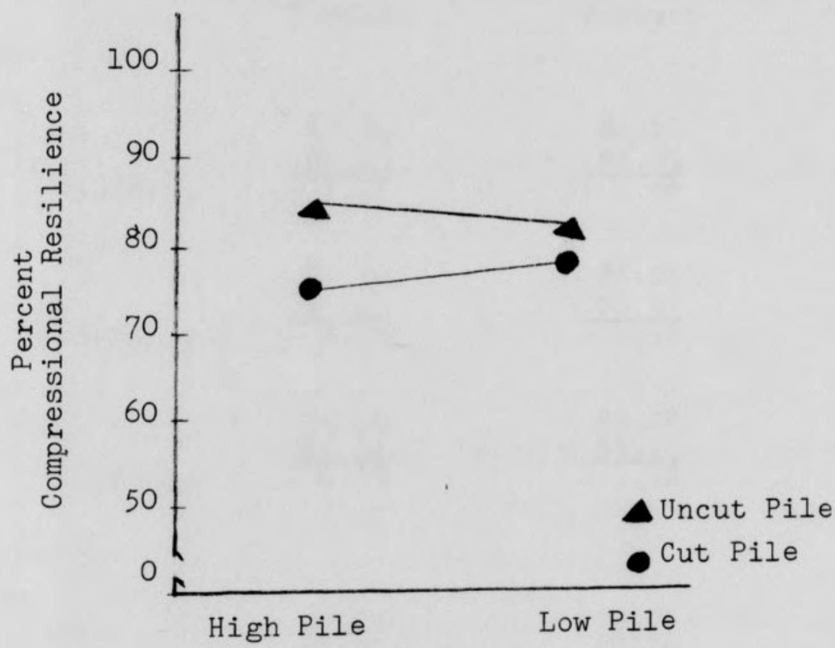

Figure 4

MEAN PERCENTAGES SHOWING THE INTERACTION BETWEEN PILE HEIGHTS AND PILE TYPES

Table 9

DIFFERENCES IN PERCENTAGE COMPRESSIONAL RESILIENCE OF THE TEST CARPETS PRIOR TO AND FOLLOWING THE SERVICEABILITY TEST

Fiber, Pile Type and Pile Height	Compressional Resilience		Difference
	Prior to Test	Following Test	
	Percent	Percent	
Uncut Pile			
Wool			
High	87.74	84.29	-3.45
Low	86.26	85.95	-0.34*
Difference	- 1.48	+ 1.66	
Acrylic			
High	86.86	85.25	-1.61
Low	83.07	80.93	-2.14
Difference	- 3.79	- 4.32	
Nylon			
High	86.09	86.28	+0.19*
Low	86.04	83.10	-2.98
Difference	- 0.05	- 3.18	
Cut Pile			
Wool			
High	80.82	79.75	-1.07
Low	81.00	80.16	-0.84
Difference	- 0.18	+ 0.41	
Acrylic			
High	77.49	76.82	-0.67
Low	86.65	81.17	-5.48
Difference	+ 9.16	+ 4.35	
Nylon			
High	84.60	77.50	-7.10
Low	78.41	80.64	+2.23**
Difference	- 6.19	+ 3.14	

*Similar compressional resilience prior to and following serviceability testing.

**Compressional resilience higher following wear than prior to wear.

exceptions, carpets following wear were slightly less resilient than carpets prior to wear. The two exceptions were two nylon carpets. The compressional resilience of the uncut nylon carpet of high pile height was similar prior to and following wear. The cut nylon carpet of low pile height was more resilient following wear than it has been prior to wear.

Findings also indicated that in both laboratory analyses carpets of uncut pile, with one exception, were more resilient than carpets of cut pile. The one exception was the uncut acrylic of low pile height which was less resilient than the cut acrylic of low pile height.

Although the uncut wool carpet of high pile height was the most resilient carpet prior to the serviceability test, uncut nylon carpet of high pile height was indicated as the most resilient carpet following wear. This is shown by a definite decrease in the resilience of the wool carpet following wear and a negligible change in the resilience of the nylon carpet following wear. The cut acrylic carpet of high pile height with only a slight decrease in resilience following wear, however, was the least resilient of the test carpets both prior to and following the serviceability test.

The uncut acrylic and nylon carpets of high pile height were more resilient prior to and after being walked on than those of low pile height. The uncut wool carpets showed a reverse effect, however, in that the wool carpets of low pile height which were less resilient prior to wear became more resilient than those of high pile height following the serviceability test.

The cut wool, acrylic and nylon carpets of low pile height with one exception were all more resilient than the respective carpets of high pile height prior to and following the serviceability test. The one exception was the cut nylon carpet of high pile height which had been more resilient than the low nylon carpeting prior to the test. Following the serviceability test the high pile nylon carpet had decreased 7.10 percent in resilience which was the greatest change in resilience to occur in any of the test carpets. The carpet which decreased in resilience the least following wear was the uncut wool carpet of low pile height.

VISUAL EVALUATION OF CARPET SAMPLES FOLLOWING WEAR

Twenty-five women compared visually the 72 carpet samples which had been subjected to a wear test to samples of the same carpeting which had not been subjected to wear testing. These 25 women were either members of the faculty or graduate students in the School of Home Economics who were willing to assist in the study. Any changes from the original texture or appearance of the surface pile were the major considerations in rating the carpeting.

A test panel of three women suggested that the rating scale be adjusted from a 1 to 5 rating to a scale that allowed fractional rating between the major classes. This change in procedure was made to aid the panel in making a more critical and precise evaluation of visible changes in the carpets.

The full range of evaluations by the panel may be seen in Table 10. The highest percentage of ratings, 83 percent, fell within the range of slight change (1.1 to 2.0) to noticeable change (2.1 to 3.0). Only a small percentage, 7.3 percent, fell within either of the extreme ranges (negligible change, 0.0 to 1.0: extreme change; 4.1 to 5.0). The remaining 9.7 percent were in the range of substantial change (3.1 to 4.0).

Although panel ratings varied, differences in mean results of visible changes were quite similar. The means of the panel ratings of the visible changes in the 12 carpets are presented in Table 11 and shown graphically in Figure 5.

The ratings for visible changes in the 12 carpets ranged from 1.90 (least changed) for the uncut wool carpet of low pile height to 2.91 (most changed) for the cut nylon carpet of low pile height. The graph and table clearly illustrate that all uncut pile carpets, with the exception of the nylon carpet of low pile height, changed less in appearance after being walked on than the corresponding carpets of cut pile.

Table 10

FREQUENCY DISTRIBUTION SHOWING THE RATINGS OF VISIBLE CHANGES IN TWELVE CARPET TYPES FOLLOWING WEAR

Rating Scale

Class 4.1 - 5.0 - Extreme Change
Class 3.1 - 4.0 - Substantial Change
Class 2.1 - 3.0 - Noticeable Change
Class 1.1 - 2.0 - Slight Change
Class 0.0 - 1.0 - Negligible or no Change

Carpet Characteristics	Classification of Ratings									
	0.0 - 1.0		1.1 - 2.0		2.1 - 3.0		3.1 - 4.0		4.1 - 5.0	
	No.	%	No.	%	No.	%	No.	%	No.	%
Wool										
Uncut Pile										
High	2	8	11	44	12	48	--	--	--	--
Low	5	20	14	56	6	24	--	--	--	--
Cut Pile										
High	--	--	8	32	13	52	2	8	2	8
Low	--	--	5	20	15	60	3	12	2	8
Acrylic										
Uncut Pile										
High	3	12	14	56	8	32	--	--	--	--
Low	--	--	10	40	14	56	1	4	--	--
Cut Pile										
High	--	--	8	32	15	60	2	8	--	--
Low	--	--	4	16	15	60	4	16	2	8
Nylon										
Uncut Pile										
High	4	16	14	56	6	24	1	4	--	--
Low	1	4	5	20	17	68	1	4	1	4
Cut Pile										
High	--	--	8	32	11	44	6	24	--	--
Low	--	--	4	16	12	48	9	3	--	--
Total No. of Ratings	15		105		144		29		7	
Total Percent*		5.0		35.0		48.0		10.7		2.3

*Total percent was obtained by dividing 300 into the total number of ratings in each column, multiplied by 100.

Table 11

MEAN RATINGS OF VISIBLE CHANGES IN APPEARANCE OF THE CARPETS FOLLOWING SERVICEABILITY TESTING

Carpet Construction	Carpet Fibers			
	Wool	Acrylic	Nylon	Mean
Pile Type				
Uncut Pile				
High	2.16	2.00	1.92	2.02
Low	1.90	2.40	2.53	2.27
Mean	2.03	2.20	2.22	2.15
Cut Pile				
High	2.60	2.49	2.61	2.56
Low	2.86	2.81	2.91	2.96
Mean	2.73	2.65	2.76	2.71
Pile Height				
High Pile				
Uncut	2.16	2.00	1.92	2.02
Cut	2.60	2.49	2.61	2.58
Mean	2.38	2.25	2.26	2.30
Low Pile				
Uncut	1.90	2.40	2.53	2.27
Cut	2.86	2.81	2.91	2.86
Mean	2.38	2.60	2.72	2.57
Overall Fiber Means	2.38	2.43	2.49	----

LSD	0.05 level	0.01 level	LSD	0.05 level	0.01 level
Pile Height	0.14	0.19	Fiber x Pile Height	0.25	N.S.
Pile Type	0.14	0.19			

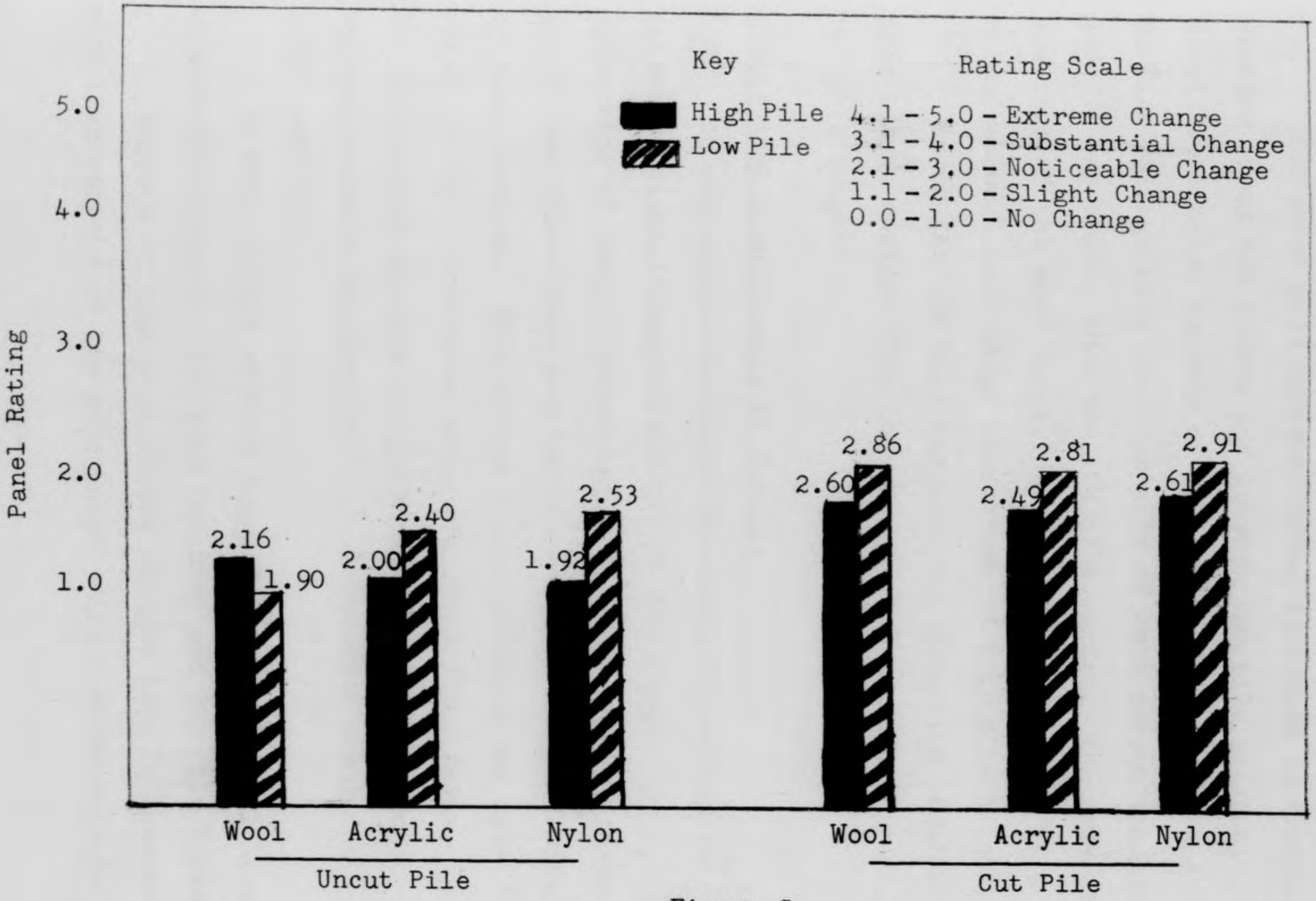

Figure 5

MEAN RATINGS OF VISIBLE CHANGES IN APPEARANCE OF THE CARPETS FOLLOWING SERVICEABILITY TESTING

The uncut pile carpets showed variation in visible changes among the fibers and between the pile heights. Acrylic and nylon carpets of both pile heights received similar ratings with the high pile of each carpet changing less in appearance than the low pile carpet. The reverse was true of the wool carpeting where carpets of low pile height showed less change than those of high pile height.

Among the cut pile carpets, the carpeting of high pile height changed less in appearance than carpeting of low pile height.

Statistical Significance of Results

An analysis of variance (Appendix F) was used to determine significant differences in the changes in appearance of the 12 tested carpet samples of three fiber types, two pile types, and two pile heights compared with original samples. Each of the three variables was analyzed for (1) differences among the three fiber types, (2) differences between two pile types, (3) differences between two pile heights, and (4) interaction among the three variables.

Visible change effects significant at the 0.01 level of probability were: (1) Pile heights, and (2) Pile types.

Carpets of high pile height changed less in appearance than carpets of low pile height with a difference in rating of 0.27. Carpets of uncut pile changed less in appearance than carpets of cut pile with a rating difference of 0.29.

Differences in changes in appearance in the interaction between fibers and pile heights were significant at the 0.05 level of probability. Mean ratings showing the differences in visible changes between fibers and pile heights and between fibers within high and low pile heights are presented in Table 12. The difference in visible changes between wool carpets of high and low pile height were not significant. The differences in changes in appearance between acrylic carpet of high and low pile height and between nylon carpet of high and low pile height were significant at the 0.05 level of probability. A difference in rating of 0.34 in which wool carpeting of low pile height changed less in appearance than nylon carpeting of low pile height was also significant at the 0.05 level.

No significant differences in visible changes were observed:

1. Among the three fibers.
2. Between the fibers and the pile types.
3. Between the pile heights and pile types.
4. Among the fibers, pile types, and pile heights.

Table 12

MEAN RATINGS SHOWING DIFFERENCES IN VISIBLE CHANGES BETWEEN FIBERS OF TWO PILE HEIGHTS AND BETWEEN FIBERS WITHIN HIGH AND LOW PILE HEIGHTS

Fiber Type	Carpet Construction		Difference
	High Pile	Low Pile	
Wool	2.38	2.38	0.00
Acrylic	2.25	2.60	.35*
Nylon	2.26	2.72	.46*
Wool vs. Acrylic	2.38-2.25	----	.03
Wool vs. Nylon	2.38-2.26	----	.11
Acrylic vs. Nylon	2.25-2.26	----	.02
Wool vs. Acrylic	----	2.38-2.60	.22
Wool vs. Nylon	----	2.38-2.72	.34*
Acrylic vs. Nylon	----	2.60-2.72	.12

LSD for comparing three fibers within two pile heights.
0.05 level = 0.247

Findings

The findings indicated that it was difficult for the panel to detect major differences in changes in appearance of the 12 types of carpets. With one exception carpeting of uncut pile of the three fibers and two pile heights did not change in appearance as much as the corresponding carpeting of cut pile. With one exception carpets of high pile height were statistically less changed in appearance than carpets of low pile height. The exception was uncut wool carpeting in which the carpet of high pile height changed more in appearance than the wool carpet of low pile height.

Cut nylon of low pile height, which showed a higher degree of matting than the other carpets, was rated as the most changed in appearance of the 12 carpet types. The carpets rated as least changed in appearance were uncut wool of low pile height and cut nylon of high pile height which received similar ratings.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

SUMMARY

This study was an outgrowth of research in which the importance of compressional resilience as a factor contributing to consumer selection of carpeting was investigated.[1] During an evaluation in which consumer reaction to fiber resilience of the 12 carpets was studied, Sears detected that marked differences in the surface appearance of the different fiber types occurred very quickly. Since the differences could not be investigated at that time, a future study involving a floor trial of the same carpets was recommended.

The major purpose of the floor trial was to evaluate how fiber type, pile height and pile type affected the resilience and changes in texture of the pile when the carpet received a moderate amount of walk-ons. Since the floor trial was limited to 12 weeks, the differences in results of compressional resilience and changes in appearance were small or many times not significant. Differences

[1]Nancy Sears, "Relation of Fiber Resilience to Consumer Selection of Carpeting," (unpublished Doctor's Dissertation, The University of North Carolina at Greensboro, 1969), p. 3.

which did exist, however, were thought to be indicative of trends of the wear life of a carpet.

The objectives of this study were: (1) to determine the difference in resilience characteristics of selected carpeting prior to and following serviceability testing, (2) to compare the resilience of the carpeting following use with the resilience prior to the serviceability test, and (3) to evaluate the changes in appearance of the carpets after the serviceability test by visually comparing the worn samples with samples which received no wear.

Carpet Samples

The 12 carpets, specially manufactured by a leading carpet manufacturer, were all of tufted construction and included three fiber types (wool, acrylic, and nylon). Each fiber type was manufactured in two pile types (cut and uncut) and with two pile heights (high and low) within each pile type. The carpets of low pile height were manufactured to be within 0.2 to 0.4 inches. The carpets of high pile height were manufactured to be within 0.4 to 0.6 inches. These specifications represented height of tufts exclusive of carpet backing.

Test Carpet

The 12 carpet samples which were coded according to fiber type, pile height and pile type were cut into nine 9 inch squares. Six of the squares or a total of 72 squares were used in the test carpet; three of the squares were retained as control samples to be used in the visual evaluation and to measure carpet thickness prior to serviceability testing.

The test carpet was made up of six replicates of each of the 12 carpets. Due to its size the samples were randomized so that the carpet would not have to be rotated or changed in any way during the test period. A three-factor split-plot design was used, with the whole plot (pile type) arranged according to a completely randomized design. The subplot treatments consisting of a 2 x 3 factorial of pile heights and fibers was arranged in a Latin Square.

A nine inch border was attached on all four sides to alleviate wear on the outer edges of the carpet squares to be tested. The carpet was then placed in a hallway in the Home Economics Building at the University of North Carolina at Greensboro for a period of 12 weeks. An electric counter was used to approximate the number of walk-ons per week. The carpet was vacuum cleaned once a week to restore pile and to aid in preventing changes in appearance.

Compressional Resilience

Carpet thickness measurements (original, compressed, and recovered) were taken with the C & R Tester prior to and following the serviceability test. These measurements were used to determine the compressional resilience which was based on 12 measurements for each carpet.

An analysis of variance for a 3 x 2 x 2 factorial design was performed on the measurements of compressional resilience of the carpets prior to and following the serviceability test. Differences were analyzed: (1) among three fibers, (2) between two pile types, (3) between two pile heights, and (3) between interactions among the three variables.

Following the serviceability test 25 women faculty and graduate students in The School of Home Economics compared visually the surface pile of each sample with control samples. A rating scale was devised and employed by the women to evaluate any changes in surface pile or original texture.

An analysis of variance, with the same variations used to determine compressional resilience, was also used in analyzing this data. Tests of significance were made at both the 0.01 and 0.05 levels.

Compressional Resilience Prior to Serviceability Testing

Prior to the serviceability test highly significant differences in the compressional resilience were indicated between the cut and uncut pile carpets, between the fibers and pile heights and in the triple interaction between fibers, pile heights and pile types. As tested in this study the uncut pile carpeting was consistently more resilient than cut pile carpeting. High pile carpeting was more resilient among carpets of uncut pile, whereas, low pile carpeting was more resilient among carpets of cut pile.

The fiber type could not be ranked in the same order within the different variables, but within the triple interaction uncut wool carpet of high pile height was the most resilient. Cut acrylic carpet of low pile height was the least resilient.

Compressional Resilience Following Serviceability Testing

Following the serviceability test highly significant differences in compressional resilience were indicated between the cut and uncut pile carpets, within the interaction between the pile types and the pile heights, and in the triple interaction between fibers, pile heights and pile types. The results of this study also indicated that the uncut pile carpeting was consistently more resilient than cut pile carpeting. High pile carpeting was more resilient among carpets of uncut pile; whereas, low pile carpeting was more resilient among carpets of cut pile.

The fibers could not be ranked in the same order within the different variables, but within the triple interaction uncut nylon of high pile height was the most resilient carpet. The cut acrylic of low pile height was the least resilient carpet as it had been prior to the serviceability test.

Visual Evaluation Following the Serviceability Test

Following the serviceability test the visual changes which took place in the carpets were highly significant between the pile heights and between the pile types. The cut pile carpeting consistently changed more in appearance than uncut pile carpeting which indicates that for the three fibers tested greater appearance retention can be maintained through the selection of uncut pile as opposed to plush cut pile.

With one exception, high pile carpeting of the three fibers and two pile types, were indicated statistically as changing less in appearance than corresponding carpets of low pile height. The one exception was the uncut wool carpet of low pile height which received the rating of least changed in appearance of all the carpet samples. The information indicates that according to this study high pile carpeting of the three fibers and two pile types would generally be the best selection for appearance retention.

CONCLUSIONS

As a result of this study the following conclusions were drawn:

1. The fiber types had no apparent effect upon the compressional resilience and upon the changes in appearance of the carpets used in this study.

2. The pile heights had no apparent effect upon the compressional resilience of the carpets used in this study.

3. The pile heights affected the changes in appearance of the carpets following the serviceability test. Generally, carpets of high pile height retained their appearance better than carpets of low pile height.

4. The pile types affected the compressional resilience and the changes in appearance of the carpets used in this study. Uncut pile carpets were generally more resilient than cut pile carpets prior to and following the serviceability test. The uncut pile carpets, also, generally retained their appearance better than cut pile carpets following the serviceability test.

5. Although the main factors of fiber type and pile height did not affect the compressional resilience of the carpets tested, the interaction of fibers and pile heights did affect the resilience of the carpets prior to the serviceability test. This was particularly true of the differences in resilience between: (1) nylon carpets of high and low pile height, (2) between acrylic and nylon carpets of high pile height, and (3) between acrylic and nylon carpets of low pile height.

6. The triple interaction among fibers, pile heights and pile types affected the compressional resilience of carpets used in this study. No one carpet could be ranked in the same order as most resilient prior to and following wear. However, the cut acrylic carpet of low pile height was least resilient prior to and following the serviceability test.

7. High uncut pile carpets of the three fiber types were more resilient than low uncut carpets prior to and following wear.

8. With one exception low cut pile carpets of the three fiber types were more resilient than the respective carpets of cut pile, prior to and

following the serviceability test. The one exception was cut nylon of high pile height which was significantly more resilient than cut nylon of low pile height.

RECOMMENDATIONS FOR FURTHER STUDY

Further research in the area of laboratory testing of carpeting is recommended as a result of this study.

1. A similar floor trial study comparing the characteristics of carpets made of wool and acrylic fibers with those made of polyester fibers; and nylon fibers with those made of polypropylene fibers.

2. A similar floor trial studying characteristics of carpeting made of bicomponent fibers.

3. A floor trial of selected carpeting in which thickness measurements are taken at stated intervals throughout the extended test.

4. A comparison of the effect of wear on compressional resilience of selected carpeting used in a floor trial with carpeting tested by mechanical means.

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APPENDICES

APPENDIX A

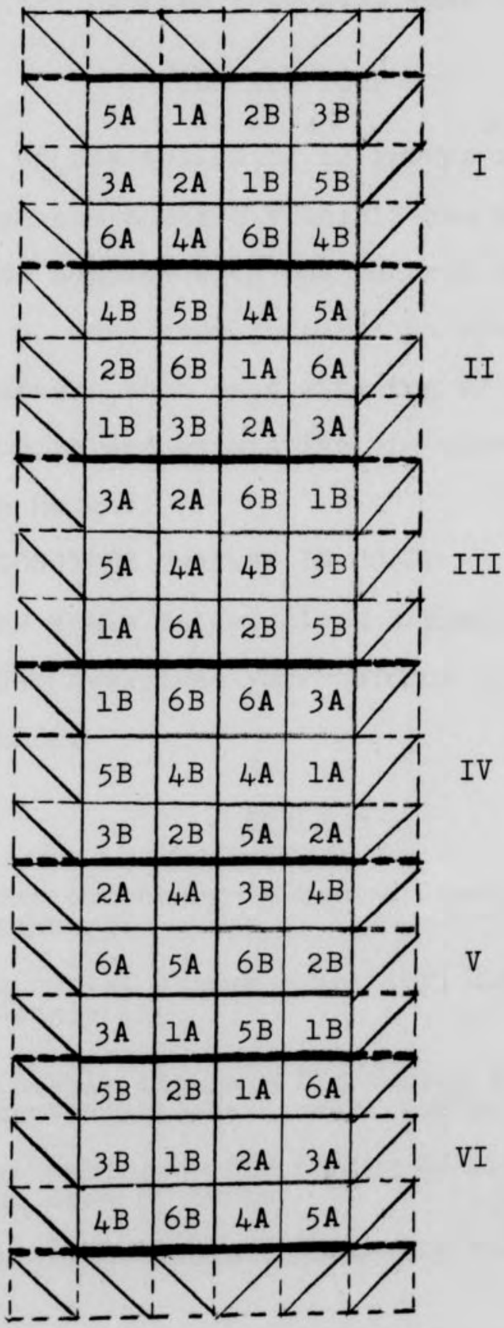
CODING SYSTEM OF CARPET SAMPLES

Fibers	Pile Height	Pile Type
M_1 - Wool	P_1 - High	A - Uncut or looped
M_2 - Acrylic	P_2 - Low	B - Cut or plush
M_3 - Nylon		

1A - M_1P_1	1B - M_1P_1
2A - M_1P_2	2B - M_1P_1
3A - M_2P_1	3B - M_2P_1
4A - M_2P_2	4B - M_2P_2
5A - M_3P_1	5B - M_3P_1
6A - M_3P_2	6B - M_3P_2

APPENDIX B

THE DIAGRAM SHOWING RANDOMIZATION OF CARPET SAMPLES



APPENDIX C

EVALUATION OF APPEARANCE AND TEXTURE OF CARPET SAMPLES FOLLOWING WEAR

INSTRUCTIONS

In each of the following 12 groups of carpets (I A through VI B) please compare visually the surface pile of the six numbered samples with the control sample.

You are to base your judgment on the changes from the original texture such as flattening or matting of the pile, loss of tufts and untwisting of tufts and/or apparent changes of pile height.

DO NOT CONSIDER CHANGES IN COLOR

Using the scale below, place a check mark in the column which best describes your opinion of the changes in surface appearance.

SCALE

5 - An extreme change - marked loss of original texture.

4 - Substantial change - matting, loss of tufts, untwisting.

3 - Noticeable change - flattening of pile, some matting, slight loss of tufts.

2 - Slight change - flattening of pile, no matting no loss of tufts.

1 - No change - indistinguishable from original.

Sample Number	Group IA				
	5	4	3	2	1
1					
2					
3					
4					
5					
6					
Total					
Average					

Sample Number	Group IB				
	5	4	3	2	1
1					
2					
3					
4					
5					
6					
Total					
Average					

Sample Number	Group IIA				
	5	4	3	2	1
1					
2					
3					
4					
5					
6					
Total					
Average					

Sample Number	Group IIB				
	5	4	3	2	1
1					
2					
3					
4					
5					
6					
Total					
Average					

Sample Number	Group IIIA				
	5	4	3	2	1
1					
2					
3					
4					
5					
6					
Total					
Average					

Sample Number	Group IIIB				
	5	4	3	2	1
1					
2					
3					
4					
5					
6					
Total					
Average					

Comments:

Group IVA

Sample Number	5	4	3	2	1
1					
2					
3					
4					
5					
6					
Total					

Average

Group IVB

Sample Number	5	4	3	2	1
1					
2					
3					
4					
5					
6					
Total					

Average

Group VA

Sample Number	5	4	3	2	1
1					
2					
3					
4					
5					
6					
Total					

Average

Group VB

Sample Number	5	4	3	2	1
1					
2					
3					
4					
5					
6					
Total					

Average

Group VIA

Sample Number	5	4	3	2	1
1					
2					
3					
4					
5					
6					
Total					

Average

Group VIB

Sample Number	5	4	3	2	1
1					
2					
3					
4					
5					
6					
Total					

Average

Comments:

APPENDIX D

ANALYSIS OF VARIANCE OF COMPRESSIONAL RESILIENCE OF TEST CARPETS PRIOR TO SERVICEABILITY TESTING

Sources of Variation	Degrees of Freedom	Sums of Squares	Mean Squares	F
Cut vs. Uncut	1	737.35	737.35	63.83**
Reps Cut vs. Uncut (Error (a))	4	46.20	11.55B	
Fiber	2	4.85	2.43	0.26 N.S.
Pile Height	1	4.36	4.36	0.47 N.S.
Fiber x Pile Height	2	202.54	101.27	10.81**
Cuts vs Uncut x Fiber	2	62.07	31.04	3.31 N.S.
Cuts vs. Uncut x Pile Height	1	70.46	70.46	7.52*
Cuts vs. Uncut x Fiber x Pile Height	2	555.11	277.55	29.61**
Error (b)	20	187.44	9.37	
Sampling Error	108	1625.28	15.05	
Corrected Total	143	3495.67	24.44	

Number of Measurements - 144

*Significant at the 0.05 level
**Significant at the 0.01 level

APPENDIX E

ANALYSIS OF VARIANCE OF COMPRESSIONAL RESILIENCE OF TEST CARPETS FOLLOWING SERVICEABILITY TESTING

Sources of Variation	Degrees of Freedom	Sums of Squares	Mean Squares	F
Cut vs. Uncut	1	885.24	885.24	90.01**
Reps Cut vs. Uncut (Error (a))	10	98.35	9.83	
Fiber	2	58.88	26.94	0.75 N.S.
Pile Height	1	4.34	4.34	0.28 N.S.
Fiber x Pile Height	2	8.70	4.35	0.28 N.S.
Cut vs. Uncut x Fiber	2	14.78	7.39	0.48 N.S.
Cut vs. Uncut x Pile Height	1	188.66	188.66	12.23**
Cut vs. Uncut x Fiber x Pile Height	2	161.15	80.57	5.22**
Error (b)	50	771.42	15.43	
Sampling Error	72	641.91	8.92	
Corrected Total	143	2828.41	19.78	

Number of Measurements - 144

*Significant at the 0.05 level
**Significant at the 0.01 level

APPENDIX F

ANALYSIS OF VARIANCE OF THE RATING OF CHANGES IN APPEARANCE OF THE CARPETS FOLLOWING SERVICEABILITY TESTING

Sources of Variation	Degrees of Freedom	Sums of Squares	Mean Squares	F
Fibers	2	0.62	0.31	0.78 N.S.
Pile Heights	1	5.54	5.54	1.40**
Fibers x Pile Height	2	2.78	1.39	0.35*
Uncut x Cut	1	23.74	23.74	6.00**
Fibers x Cut vs. Uncut	2	0.82	0.41	0.37 N.S.
Pile Height x Cut vs. Uncut	1	0.03	0.03	0.09 N.S.
Fiber x Pile Height x Cut vs. Uncut	2	2.32	1.16	0.29 N.S.
Ind (Fiber x Pile Height x Cut vs. Uncut Pooled Error)	288	113.86	0.39	
Corrected Total	299	149.74	0.50	

Number of Ratings - 300

*Significant at the 0.05 level
**Significant at the 0.01 level