AN EVALUATION OF SELECTED TYPES OF SYNTHETIC, WOOL AND SYNTHETIC, AND WOOL CARPETING

Thesis for the Degree of M. A.

MICHIGAN STATE COLLEGE

Elizabeth Wells Benson

1952

SIS

This is to certify that the

thesis entitled

An Evaluation of Selected Types of
Synthetic, Wool and Synthetic and
Wool Carpeting

presented by

Elizabeth Wells Benson

has been accepted towards fulfillment
of the requirements for

Master of Arts degree in Textiles and Clothing

Hazel B. Strahan
Major professor

Date May 20, 1952

O-169

AN EVALUATION
OF SELECTED TYPES OF SYNTHETIC, WOOL AND SYNTHETIC, AND WOOL CARPETING

By

ELIZABETH WELLS BENSON

A THESIS

Submitted to the School of Graduate Studies of Michigan State College of Agriculture and Applied Science in partial fulfillment of the requirements for the degree of

MASTER OF ARTS

Department of Textiles, Clothing and Related Arts

1952

Acknowledgments

The writer wishes to express her sincere gratitude to the following people:

Miss Hazel B. Strahan, head of the Textiles, Clothing and Related Arts Department, for her guidance and assistance in selection of a problem and its supervision.

Professor Bruce E. Hartsuch for his willing assistance in the Chemical analysis of the samples.

Miss Sarah Brier for her assistance in the Textile Laboratory.

Elizabeth Wells Benson

TABLE OF CONTENTS

CHARTS AND PLATES

I. INTRODUCTION

Price and limited availability of carpet wool has resulted in increased production of carpeting in which the use of all-synthetic or synthetic-wool blends are dominate. Because synthetic pile is relatively new on the market there is reluctance on the part of the consumer to accept it in place of the traditional all-wool pile carpeting. An understanding of carpet construction, the problems of the industry, and serviceability studies would aid the consumer in intelligent selection of carpets for their specific needs.

All carpet wool is imported. Argentina furnishes approximately one-half of our needs.[9] Other sources selling to the United States are Scotland, China, Mongolia, Tibet, Egypt, India, Iraq, Syria, Iceland, New Zealand, Ireland, Portugal, Italy and Spain.

Seventy percent of all carpeting produced in the United States is made by six large companies; namely Mohawk Carpet Mills, Bigelow-Sanford Carpet Company, Alexander Smith & Sons carpet Company, and the Firth Carpet Company. The Bigelow-Sanford Company is the largest and the oldest, having celebrated its 125th anniversary in 1950.

All manufacturers have been concerned over the tight supply of carpet wool and the high prices. The average cost of clean carpet wool in 1939 was 23.7 cents per pound. Due to the world political and economical conditions following World War II, price of wool soared to a peek of $2.24 per pound in March 1951.[39] In <u>Rayon and Synthetic Textiles</u> for

September 1950, Mr. Goodwin of the Magee Carpet Company was quoted as saying:

> "It used to be a standard saying in the carpet field that if wool went to $.50 a pound, that was as far as a carpet manufacturer could go and still maintain a market for his product. Wool today(1950) for the average blend has reached 95 cents a pound, and there is a terrific shortage."(21)

It is only natural that this condition would further interest in the use of synthetic fibers. However, this is not a sudden interest for some of the carpet companies have been experimenting with synthetic carpet fibers for more than fifteen years.

The rayon industry likewise is interested in developing fibers suitable for the carpet industry. Daniel SMall writes in a Market Newsletter in Rayon and Synthetic Textiles, August 1950

> "The carpet industry imports as much as two hundred thousand pounds of carpet wool per year. If we could assume one-half this market it would be well worth our while".

American chemists have felt for some time that the right synthetic would be a boom to the carpet industry. Success in developmental research could assure the mills a free and stable market. The fiber would be clean, white, and predictable in its uniformity of quality. Desired characteristics such as resistance to moths, fire, and soil lie within the possibility of research development.

Fibers suitable for carpeting must have length, stiffness, fullness, resiliency and strength. These qualifications are hard to meet. Of the four hundred different types of wool on the international market, no one type possesses all of the above characteristics, thus necessitating blending of many different kinds of carpet wool.

Synthetic apparel fibers are not satisfactory for use in carpeting, as a coarser, stiffer, more resilient fiber is needed. Research chemists have attacked this problem from two directions; first, through continued experimentation with re-generated cellulose, and secondly the development of new carpet fibers from nylon, Orlon and Saran. Today the leading man-made carpet fibers are for the most part made of regenerated cellulose. Avisco '15', produced by the American Viscose Company is a 15 denier viscose rayon. Estron, a product of the Tennessee Eastman Company, and Celcos, a Celanese Corporation product are both cellulose acetates. Nylon makes an excellent pile for carpeting, but the fiber is currently too much in demand for other uses, and too expensive for the construction of moderately priced carpeting. Although Orlon is considered to be the most wool-like of all synthetics, it is still in the experimental stage as a carpet fiber.

The blending of two or more fibers should not imply adulteration. It is true that during the war, some carpet manufacturers felt forced to purchase rayon waste material for use in production. This situation was obviously detrimental to the industry and the use of rayon waste was soon eliminated. The $152,000,000[37] carpet industry could not afford to jeopardize its reputation by the use of a fiber that had nothing to offer the finished product except availability and lower cost.

However, rayon if made to carpet fiber specifications does offer certain advantages. Technological improvements have made possible the processing of fibers of desired diameters, which may be cut into desired lenghts. Advantages lie in the fact that these fibers are completely moth-proof and flame resistant, and they can be dyed in clear, brilliant colors.

Rayon and wool fibers combined in blends tend to compliment one another. Wool is neither moth nor fire-resistant. It's greatest values are in it's resiliency and bulk, both of which are lacking in synthetic fibers unless a permanent crimp is added. Wool soils more readily than rayon, but gives up soil more readily when a commercial ~~cleaner~~ solvent is applied.

Blends must be planned to give the best quality values at the most economical cost. It has been found that if 25% or more of a fiber is blended into a carpet it will enhance the carpet by its good points or weaken the carpet with its poor points--thus, blending is dependent upon the characteristics of the fibers to be blended. It is a complex process requiring new machines and technology, which must be learned by the carpet mill employee, as well as the producer of synthetic fibers.

G. E. Schulz, President of the Nye-Waite Carpet Company, in communication with the Michigan State College Textile Department writes:

> "I am disposed to believe two things,--that some of the blends in synthetic carpets will work out satisfactorily and further that eventually a good share of the production of the carpets will be from 100% synthetic fibers. Some of them are not satisfactory for such specifications at present. In my opinion the industry should have adopted synthetic materials several years ago instead of waiting for the emergency that has developed."

Due to the increased production of all synthetic or synthetic-wool blends now available in the retail market, there has been an increased number of consumer inquires concerning their performance. It was thought a study simulating normal use and care of four of these new carpetings for comparison with traditional all-wool carpets would be of interest and value to consumers. It would aid in determining the relationship of price in respect to performance, and might present some suggestions for information which should appear on the labels of carpets in order to aid the purchaser in his selections.

This specific study plans:

First, an analysis of the initial physical properties of four selected types of carpeting containing a blend of synthetic and wool fibers or 100% synthetic fibers in the pile, and four wool pile carpets comparably priced and similar in appearance. Chemical and microscopic analysis of the pile and backing yarns; specifications of weave and yarn structure; weight per square yard; density and height of pile; and compressional resilience of the pile constitute specification analysis.

Secondly, a comparison of performance under conditions simulating normal home use and care was planned as laboratory testing in colorfastness to light; subjective comparison for alteration in appearance of samples abraded a constant number of cycles; and relative efficiency in removal of standard soil by vacuum cleaning and shampooing. Comparison of the degree and rate of recovery from crushing constitutes a fourth performance test.

II. REVIEW OF LITERATURE

Federal laws require a manufacturer to state the fiber content of all carpet pile. However, it does not require that the percentages of wool from different sources, nor the source be divulged. Each manufacturer decides upon the proper blending of several different wools of varying characteristics for the specific grade and type of carpeting he wishes to make. For instance, a high-grade carpet might be composed of a certain amount of wool from Turkey or Syria for added strength; South American wool for luster; or Chinese wool for resiliency. For ease in spinning, these short fibers might be twisted with the long fibers of the black sheep raised in Scotland. The amount of each fiber used in each type of carpet remains the trade secret of the producer.

Federal laws require that carpets containing rayon be labeled as such. However, they do not specify that either the type of rayon or the percentage used in wool-synthetic blends be placed on the label. Neither is it necessary to state whether the pile is constructed of apparel or carpet rayon fibers or rayon waste. However, many carpet manufacturers and textile fiber mills are designating their new synthetic carpet fiber through the use of a specific trade name rather than the term 'rayon' in order to designate its end use.

"Avisco-15", a viscose rayon produced by the American Viscose Company is the synthetic fiber used by the Mohawk Carpet Mills, and others. The number "15" refers to the denier of the filament, which is comparable to the average fiber diameter of the best carpet wools. The filaments from which viscose staple carpet fiber is cut consist of a number of highly uniform rod-like fibers of a natural white. Avisco "15" is permanently crimped; the yarns being cut into approximately 3 inch lengths, and delustered to the degree considered best for carpet use.(34) The Bigelow-Sanford Carpet Company also uses a viscose carpet fiber which is produced in their rayon mill in Rocky Hill, Connecticut.

Estron is the name designated by the American Society of Testing Materials for all cellulose ester fibers. Estron carpet fiber is produced by the Tennessee Eastman Company, and has been used by the James Lee and Son's Carpet Company in the manufacture of their synthetic carpets. Cellulose acetate filaments are strong, uniform and white, with a high degree of resiliency, and a hand similar to that of wool. Cellulose Acetate fibers are slightly more difficult to dye than viscose rayon fibers and colors in finished products may be affected by gas fumes. Celcos is produced by the Celanese Corporation. It, too, is cellulose acetate. A "17" denier Celcos is used by the Alexander Smith & Sons Carpet Company in their manufacture of synthetic-blend carpetings.

Nylon, a product of Dupont De Nemours and Company, is characterized by its excellent durability and high degree of resiliency. Unlike wool it is not damaged by moths and not easily affected by changes in humidity. Carpets of nylon pile, produced by the Nye-Waite Carpet Company, and others, are being primarily used in business establishments where durability is more important than initial cost. The Firth Carpet Company announced recently their production of a new 'carved' broadloom of vinyon. This carpet fiber is called 'cellini', and is not currently in commercial production. Orlon, Saran, Velen, Vicara and other synthetic fibers are also being tried out experimentally for use in carpet manufacture.

In the selection of the best synthetic carpet fiber for a specific need, the manufacturer must consider price and fiber size. Nylon, vinyon and other similar fibers are expensive, costing from three to four times as much as fibers made from a cellulose base such as Avisco, estron and Celcos.[(18)] Synthetic fibers which are to be blended with wool must be comparable in length, weight, diameter and strength if the resulting yarn is to be satisfactory. Carpet wools range from 1 to 13 inches in length, while synthetic staple fibers are cut in three inch lengths for convenience in spinning. The specific gravity of wool is 1.30. The specific gravity of synthetic fibers depends upon the process used in manufacturing--cellulose acetate being 1.33 and viscose 1.53[(38)].

Woolen carpet yarns are much coarser than those used in the apparel industry. They are usually 1.6 to 2.4 Typp, whereas woolen clothing yarns vary from 4.8 to 6.4Typp.[(38)] Clothing yarns are made from rayon filaments which range from 2 to 7 denier, carpet yarns from 15 to 17 denier rayon.

According to the American Wool Handbook (1948) carpet wools ranged from 15 to 70 microns in diameter. However, ideal carpet wool should contain approximately 65% by weight of true wool fibers, with an average diameter of no more than 24 microns, and approximately 35% by weight of heterotypical fibers with an average diameter of at least 30 microns.

Rayon staple fibers may be produced as fine or as coarse as is specified by the manufacturer. Within certain limitations, the coarser the fiber the better it complies with ideal specifications. However, if the synthetic fiber is to be blended with wool the diameter of the fibers must be comparable. The '15' denier Avisco fiber measures approximately 38 microns in diameter, and the '17' denier Celcos approximately 45 microns.

The tensile strength of wool yarns used in carpet manufacture ranges from 40 to 200 pounds according to data compiled for the American Wool Handbook[38]. These figures represent the results of tests in which the skein breaks of 15 yard skeins wound on $1\frac{1}{2}$ yard reels were recorded. Although no tests concerning the strength of rayon carpet yarns have been published, synthetic yarns are generally thought to have a greater tensile strength than wool.

However, the value of a fiber for use in carpet yarns is more dependent upon such latent characteristics as its fiber surface, interfiber relationships, resiliency, fiber crimp, and energy absorption properties than upon its tensile strength. The surface of a fiber is very important in a carpet yarn because of the nature of the wear to which the yarn will be subjected. Gonsalves[14] performed a series of tests on rayon filaments which tend to prove that the outside layer of a rayon filament is stronger than the core. This was accomplished by laying a filament around a roller, and rotating it under tension. It was discovered that when the outer surface was worn, it became cracked and fissures were formed. The localization of additional stress resulted in the final breakage of the filament.

According to Matthew,[19] wool fibers are not so dependent upon the strength of their outer layer. Not only is the external sheath of tissue resistant to crushing stress, but the internal cortical cells are so arranged as to present a very firm resistance to rupture. Thus, these in-

inherent differences in the structure of wool and rayon fibers account for the difficulties in determining accurately their expected performance characteristics.

The amount of friction between fibers is determined by their coarseness, static force, and the ability of the fiber to transmit stress. The latter is particularly pertinent in a discussion of carpet fibers, because of the constant application of stress caused by footsteps and the weight of furniture. In order for a stress to reach the further end of a yarn in which it originates, forces must be transferred from fiber to fiber along and throughout the yarn. These forces can only be transferred at points of fiber-to-fiber contact.[32] In the transmission of a normal load, the nature of the stress is distributed over the area in a manner prescribed by the shapes of the load, and their relative mechanical properties.[13]

The Textile Research Journal has published several articles concerning stress analysis by Platt.[23][24][25] He states that every textile fiber possesses a non-linear stress-strain curve for ordinary rates of loading, depending upon its geometric form and type of construction. He points out that there are many things to take into consideration in making the curve; namely, the laws of static equilibrium, the deformation of the structure, and the action of stress on the cross-section of the fiber.

According to Dillon,[10] the quality of resiliency is measured by a fiber's reaction to stress, and the amount of time involved between the deformation and a satisfactory recovery. The resiliency of wool is essentially different from that of other fibers. Being fairly stiff and springy, it is not readily deformed by short loading periods but under longer loads it becomes increasingly compliant.[38] Rayon fibers do not inherently have as much natural resiliency as wool. Chemists have sought to achieve comparable resiliency in rayon by crimping the fibers.

Rainard and Abbot[26] define crimp in a fiber, 'whether it be regular or irregular, as the degree of deviation from linearity which the fiber possesses'. At first, artificial fibers were crimped to increase bulkiness of the yarns but manufacturers soon realized that it had a far more important effect upon the yarn in that it made it resilient.[6] Results of laboratory measures, described by Barach and Rainard[6], show how much crimp improves a fiber. In a large scale machine for crimping naturally resilient fibers, the fibers were crushed together so as to fold them. After boiling an hour, they were tested, woven into carpets and tested again. Tests showed that there was an actual increase in wear for carpets made with crimped fibers over those made with straight fibers. The crimped fibers had a measurably higher ability to form stabilized structures. An uncrimped fiber can collapse under compressional loads in one or two places but a highly crimped fiber should behave somewhat like a spring under compression. Crimp also improves the hand of the carpet pile. Rainard and Abbot[26] emphasize the fact that a high degree of regularity of crimp is not necessary as it causes close-packing and decreases the bulking tendency of the fiber. If a single crimp is able to stand-off its neighbors, it will create a bulking effect regardless of its shape. Moisture and heat increase the crimp, thereby increasing the resiliency of naturally resilient fibers in the same way that the curl of human hair is influenced by moisture and warmth. However, when fiber crimp is achieved artifically as is the case of synthetic fibers, the crimp is not affected as greatly by humidity and temperature.

Wear is caused by abrasion of one kind or another. Backer[4] explains three different ways in which single fibers, touched by the projection of a foreign surface will act. First, the fibers will be subjected to frictional wear, such as occurs when a person walks across a carpet. Secondly, the fibers will be subjected to surface cutting processes, such as the effect of glass and sand ground into the pile of a carpet by walking. Uneven surface protuberances result when the abradant is extremely forceful, such as the effect resulting from the surface clawing of the carpet by a cat or dog. Through tests made in cooperation with the army concerning clothing, Backer[4] discovered that there is a distinct barbed effect on the surface of spun viscose fibers which have been severely abraded mechanically. This effect has been suggested as a means of 'felting' viscose fibers. However, in the case of carpet pile--felting means matting, an undesireable characteristic. According to Schiefer[30], the slow process of wear evolved by walking on a carpet will break rayon fibers into short segments, whereas wool fibers are frayed and split at the tip and some of them are fractured. Both Schiefer[29] and Backer[4] speak of coatings from worn-out wool fibers which form on the material being abraded.

Various fibers recover from small strains at different speeds, and different abradants will affect fibers differently. For instance, nylon might wear better than wool when subjected to one test, whereas another test might show wool as the better fiber. Therefore, it is important that fibers be spun into yarns of specified size, weight, etc., for a specific purpose.

Yarns form the medium which relates the properties of fibers to the properties of the carpet pile. However, many steps are necessary to convert wool fleece into carpet yarns. Man-made fibers are more easily converted, although they too must be sorted, dyed and spun.

Wool arrives at the mills dusty and dirty. The fleeces must be pulled apart and blended with the fleeces from other sources in accordances with the manufacturer's specifications. The wool is next scoured in warm water in order to remove accumulated grease, dirt and discoloration. Synthetic fibers, rigidly controlled throughout the manufacturing process, are without foreign matter which might influence the quality of the batch, and therefore are ready for conversion into yarns as soon as the fiber is manufactured.

As a rule, carpet fibers are dyed before they are spun. This process, regardless of the type of fiber is not an easy one. A wool fiber is complex; consisting of a smooth, uniform outer layer known as an exo-cuticle. Beneath this lies a second layer, the endo-cuticle, which is pitted and ridged longitudinally. Within the cuticle lies the cortex. The rate and degree of penetration of dyes are influenced by the character of both the cuticle and cortex, as well as the dye itself. Experiments show that the dye must penetrate the cuticle, and diffuse with comparative ease through-out the cortex, if the dye is to be uniform throughout.[20] The coarser the wool fiber, the more difficult it is to dye it satisfactorily.[39] One theory concerning the dyeing of avisco fibers is that single molecules of dye are absorbed on the surface of the fiber and reach the center through a diffusion process. The dye is fixed in the cellulose by co-ordinating bonds and each dye molecule is 'set' by the cellulose chain with which it is combined.[28] Another factor in the dyeing of this type of rayon is the fact that regenerated rayons lose from 40 to 50% of their dry strength when wet. Inasmuch as viscose swells when wet, it packs readily, and is best dyed in raw stock, in pressure machines.[38] A special acetate dye has been developed for cellulose acetate as it does not dye satisfactorily with dyes used for other fibers. It is believed that the dye is attached to the cellulose acetate fibers by hydrogen bonding to the carboxyl oxygen of the ester groupings.[28] Cellulose acetate must be dyed at a temperature not exceeding 170° as luster is impaired and saponification sets in at higher temperatures.[38]

The dyeing of a material in which two or more fibers are blended together is termed 'union dyeing'. Union dyeing is a complex process, the science of which must be based on the dyeing behavior of the individual fibers. Often in the dyeing of fiber blends the manufacturer utilizes the different dying characteristics of the fibers to achieve a 'frosted' effect in the yarns. Great batches of raw stock are dyed in dye-vats, then spread in layers in blending bins. Vertical cuts through the layers are fed into a picker, thus pulling the locks of wool apart and helping to blend the fibers uniformly.

The fibers, now ready to be carded and combed, pass through revolving cylinders closely studded with fine wire teeth. These cylinders separate and comb the fibers until they lay parallel. The fibers, leaving the carding machines in fluffy strands are known as rovings. The roving is then spun between paired rollers. By combining two, three or four single strands and twisting them together, a proportionately thicker and stronger yarn is produced.

Truitt[37] defines torsional rigidity as 'that property, which resists twisting torsion and opens up the yarn when cut into tufts so that the individual fibers separate and spread against adjacent rows of tufts'. This rigidity depends upon the amount of moisture in the wool, the rigidity of dry wool fibers being about 15 times greater than that of fibers saturated with water.[38] For this reason spinning rooms are equipped with humidifying systems to keep the humidity as high as possible. The importance of taking the tortuosity of the yarn into consideration is discussed by Schwarz, in an article concerning yarn structure in the Textile Research Journal for March 1951.[32] When a yarn is distorted so that it's axis lies in a spiral formation rather than a single plane, the twist is changed. In order to produce a balanced yarn with singles of a given twist, the manufacturer must make allowances for tortuosity.

Platt[25] makes three statements of interest concerning carpet yarn structure. First, when yarn twist is increased, there is a decrease in modulus of elasticity and resiliency. Second, under a given external tension, those fibers in the higher-twisted yarns are under greater stress and strain than those in the low twisted yarns. Third, when yarn twist is increased, there occurs an increase in yarn denier. As a decrease in resiliency and an increase in potential strain are undesirable factors for carpet yarns, it would seem that there are some definite disadvantages in the use of high-twist yarns for carpets. However, an advantage lies in the fact that the more twist in the yarn the more resistant it is to both soil and abrasion.

After the carpet yarn has been prepared for weaving, the producer must determine not only the number of tufts and the weave best suited for each particular type of carpet yarn but also the proper fibers for use in the backing and the number of shot and stuffer yarns.

Jute has been the choice fiber for use as stuffer yarns for many years. It is obtained from the bast of various species of Corchorus, grown in India. It provides body, stiffness and firmness to the carpet although it is recognized that it loses considerable strength when wet. For this reason, and because of limited availability, Kraftcord and other developments are, to a certain extent, replacing the use of jute.

During the war, carpet manufacturers, unable to obtain jute in the necessary quantities, used a specially processed paper made from wood, called 'fiber' or 'Kraftcord.'. Because Kraftcord was introduced during the war years, it was considered a substitute for jute. Today, it is being used more and more and has been found satisfactory. It is twisted and treated to make it tough and waterproof, and has many desireable characteristics for use in carpet backing.

Kraftcord is often used for the 'shot' or crosswise threads in a carpet. Two-shot means that there are two crosswise threads for each row of loops or tufts. Three shot is better than two shot, for it helps to hold the pile more securely. The number of shots may be determined by bending the pile crosswise, and counting the yarns between two rows of tufts.

Chain or warp yarns are the criss-cross yarns which bind the entire carpet together. Usually, the warp yarns are of cotton, although rayon has been used. Stuffer yarns of cotton, jute or 'fiber' add bulk, stiffness and padding to the carpet.

The number of tufts or loops per inch across the width of the carpet is called 'pitch'. The number of rows of tufts per inch in the length-wise direction are called 'wires'. The density of the carpet is the number of tufts per square inch; that is, pitch times wires.

There are three basic weaves in carpet manufacture; namely velvet, wilton and axminster. No one weave is necessarily superior to another for there are high, low and medium grade carpets constructed on each type of loom.

The velvet weave is the simplest of the three. For this reason, it has a lower production cost than other pile rugs and is generally believed to have a higher dollar value in the low-price field.[(8)] A good grade velvet is very durable. Although velvet is ordinarily a cut-pile construction, a loop-pile may be made on a velvet loom. If the loops are small, even and give the appearance of a tapestry the carpet is frequently said to be of a tapestry weave, although this term is technically incorrect. When the loops are uneven in size or height, the carpet will be referred to as a looped pile of velvet construction. The quality of a velvet rug depends upon the type and quality of the fiber used, the height of the pile, its weight per square yard, the ply of the yarn, number of shot, and the number of tufts per square inch. Federal specifications (1937) for carpets to be purchased for government use list only one type of velvet carpet. In this carpet, the yarns, made of carded, spun and blended wools were to be three-ply. The desired pitch was 216, or 8 per inch and the number of wires, 8 3/4 , thus making the density 70 tufts per square inch. Dilts [(11)] lists two other grades of velvet a fine quality velvet, usually having a one-half inch pile depth, two or three shot, 8 to 10 wires with a pitch of 8 or 10, and a density of 80 tufts per square inch; and, a low grade velvet, ordinarily having an extremely rigid backing, 6 or 7 wires, a pitch of 6 or 7 and only 42 tufts per square inch. The pile yarns in velvet carpet construction are on the surface so they must be carefully selected. Stuffer yarns of jute or fiber are used as a cushion and backing.

In the wilton construction, the filling, warp and stuffer yarns form the back structure of the carpet and also constitute the weave. The warp yarns are split into two sections, alternating warp ends being threaded through alternating harnesses in the loom, thus forming a V shaped opening called the 'shed'. The filling yarn is inserted through this opening. Usually the pile is shorter than in comparable carpets of axminster and velvet weaves. The quality of a wilton depends upon several factors; namely, the quality of yarn, the number of frames carried in the backing of the carpet, the density of the pile, the ply of the yarn, and the number of shot. Federal specifications cover four types of wilton carpets (1931), two of which have worsted pile.[12] Type I is 3-shot, woven on 6 frames with 3 ply yarns, 13 wires per inch, and a pitch of 9.5; or approximately 123 tufts per square inch. Type II differs from type I in that it has 5 frames and 10.5 wires. The proportion of pile to total weight in both types of carpeting should not be less than 56%. Type III is woven on 2 or 3 frmes, 2-shot, 9 wires and a pitch of 9.5; the portion of pile to total weight to be no less than 44%. Type IV is woven on 5 frames with a pitch of 6 2/3 and 8 wires; or approximately 53 tufts per square inch; the portion of pile to total weight to be 66% or more.

Axminster carpets are made by fastening tufts of yarn into the backing by means of heavily sized crosswise threads. These produce pronounced ridges across the back, thus making it possible to roll axminsters in the lengthwise direction only. The quality of axminsters varies according to the quality of the fiber, the number of tufts per square inch, and the pliability of the backing. Specifications for axminsters listed in the Federal Standard Stock Catalog require 7 or more rows of tufts per inch, and a pitch of 7, or approximately 56 tufts per square inch for high quality carpets. 'Extra high quality' carpets require a pitch of 9, or approximately 63 tufts per square inch. The porportion of the pile to the total weight of the carpets in both grades should not be less than 42%.

In addition to the three basic types of weaves, there are several other special types. Chenille carpets are woven in two operations, making them very pleasing in appearance but expensive to produce. The lokweave carpets are of different weave constructions, yet the carpet may be cut in any direction without fear of raveling. Pile yarns go all the way down through the backing of the carpet and up again and are firmly locked in place by a special sealer. Carpets are also being made with thick sponge-rubber backing, so deep that it forms its own cushiony underlining. This type of carpet is cemented to the floor and requires no special seaming. These types of carpets constitute only a small portion of total production.

Research concerning the performance characteristics of carpets has been done for the most part by the carpet manufacturers, working cooperatively with the Bureau of Standards. The tests performed by the latter were under the direction of Herbert F. Schiefer. Experimental procedure and results of these tests have been published in the Journal of Research, one paper appearing in the February 1934 Journal[30] and another in the November 1942[31] Journal.

Prior to the 1934 publication, two series of twelve velvet carpets were studied for the effect of density and height of pile on the durability of carpets. It was noted that resistance-to-wear was increased by a greater amount when the pile density was increased than when the pile height was increased by the same percentage. It was further noted that pile consisting of fine fibers was readily compressed by the application of a load, whereas pile consisting of coarse fibers was stiff and unbending. Many of the fine fibers in wool pile were broken off during the early part of the abrasion tests by the slipping and twisting actions of the machines, whereas coarse fibers were more likely to fracture near the anchorage of the pile in the carpet backing. According to Schiefer, Ashcroft has published results in the Melliand Textile Monthly for March 1933 showing that the rate of wear of wool pile will increase almost directly with the time required to boil the yarn in the dyeing process, thereby accounting for the uneven wear observed in carpets in which the pattern consists of several colors. Although it was difficult to determine the effect of the pile anchorage on the durability, Schiefer thought it worth while to note the effect of the wear test on a carpet having the pile tufts exposed on the back. When this carpet was tested, the wool fibers gradually worked through to the back where they became matted together.

The wear study performed between 1939 and 1942[31] was done in the laboratories of the Bigelow Sanford Carpet Co., the Mohawk Carpet Mills, Inc., the Alexander Smith & Sons Carpet Co., and the United States Testing

Company. Tests were made on twenty-four carpets of either axminster, velvet or wilton weave. Some of the carpets in this study were those in regular production but others, including an experimental carpeting of fifty percent rayon and fifty percent wool, were woven to specifications. Although the tests were extensive, Schiefer did not feel that the analysis of the carpets tested yielded sufficient data to determine the probable durability of different types of carpeting.

Physical analysis of the carpets used in this study included determination of weave, rows and pitch per inch, weight per tuft, length of tuft, height of pile, initial thickness of pile and backing, and the density of the pile. A density index number for each carpet was determined as the product of the number of rows per inch, the pitch per inch, the weight of tuft per inch length, and the pile height. This number was used as a criteria for determining the expected wear of the carpets. Although the correlation was high, there was some indication that it was affected by the type of weave, or more likely, the wool blend.

The actual wear testing was conducted by Schiefer, by placing the carpets under study in a busy corridor of the Procurement Building in Washington, D. C. During the six months of the study, the carpets were vacuumed each day and the dirt removed weighed. At intervals, the height of the pile was measured without removing the carpets from the floor. The results in the serviceability tests were compared with data on the laboratory abrasion tests. The correlations were highly significant though differences were noted. Because the backing of a carpet wears down as much as 33% during a service test, change in the thickness of the pile of a carpet during a test has been found to be the best measure of the amount of wear. It was noted that the pile decreased very rapidly during the early stages of the test because of pile matting, but decreased at a fairly uniform rate for the remainder of the wear test. Schiefer again stressed the importance of density, stating that an increase of 100% in the number of tufts per square inch produced an increase of about 225% in the number of revolutions required to wear the pile down to one-fourth its matted thickness. This experiment also involved a study of the effect of humidity and temperature upon the wear qualities of carpets. Results showed that relative wear increased significantly with increase in relative humidity; a 10% increase in humidity above 65% r.h. corresponded to a 15% increase in relative wear. This study showed that, as temperature was increased, the relative wear of the carpets appeared to decrease. Schiefer, therefore, stressed the necessity of testing carpets in an atmosphere of controlled temperature and relative humidity. A difference in wear indices was also noted when the nozzle of the vacuum cleaner was lowered or raised. Wear increased on an average of 3% when the height of the nozzle was raised from 1/8 to 3/8 inches from the carpet, the wear indices increased 75%. This increased wear was attributed to the ineffective cleaning at greater height.

Results of tests performed by Beckwith and Barach are recorded in an article entitled 'Notes on the Resilience of Pile Coverings', Textile Research Journal for June, 1947. They define resilience "as the ratio of work returned upon release of a compressional load to the total work done in compression. Tests consisted of loading the fabric at steps of 0.5 pound to 5.0 pounds per square inch. The density (tufts per square inch) and the height (thickness) of the carpet were taken into consideration because they partially determine resilience. When the density of carpeting is low, the force of the load causes the pile to collapse quickly; the backing structure then absorbs most of the applied force. The greater the density, the more the force is dissipated by resistance of the pile to bending. This study also shows that, with density constant, the higher the pile, the more the force is absorbed by the pile. If the pile is exceptionally high the bending of the pile will completely absorb the force. The greater the number of tufts per square inch, the more opportunity there is for the fibers to become entangled due to the pressure of the load. This factor reduces the ability of the fibers to 'spring back', after the load has been removed. With a constant density, 'work returned' will increase with increased pile height. This relationship is to be expected, because the effect of the back structure is gradually eliminated with an increased pile height. The following conclusion is given: "the effect of a force on the pile of a floor covering is better expressed in terms of the work done and work recovered than by the ratio of these two values."

In another article entitled "Dynamic Studies of Carpet Resilience" in the Textile Research Journal of June 1949, Barach showed, through photography, the effects of walking upon a carpet. Results in this study showed that walking on a carpet subjects it to rapid loading of about 12 pounds per square inch per second and that this load is then withdrawn at the same rate. The photographs also showed that fibers bend in groups rather than singly. He emphasizes the fact that there is a constant opposition between the elements of the fibers; one measurement which he terms dynamic--constantly attempting to force the fiber to return to its original vertical position in the pile of the carpet; the other force within the fiber (static measurement) constantly attempting to remain in the bent position caused by the load applied to the fiber. This author also emphasizes the importance of carpet backing. If the backing is not stiff and of firm structure the pile will bend very easily--in fact the desire of the carpet pile to return to an upright position might be impaired. The more firmly woven the backing and the more sizing applied to it, the more nearly upright the pile will remain. This means less 'compression' in resiliency, but it also means more 'recovery', thereby causing the ratio between the work accomplished and the work recovered to be higher.

Tests performed by the National Bureau of Standards reveal that the use of rug cushions (underlays) increased wear of carpets 73 to 146%.(30) These cushions, costing only a fraction of the price of a carpet, may be purchased of hair, jute, cotton, paper or rubber. Although all underlays increase durability to some extent, the thick resilient cushions prolong the life of carpets more effectively than those that are hard and stiff.

All new carpets, regardless of fiber content, will shed for the first few weeks. There are two reasons for this: First, pile yarns of wool may be constructed of long and short fibers. In weaving these yarns are cut in such a way that many of the short ends do not reach down far enough to be bound into the backing of the carpet. They are, therefore, held in place only by contact with the other pile fibers, and as the carpet is used they work loose and are carried off as lint. The fewer short fibers in a carpet yarn, the less shedding. For this reason, synthetic carpet fibers are cut as long as can be handled satisfactorily on available spinning machines. Shedding is also due to the fact that there is a lack of moisture in a new carpet. This encourages shedding until the carpet has been laid for awhile and has had a chance to re-absorb moisture from the atmosphere.[2]

Some carpets that have been laid for several months develop lights and shadows in certain spots, particularly in places were traffic is heavy. This factor is not dependent upon the fiber of the pile, but rather on the construction of the carpet. Smooth plush-like pile is subject to matting. The sides of all pile fibers reflect light more intensely than do the cut ends, and when the pile fibers are bent they will reflect light at a different angle from the rest of the carpet.[11] Synthetic fibers are known to have more sheen than wool fibers, and they mat easily. Therefore it would seem possible that spots due to light reflection might be more prevalent in synthetic pile carpets, then in those with an all-wool pile.

All carpets are subject to changes in hue. Delicate tints fade through exposure to sunlight more quickly than stronger colors.[8] They are also more affected by atmospheric dust, a discoloration which may be minimized through the application of a commercial cleaner.

A knowledge of the substances called 'carpet soil' give an appreciation of the need for keeping carpets as clean as possible. In a pamphlet published by the Hoover Vacuum company,[11] carpet dirt is divided into three general types of material:

1. Surface litter, such as lint, hair threads, ravelings, and sewing room scraps.

2. Light clinging dirt which is deposited on the top of the rug by air currents but is worked about half way down into the pile tufts by the tread of feet on the carpet. This type of carpet dirt is quite readily removed even by the least effective electric cleaning. After it is removed the carpet appears clean at the surface although large quantities of dirt may remain farther down in the pile tufts and in the furrows between the rows of pile.

3. A heavier type of dirt composed of fine sand, powdered clay, powdered limestone, gypsum, etc., bound together with sticky substances such as asphalt, grease, rubber oils and fats, present in quantities as great as one-half pound to ever ten pounds of dirt.

Surface litter and light clinging dirt are easily removed from carpets by vacuuming. However, the portion of carpet dirt most harmful to carpets is the heavy type of soil described above under item 3. It is also the most difficult to remove. Many of these particles are hard and glass-like in texture with sharp knife-like edges which work themselves into the base of the pile tufts and into the backing of the carpet. When these sharp, hard particles are rubbed against the soft fibers of the pile due to pressure caused by walking, they cut the yarns.

In order to remove soluble grease and fats, or to brighten the surface of carpets, a commercial cleaning fluid is more satisfactory than soap and water. Soap solutions, particularly those containing alkali, may destroy the natural oil in the fibers and produce color changes.(8) Water also is detrimental to a carpet if used in too great quantities. It may weaken such backing fibers as paper and jute and it may affect the twist of carpets with a frieze pile. Sand and other insoluble particles of soil cannot be removed successfully with a commercial cleaning fluid, so for this reason, carpets should be sent to a professional cleaner at least every other year.

III. EXPERIMENTAL PROCEDURE

Selection of Carpeting: Samples were chosen from the limited supply of synthetic and synthetic-blend carpets on the market in Lansing, Michigan during the spring of 1951. Blends of 50% Avisco and 50% wool were available in sufficient quantities for this study, as were carpets of 100% estron, a cellulose acetate produced by the Tennessee Eastman Company.

The price range for synthetic pile carpets was as variable as prices for wool pile carpeting. A 100% estron axminster could be purchased for $6.50 per square yard. Blends of wool-avisco, and wool-Celcos ranged in price from $9.00 to $15.00, while custom-made nylons of carved pile were available through special order, but at prices prohibitive for the average consumer.

Of the samples chosen for this study, two were 100% estron but represented different quality grades and construction; and two were of medium priced wool-Avisco* blends produced by different manufacturers. All-wool carpets comparable in appearance, weave and weight were selected for comparison with the synthetic carpeting. However, their price ranged from $1.00 to $3.50 more per square yard.

* For convenience, in this study, Avisco,(the American Viscose Company Trade Name for carpet yarns) is used to designated the viscose carpet yarns used in both carpets. Mohawk Carpet Mills used Avisco--The Bigelow-Sanford Company has their own rayon mill.

The construction, pile fiber content, and price per square yard for the eight carpets used in this study are summarized:

TABLE I
Carpets Used in Study

Carpet No. And Code*	Manufacturer	Fiber Content Of Pile	Construction	Price Per Square Yard
1 L-E-A-1	James Lees & Sons Carpet Company	estron (cellulose acetate)	axminster	$6.50
2 L-W-A-1	James Lees & Sons Carpet Company	wool	axminster	$7.50
3 L-E-W-L-2	James Lees & Sons Carpet Company	estron	wilton loop pile	$10.50
4 Ma-W-W-L-3	Masland Carpet Company	wool	wilton loop pile	$14.95
5 B-WA-V-L-2	Bigelow Sanford Carpet Company	wool & viscose	velvet loop pile	$10.50
6 B-W-V-L-3	Bigelow Sanford Carpet Company	wool	velvet loop pile	$12.50
7 Mo-Wa-V-2	Mohawk Carpet Mills Inc.	wool & avisco	velvet	$ 9.50
8 AS-W-V-3	Alexander Smith & Sons Carpet Company	wool	velvet	$13.50

*Code: 1st letter: Manufacturer
2nd letter: Fiber
3rd letter: Construction
4th letter: Loop pile
Numeral: price group

The pile yarns of Carpets 1 and 2 have practically no twist which gives them a fuller appearing pile than they actually possess, (see Plate I, appendix). These two carpets are light weight with only 35 tufts per square inch. A rubberized backing gives a certain amount of firmness to the carpeting but also contributes to a stiffness not apparent in the others.

Carpets number 3 and 4 were constructed on the two-frame wilton loom. A pleasing, all-over leaf design was achieved through variation in tones of the same color and pile loops of varying size and height, (see Plate II, appendix). These two carpets were the heaviest tested. The pile yarn used was two-ply with only enough twist to hold the ply together. The pile was caught into every other warp of the backing instead of the usual method of catching the pile into each warp. However, the pile gives coverage because of the size of the yarns and the looseness of the twist. Actual count of the tufts per square inch is 54, although the closeness of the weave of the backing would suggest twice as many tufts.

Carpets 5 and 6 appear identical to the extent that it is difficult to determine which carpet contains the blend of wool and viscose fibers, (See Plate III). Both carpets are of velvet weave construction. The uneven loops form a pattern often referred to as 'treebark', but which the manufacturer designates as 'corday'. Two single yarns of high twist are woven into the pile as a single yarn. These differ from two-ply yarns in that the two single yarns are not twisted together. This gives the appearance of twice as many tufts as its actual count of 64 per square inch. The backing of these two carpets was heavily sized with a plastic-like substance which makes them stiff and unpliable.

Carpets 7 and 8 are both of cut-pile velvet weave construction (see Plate IV, appendix). Number 7, the wool-avisco carpet, appears very similar to all-wool carpeting although its tufts are not as coarse and it is brighter in color. Low twisting characterizes the singles of the two-ply yarns used in both carpets, but the twist of the plies is high. These yarns are typical of all frieze carpetings. Both carpets have a density of 64 tufts per square inch.

Specification Tests:

A. Chemical: Verification of fiber content in the pile of the carpets was made by using three different tests. Each test was performed three times using 2 to 4 grams of carpet pile per test. The averages of the test were recorded.

A potassium hydroxide test to dissolve wool fibers was used. This test was recommended by Hartsuch. (15)

> Dry and weigh samples. Drop into 250 cc of 10% KOH which has been brought to 50° in a water bath. Maintain sample and solution at this temperature for 30 minutes, stirring every five minutes. Filter through a Gouch filter. Wash with dilute acetic acid. Wash with water. Dry the residue(non-wool fibers) and condition before weighing.

A sulphuric acid test to dissolve viscose rayon was used. This test was suggested by Skinkle. (33)

> Dry and weigh sample. Immerse in 200 cc of boiling 1% solution of sulphuric acid 7 to 10 minutes. Transfer to a Gouch filter and remove excess acid by suction. Place sample in 200 cc of a 70% solution by weight of sulphuric acid at 100°F and work it for 15 minutes. Filter on a Gouch filter or a 100 mesh screen and wash well with cold water. Place sample in a beaker of 2% sodium bicarbonate at room temperature for 5 minutes. Filter again, wash well on the filter, dry and weigh.

An acetone test to dissolve cellulose acetate was the third test used. The procedure suggested by the American Society for Testing Materials (1) was used.

> Take the clean fiber and agitate vigorously for 15 minutes in about 50 times its weight of acetone at room temperature. Rinse the residue by alternate squeezing and immersion in acetone, using two fresh

> portions of acetone. Allow the residue to dry and immerse in water at about 70°C. Remove the excess water by squeezing, and dry the residue at 105° to 100°C to constant weight.

Microscopic Tests: In preparing test specimens for examination under the microscope, the fibers were first boiled in distilled water in order to remove any natural or applied oil, starch or sizing which might obscure the characteristic structure of the fiber. The fibers were then dried and placed on a glass slide. After teasing the fibers apart with a dissecting needle, they were covered with a second glass slide and examined at 100x with transmitted light. Visual observations were recorded.

Physical Tests: Physical tests for specification analysis were performed in accordance with the standard methods of testing pile floor covering designated by the American Society for Testing Materials, as published in the Society's Manual for October 1946.

The weight of the carpets was determined as follows: 4 samples, each 16 square inches in area, were conditioned and weighed on a balance. The average weight per square inch was calculated in grams, and the average weight per square yard in ounces.

The samples were then dissected, dividing the yarn according to its utility in the carpet--that is pile, warp, stuffer and filling. The samples were again reconditioned. The average of the weights for the pile yarn was determined and calculation for the average weight of pile per square inch (in grams) was made for each carpet. The average weight of pile fibers per square yard (in ounces) was also calculated. Averages of the weights of warp yarns, stuffer yarns, and filling yarns were also calculated in grams per square inch. The total weight of the backing of each carpet was recorded in grams per square inch and ounces per square yard.

The thickness of the carpet was determined as follows: The carpets were measured with the Schiefer Compressometer to the nearest .0001 inch distance between the two plane surfaces of a fabric under a pressure of .1000 ± .001 pounds per square inch, using the circular pressure disc which is 3 inches in diameter. The pressure was applied slowly to avoid impact. The average of five readings taken at uniffromly distributed places over the area of the surface was recorded as the thickness of the carpet.

In order to measure the thickness of the carpet backing, this procedure was followed: The pile yarn was removed by clipping from a 25 square inch section of carpeting. All pile which was not removed in this way was burned off with a flame. By alternate charring and brushing the total pile was destroyed without damage to the back construction. The thickness of the remaining back construction was then measured with the compressometer to the nearest .0001 inch under a pressure of 0.75 ± 0.0001 pounds per square inch, using the one inch circular pressure disc. An average of five readings taken at different places within the exposed back construction was designated as the thickness of the backing.

The thickness of the pile of each carpet was determined by calculating the difference to the nearest .0001 inch between the total thickness of the carpet and the thickness of the backing.

The rows of tufts per inch was determined by counting the number of rows in 10 inches at different places with no two determinations being made in the same row. The average number of rows per inch was calculated and recorded to the nearest whole number.

The number of pile ends per inch of width was determined by counting the tufts in a space of not less than 10 inches at three different places throughout the width of the carpet. The average number of pile ends per inch was calculated and recorded as pitch per inch. The number of shots for each row of loops was also recorded.

A density index number for this study was calculated as follows:

$$\underline{2(\text{density x 2 weight of tuft(grains) x pile height})}$$

This formulae differs from Schiefer's* in one respect. Inasmuch as there was no means for measuring the length of a tuft, twice the weight of a tuft was substituted for the weight of a tuft per inch length.

Laboratory Tests:

A. Resistance to Abrasion: Perhaps the most important single factor for the consumer-buyer to consider in a carpet is its ability to withstand continuous traffic. One method which can be used to test this factor is a serviceability study in which the carpets are subjected to normal use. Wear studies necessarily require a much longer time than laboratory studies. The time differential makes necessary laboratory tests which can be concluded and the results of the test made available concurrently with the product when it reaches the consumer market.

However, a wear index for each carpet may be obtained in the laboratory by charting the average number of cycles required to wear

*Schiefer's density index number:

$$\underline{2\ (\text{density x weight of tuft per inch length(grains) x pile height})}\ (31)$$

out carpets on an abrasion machine. Testing equipment for measuring abrasion for this study was limited to the Taber Abraser. It is admittedly an inadequate instrument for use on carpets, but it does offer comparison in relative serviceability of the different carpetings in this study.

Testing carpets with this instrument offered many problems. The carpets were too thick to stretch over the sides of the specimen holder, as one would a piece of dress fabric. If trimmed to the exact size of the specimen holder, the wheel-rim was too large. This problem was solved by placing a piece of muslin on the specimen holder first, and carefully cutting the rug samples to the exact size of the specimen holder, before applying over the cloth. If the sample was too large, the carpeting buckled; if too small, there was the possibility that tufts, not caught under the rim would be lost during the test.

Several different abrasion wheels were used in the pre-test. cl7f wheels were found to give the most consistent results. The first set of cl7f wheels which was used, wore out the carpets in 500 to 11,000 cycles. Three new cl7f wheels were ordered, but the cycles required to produce a similar degree of wear ranged from 1,500 to 20,000. However, there was a definite relationship in the data from the pre-test and this study. Each carpet wore out approximately two and one-half times as quickly in the pre-test as those recorded in this study. A date mark stamped on the new wheels suggested that these wheels be used before June 1953 for accurate results. Inasmuch as no date mark was stamped on the wheels used in the pre-test, it was felt that they may have been quite old and dried out to the extent that their abrasion action was significantly greater. The fact that analysis of the data from the different rug types and grades in the pre-tests bore a direct relationship to the data from the subsequent tests indicates that abrasion test results may be affected by many different factors and that comparison of test results should be subjected to careful analysis before valid conclusions can be drawn.

In this study, three samples of each carpet were abraded until worn out. This point was designated as the number of cycles necessary to abrade the pile until the back construction could be seen along the entire path of the abrasion wheels. The 'wear-out' indices were then arbitrarily determined, and division into 'low', 'medium' and 'long wearing' groups was made. Three additional samples of each carpet, falling in the 'low-wearing' group were abraded to 1500 cycles. In the 'medium-wearing' group, three additional samples were abraded to 4500 cycles. Likewise, three samples of carpets most wear-resistant were abraded 9000 cycles. The appearance of each sample was checked and recorded at intervals of not less than 250 cycles, and in many instances at greater frequency, depending upon the appearance of the specimen. Loss in twist, change in color, loose tufts and first signs of wear were recorded and subsequently evaluated. Between each test of a given sample, fifteen control samples of 120 count muslin were abraded. If these control samples were completely worn out in 75 to 90 cycles, the wheels were considered to be satisfactory for the continuance of testing the carpet samples. The wheels were refaced with sandpaper each 1000 cycles.

An attempt was made to gather the lint from each carpet abraded in a small paper sack in the vacuum cleaner as a check on loss of weight. Such difficulty was encountered in collecting all the lint that the results were considered unreliable and the procedure discontinued. After each abrasion test the samples were conditioned for 24 hours, and then weighed and recorded as conditioned weight.

B. Soil Retention Test: The abrasive quality of soil ground into carpets during normal use sometimes cuts at the base of the pile. It is therefore of interest to the consumer-buyer to know which fibers best resist dirt.

For comparison of soil retention properties of carpet fibers, the following test was used: The eight carpet samples (12" x 27") were conditioned and then weighed. At fifteen different times thereafter, 25 grams of a standard soil of the following consistency was applied; 70% by weight of sand, 5% each of cracker crumbs, mineral oil, dried leaves from trees, and carbon. 1% each of the following were added; salt, sugar, Bon Ami, and cigarette ashes.

In order to simulate actual use, the standard soil was rolled into the pile of the carpet with a rolling pin with 25 strokes in each direction, for a total of 100 strokes. After standing for 2 hours, the soil was again rolled into the carpets, and then removed with the furniture brush attachment of the Hoover vacuum cleaner. Each carpet sample was vacuumed by brushing slowly over the surface with three strokes of the vacuum in one direction of the sample and ten strokes in the opposite direction. This was repeated a second time. Thus each cleaning procedure consisted of 60 strokes of the vacuum on the sample.

At the conclusion of the application of soil, one-half cup of mystic foam was used to clean each carpet. Directions given on the mystic foam container were followed. After the carpet was shampooed, it was dried, vacuumed, conditioned and weighed. Subjective comparison was made with the control sample for cleanliness, change in color, and loss of twist in the yarns.

C. Colorfastness To Light: Total normal utility expectancy in a carpet will vary with the use given it, but ten years may be taken as an arbitrary figure for normal wear. During that time, carpets are exposed to direct sunlight as well as indirect light. Fading in a carpet is obvious inasmuch as those areas on which large pieces of furniture have been set do not fade to the extent that the exposed areas fade. Consequently, any rearrangement of furniture frequently points up color differences in relatively small areas, and definitely detracts in the over-all appearance of the floor covering.

The Hatch Textile Research and Testing Laboratory at 25 East 26th Street, New York City, has compiled a Table of Fade-ometer and Sunlight Equivalents. in which they suggest that 100 hours is the minimum number of hours for satisfactorily testing carpet samples in a fade-ometer. They consider 100 hours equivalent to 21 days of sunlight (6 hours per day) in June, July and August; 63 days in September, April and May; 125 days in October, November and March; and 375 days in December, January and February. These equivalents are based on data determined by the American Association of Textile Chemists and Colorists and are subject to changes according to geographical location, atmospheric conditions, humidity, air pollution and the like.

The standards designated for reporting colorfastness to light are as follows:*

Class 0 Carpets which show an appreciable change in color after exposure for 10 hours.

Class 1 No appreciable change in color after exposure to light for 10 hours.

Class 2 No appreciable change in color after exposure to light for 20 hours.

Class 3 No appreciable change in color after exposure to light for 40 hours.

Class 4 No appreciable change in color after exposure to light for 80 hours.

Class 5 No appreciable change in color after exposure to light for 160 or more hours.

* Fade-ometer Instruction Sheet--Paragraph 53.

Tests in this study were run for 80 hours, 100 hours, 160 hours and 200 hours respectively. Because fadeometer frames are so small in comparison with a room sized carpet, one frame was used for each test so as to expose as much of the carpet area as possible.

Crush-Resistant Test: Inasmuch as furniture is moved from place to place in a room, the carpet with low resistance to crushing will show matted or crushed areas due to the weight of the furniture. When this occurrs it suggests that the fiber used in the carpet pile has a low degree of resiliency.

In this study, a comparison of the degree of crush resistance in synthetic and wool-synthetic blends is based on calculations of the total weight of a book case filled with a normal number of books, in relation to the number of square inches resting on the carpet. The weight per square inch was then calculated for the specimens used in this study.

Laboratory test procedures were designed to simulate normal conditions of use. A series of weights totaling 25 pounds 10 ounces were placed on the various carpet samples. This number was obtained by multiplying 2.3 pounds per square inch by the 9 square inches of carpeting over which the total load was applied.

The carpet samples were conditioned under standard conditions of testing, $70^{\circ}F \pm 1^{\circ}$ and $65\% \pm 1\%$ relative humidity. The Schiefer Compressometer was used to determine compression[a], recovery[b], compressional index number[c], compressional resiliency[d], and standard thickness[e]. Each test was recorded on a 'Compressometer Data Sheet', and results tabulated for Table V in the appendix.

This test procedure was repeated, following the application of weights for 75, 150, and 300 hours respectively. Readings were taken immediately following the removal of the weights. Data is recorded in the appendix, Tables VII through XI. Trial tests indicated that all of the carpets appeared to have reached maximum crushing after

(a) Compression: The amount of work done(or compressed) expressed in .0000" due to the application of loads up to 0.2 pounds per square inch.

(b) Recovery: The amount of work recovered expressed in .0000" from said load to .01 pound per square inch.

(C) Compressional Index:The difference between the thickness at .05 pounds pressure per square inch, and .15 pounds pressure per square inch divided by the standard thickness of the carpet.

(d) Compressional Resiliency: The ratio (in percentage of the work returned upon release of a compressional load to the total work done in compression.

(e) Standard Thickness: The thickness, in .0000" of a carpet at 0.1 pounds pressure per square inch.

300 hours under the weights applied. In the selection of some samples difficulties were encountered. Carpet number 3 which was of looped wilton construction, was particularly difficult, as the pile yarns had been brought through the backing and tied in the same manner as one would tie threads in making a needle-point for upholestry. Carpets 1 and 2 were uneven because of the large amount of sizing applied to the backing. In readings obtained with as sensitive instrument as the Schiefer Compressometer, even minor differences in carpet construction were reflected.

IV. DISCUSSION OF RESULTS

Schiefer[30] stresses the fact that many inconsistencies may be found when testing carpets. These he attributes in a large measure to a lack of uniformity of production in carpet manufacturing. It could also be attributed to the innate differences in wool from various sources, and to the newness of the synthetic fibers, many of which are still in the experimental stage.

The results of this study and their subsequent evaluation are not sufficient in scope to be predictive of the wearing quality of the eight carpets tested. However, the analysis of the initial properties of the carpets and the laboratory performance tests suggest several pertinent factors concerning differences in the behavior of carpets with pile fibers of wool and those in which synthetic fibers have been used.

<u>Chemical Analysis:</u> Chemical analysis of the carpets verified the fiber content appearing on the label or indicated by the salesman. Carpets 5 and 7 were sold as blends of wool and Avisco. It was thought that the percentage would be approximately 50% of each fiber. The composition of Carpet 7 was found to be approximately 45% wool, 50% Avisco and 5% sizing. The backing of carpet 5 was so heavily sized that bits of sizing, of a transparent, plastic-like composition, clung to the uncut

pile, and could not be separated from the pile by boiling in a 1% solution of HCL. However, this sizing dissolved to a certain extent in the sulphuric acid. The exact composition of this carpet could not be determined accurately for 56.1% of the carpet contained both viscose fibers and sizing, 35.9% was wool, and 8% of the weight was lost--evidentally sizing which dissolved. The pile used for carpets 2, 4, 6, and 8 was 100% wool, whereas the fiber used for carpets 1 and 3 was cellulose acetate. For further information concerning chemical analysis of the carpets, see Chart II in the appendix.

Microscopic Tests: Microscopic tests revealed much irregularity in the size of the wool fibers, whereas synthetic fibers appeared uniform in size. The exact nature, structure and arrangement of the scales of the wool fibers differed considerably within the pile of each carpet. Occasionally the individual scales would completely surround the entire fiber, but as a rule, two or more scales occurred in circumference. The scales appeared to fit tightly together with very few 'free edges', suggesting that fibers were chosen which would present a minimum of 'matting'. In some cases, the surface of the scales was more or less concave, a characteristic of coarse fibers. Many of the coarse fibers contained a dark medullary cylinder consisting of several rows of cells. Carpets 2 and 8 showed much evidence of this type of fiber. Those of carpet 2 were also very uneven in size, and the appearance of several under the microscope was that of a jumbled mass. Carpet 4 appeared to be composed of comparatively fine, even and orderly fibers. All synthetic fibers appeared to be coarse in comparison with wool fibers. They also appear much more ribbon-like and gave no evidence of the 'roundness' apparent in the wool fibers. They were uniform in size and similar in markings. All synthetic fibers had been delustered, thereby making it difficult to differentiate between the viscose and the cellulose acetate fibers.

Physical Tests: The total weight in ounces per square yard of each of the eight carpets tested is given below. The weight of pile yarns, stuffer, warp yarns and shot are recorded as percentages of the total weight:

TABLE II
Carpet Weights

Carpet Number and Code *	Total Weight In Ounces Per Square Yard	%Weight In Pile	% Weight In Shot	% Weight In Stuffer Yarns	%Weight In Warp Yarns
1 L-E-A-1	44.0980	36.5%	40.4%	0.0%	23.0%
2 L-W-A-1	46.7097	33.2%	40.9%	0.0%	24.9%
3 L-E-W-L-2	65.5443	56.5%	13.2%	18.7%	11.3%
4 Ma-W-W-L-3	61.4864	50.6%	19.2%	16.7%	11.9%
5 B-WA-V-L-2	57.8723	60.2%	17.0%	8.6%	14.2%
6 B-W-V-L-3	60.8002	60.4%	17.3%	10.0%	11.4%
7 Mo-WA-V-2	56.7285	50.2%	17.2%	17.5%	14.8%
8 AS-W-V-3	67.9872	50.0%	12.8%	23.0%	14.2%

* Code: 1st letter: Manufacturer; 2nd Letter: Fiber; 3rd Letter: Weave; 4th Letter: Loop Pile; Number: Price Group

The above figures suggest that approximately two-thirds of the weight of an axminster carpet is in the backing of the carpet. In wilton carpets the weight is approximately 50% pile and 50% backing yarns; while carpets with velvet construction have from one-half to two-thirds of their weight in the pile yarns.

A Table of Weights, including the weight of carpet, pile and backing in grams per square inch is included in the appendix, Chart III.

The standard thickness (or height) in .0001 inches is the thickness at .1 pounds pressure per square inch, when tested with the Schiefer Compressometer. The thickness of the pile and the backing are recorded below:

TABLE III
Thickness Expressed In .0000 Inches

Carpet Number and Code*	Standard Thickness	Thickness of Pile	Thickness Of Backing
1 L-E-A-1	.3119"	.1885"	.1234"
2 L-W-A-1	.3583"	.2165"	.1418"
3 L-E-W-L-2	.3530"	.1862"	.1668"
4 Ma-W-W-L-3	.3433"	.1785"	.1648"
5 B-WA-V-L-2	.3700"	.2230"	.1370"
6 B-W-V-L-2	.3600"	.2230"	.1370"
7 Mo-WA-V-2	.3000"	.1907"	.1093"
8 AS-W-V-3	.3600"	.2219"	.1381"

* Code:
1st Letter: Manufacturer
2nd Letter: Fiber
3rd Letter: Weave
4th Letter: Loop Construction
Number: Price Group

The number of rows per inch, the pile ends per inch, the density, number of shot per weave-repeat, and the number of stuffer yarns are recorded below:

TABLE IV
Carpet Construction

Carpet Number and Code*	Pitch	Wires	Density	Shot	Stuffer Yarns
1 L-E-A-1	7	5	35	2 double 1 double	2
2 L-W-A-1	7	5	35	2 double 1 double	2
3 L-E-W-L-2	9	6	54	2	4
4 Ma-W-W-L-5	9	6	54	2	2
5 B-WA-V-L-2	8	8	64	2	2
6 B-W-V-L-3	8	8	64	2	2
7 Mo-WA-V-2	8	8	64	2	3
8 AS-W-V-3	8	8	64	2	4

*Code: (1) Manufacturer (2) Fiber (3) Weave (4) Loop Pile (5) Price Group

A density index number based on the formulae: 2(density x 2 weight per tuft in grains x height of pile in inches) was computed for each carpet. A Density Index Number Chart is included in the appendix (Chart V). The numbers obtained are also listed on page 46, TABLE V.

Resistance-To-Wear Test: Aside from the general appearance of carpeting, serviceability is of prime importance. Many factors must be taken into consideration in determining the durability of a carpet.

Results of tests performed show a definite relationship between the number of cycles required to completely wear-off the pile of the carpet and its Density Index Number. The data give no definite indication that the use of synthetic and synthetic blended with wool has decreased abrasion resistance. Carpet 5, a blend of 55% viscose and 45% wool ranked second in abrasion resistance. As this carpet was also second highest in Density Index Number, it suggests the importance of density, size of yarn and thickness of pile over fiber content.

TABLE V
Cycles Required to Wear Out Carpets

Carpet Number And Code		Density Index Number	Cycles Required To Wear Out Carpets
		High Resistance to Wear	
6	B-W-V-L-3	11.13	20,000+
5	B-WA-V-L-2	10.96	16,425
8	AS-W-V-3	10.86	15,500
		Average Resistance To Wear	
7	Mo-WA-V-2	7.27	9,208
4	Ma-W-W-L-3	7.32	8,150
3	L-E-W-L-2	9.29	4,950
		Low Resistance to Wear	
2	L-W-A-1	4.51	2,500
1	L-E-A-1	4.15	1,250

It is obvious from the above figures, that no one number of cycles could be chosen as a constant number for comparison of all eight carpets tests. Therefore, carpets with low density index numbers were worn to 1250 cycles, (See Plate VII, appendix). Carpets with average density index numbers were abraded to 4500 cycles, (See Plate VIII, appendix);

while carpets of high density index numbers were abraded to twice the number chosen for the carpets of average density index number, or 9,000 cycles, (see Plate IX, appendix).

Each group contains a wool carpet as well as one of estron or wool and avisco blend. The photographs show that within each group the synthetic and synthetic-wool blends are more severely worn by the number of cycles to which they were abraded. The density indices for the axminster carpets 1 and 2 are approximately the same, but after 1,250 cycles the estron carpet is completely worn out while the pile of the wool carpet still completely covers the backing, (see Plate VII). Sample 3 and 4, both of wilton construction were worn to 4,500 cycles. At this point, the estron carpet is almost completely worn out and the wool carpet pile is still intact, (see Plate VIII, appendix). Carpets 5 and 6 are the most abrasion resistant, yet the carpet containing approximately 55% viscose and 45% wool shows some wear at 9,000 cycles while the wool carpet (identical to carpet 5 in weave, construction and appearance) shows almost no wear. Although in the wear-out test, carpet 5 was more resistant to abrasion than carpet 8, it shows more wear at 9,000 cycles than this all-wool carpet, (see Plate IX, appendix). Carpet 7, of wool and avisco fibers, is obviously more worn at 4,500 cycles than the wool carpet number 8 is at 9,000 cycles--although both are of cut velvet construction and very similar in appearance and weight, (see Plates VIII and IX, appendix). Sample 7 has an index number almost identical with number 4, an all-wool carpet. In this case the wool-avisco blend wore 1000 cycles longer than the wool wilton. This suggests that a difference of 10 tufts per square inch in density of the two carpets might have been more of a deciding factor in wearing quality than either fiber content or the lower pile height of the blended carpet, (see Photograph Plate VII for a comparison of Carpets 4 and 7 at 4,500 cycles).

This test suggests too, that viscose rayon is more resistant to wear as a carpet fiber than estron. However, it should be pointed out that the viscose fibers were blended with wool, whereas the pile of the estron carpets was entirely synthetic.

Occasionally carpets become worn, not by abrasion but through the loss of tufts. A series of preliminary tests revealed that a carpet identical to Carpet 8 except in color, showed a marked tendency under the abrasion wheels to lose tufts. This tendency was first noted at 3500 cycles. After 7,000 cycles enough tufts were missing to seriously impair the serviceability of the carpet. However, when the same carpeting was purchased in another color for this study, no tufts were lost, so it is not possible to draw any conclusions.

No change in color was noted in any of the carpets during the entire series of abrasion tests nor was there any indication of a coating composed of minute particles of wool formed from the worn-out fibers as noted in some abrasion studies conducted by Backer (4) and Schiefer (29).

<u>Soil Retention Tests:</u> Surface litter is unsightly and unhygienic. It should be removed from the carpet as quickly and easily as possible. Soluble grease and fats should be removed through the application of an effective commercial rug cleaning fluid. Particles of dirt which are sharp and gritty are detrimental to the carpet; under heavy traffic they are ground into the pile and cut the fiber at its base. The latter type

of soil should be removed by professional cleaners.

Cleaning tests performed on the samples of carpeting in this study were not designed to make any comparisons concerning ease in vacuuming, for the samples were vacuumed on a table-top rather than on the floor as one would normally do. However, certain factors were suggested by the reactions of the various carpet samples to vacuum cleaning. For ease in cleaning, a carpet should be of sufficient weight to stay in place. Carpets 1 and 2, although heavily sized with a rubber-like sizing, tended to buckle unless they were cleaned in the widthwise direction. It was felt that this was due to their light weight. In vacuuming Carpet 2, it was observed that strokes of the vacuum from opposite directions caused 'shading' of the pile. This could be attributed to the low resiliency of the coarse wool fibers, or to the plush-like surface of the pile. However, Carpet 1, of estron, also had a 'plush-like' surface pile, yet no 'shading' was observed.

The cleaning procedure selected during the pre-test was found to be more than adequate for cleaning the carpets of cut pile construction, but not sufficient to clean those with an uneven or loop pile. An attempt to throughly clean the carpets of surface litter in the pre-tests showed that Carpets 1, 2, 7, and 8 of cut pile were clean in two or three minutes. Carpet 3 and 4 of wilton construction and uneven loop-pile were cleaned in four or five minutes. Carpets 5 and 6, of velvet construction with uneven loops which formed a textured appearance were not thoroughly cleaned in six minutes of surface cleaning with a suction-type vacuum cleaner. It was felt that a rotating type of vacuum cleaner would be more

Because considerable lint was removed from the carpets during the pre-tests, the carpets were thoroughly vacuumed before the actual soil-retention tests were conducted. However, the carpets, particularly those with cut pile, continued to shed throughout most of the test. In the process of shearing carpets after weaving, many of the sheared ends fall onto the carpet and are held there by the pile tufts.(2) These 'ends' are removed by the suction action of the vacuum cleaner. Although all new carpets will shed for a certain period of time, Carpet 2 (100% wool) shed more than average, whereas Carpet 1 (100% estron) shed the least of the carpets of cut-pile construction. This was undoubtedly due to the fact that the pile used for synthetic carpets is cut to specification, thereby eliminating short ends which might no have become fastened in the backing of the carpet.

During the soil-retention test, all carpets showed continuous gain in weight, (see Chart VII, a, b, c, Appendix). However, after 15 applications the gain in weight was almost negligible. No degree of consistency was noted concerning the actual amount retained during each test. For instance, Carpet 2 gained 2.5% of its original weight during Test 6; 0.9% during Test7; and 3.2% during Test 8. Schiefer(31) suggested that there was a definite correlation between the weather and the amount of soil carpets retain. Therefore the differences in readings from day to day could be attributed to the amount of moisture in the air.

The amount of soil retained by the carpets after 15 applications and the subsequent removals of soil, and a description of the soiled carpets are summarized in Table VI.

TABLE VI

Amount of Soil Retained by Carpets*

Carpet Number Code**and Fiber	Control Sample Weight*** (Grams)	Soil Retained in Grams	Percent Gain In Weight	Subjective Observations
1 L-E-A-1 100% estron	373.7	34.7	9.3%	Fairly soiled. No surface litter. Colors dulled by soil. Need of dry-clean-ing.
2 L-W-A-1 100% wool	400.5	115.0	28.7%	Very soiled. No surface litter. Colors very dulled by soil. Appearance does not indicate the large amount of soil retained. Very much in need of dry-cleaning.
3 L-E-W-L-2 100% estron	574.2	47.9	8.8%	Very soiled. Surface litter. Colors dulled by soil. Need of good vacuuming with a rotary vacuum and a dry-cleaning.
4 Ma-W-W-L-3 100% wool	467.4	79.9	17.1%	Very dirty. Surface litter. Tops of high pile very dark with dirt. Very much in need of dry-cleaning.
5 B-WA-V-L-2 Wool & viscose	463.7	52.5	11.3%	Fairly soiled. Surface litter. Color dulled by soil. Need of good vacuuming with a rotary vacuum. Dry-cleaning desire-able.
6 B-W-V-L-3 100% wool	491.8	56.4	11.5%	Fairly soiled. Surface litter. Colors not dulled by soil. Carpet appeared to need a good vacuuming with rotary vacuum, but did not appear to need dry-cleaning.
7 Mo-WA-V-2 Wool & viscose	409.3	38.0	9.3%	Very soiled. No surface litter. Colors very dulled by soil. Need of dry cleaning.
8 As-W-V-3 100% wool	514.9	87.4	16.9%	Very soiled. No surface litter. Color dulled beyond recognition. Need of dry-cleaning.

*15 applications of soil

** Code: 1st letter: manufacturer; 2nd letter: fiber; 3rd Letter: Weave; 4th letter: loop pile; number; price group.

*** Sample size: 12" x 27"

The above figures suggest that carpets containing synthetic fibers will not retain as great an amount of soil as will carpets of all-wool pile. Dirt will cling to the scaly surface of the wool fibers whereas synthetics, which are smooth and rod-like in structure, give up soil more readily. However, in comparing the carpets in percentage of weight gained through retention of soil it is evident that other factors such as weave, size of yarn, twist, density and sizing also influenced soil retention.

Carpets 1 and 2, of axminster weave, have less than the average number of tufts per square inch. Therefore, it is possible that the soil had a better opportunity to pass down through the pile to the base of the carpet, where it could have been held by the interlocked, scaly surfaces of the wool fibers in Carpet 2, or by the fullness of the loosely twisted tufts. The synthetic fibers of Carpet 1 (estron), with less fullness in the tufts and no scales, may have released the dirt to the suction of the vacuum cleaner more readily.

Carpets 5 and 6, of velvet weave construction with a textured pattern formed by loops of uneven heights, were almost identical in their soil retention properties, although Carpet 5 contained a blend of wool and viscose and Carpet 6 is 100% wool. This suggests that the following properties may have contributed to a fairly high resistance to soil: high yarn twist, fullness of the loops, and the different heights of the pile loops. The theory concerning the latter being, that dirt falling on the carpet is likely to come in contact with the high pile first; as it is worked into the carpet, the low pile suspends the soil rather than allowing it to fall immediately to the base of the pile.

As dirt ground into the pile through heavy traffic will act as an abrasive, it would seem logical that carpets retaining large percentages of soil would wear out more quickly than the abrasive test on clean carpeting would suggest. For instance 1250 cycles were required to wear out carpet number 1 (100% estron, axminster), whereas carpet number 2 (100% wool axminster) could withstand twice as many cycles of the abrasion wheels (see Plate VII, appendix). However, vacuuming removed four times as much soil from the estron carpet as the wool carpet, as shown in Table VI. If the abrading could be done after the carpet had been subjected to normal use for a given period of time it would give a more accurate picture of the difference in wear characteristics of wool and synthetic carpets, and also a clearer picture of the damage caused by 'soil-retention' characteristics of carpets.

All carpets cleaned with comparative ease, but differences in cleanliness were noted when these carpets were compared with control samples. Carpet 4, a wool of pale green, was the most soiled; carpets 1 and 3 both rose-colored (100% estrons) were also unsatisfactorily cleaned. Carpet 2, a wool axminster of light green seemed to have changed color slightly--this new hue was more yellow-grey, as if there had been a change in color caused by some factor other than cleaning. No other change in color was detected, nor was the twist of the two friezé carpets affected. Carpets 5, 6, 7, and 8 cleaned satisfactorily. As these carpets were above average in quality, it would suggest a definite relationship between quality and 'ease in cleaning', regardless of the fiber of which the pile was made, or the construction of the carpet. However, all of the carpets did have a washed appearance. This appearance was identical with that of any wool (such as a wool blanket) after it had been washed and dried. The yarns seemed slightly frayed, and there were more fiber ends on the surface of the pile, although, upon close inspection, no decided change in the yarns had taken place. The estron pile of Carpet 1 appeared to have become slightly matted during the cleaning process, but this may have been due to its plush-like construction.

Because of the fact that the carpets were cleaned in a stationary position--as one would clean a carpet on the floor in the home, it was not expected that all of the soil would be removed. This type of cleaning is only expected to partially restore original appearance by removing the atmospheric dust, soluble fats and grease. The following table shows the amount of dirt unaffected and remaining in the carpets after shampooing.

TABLE VII
Weight of Carpets After Shampooing With Mystic Foam
Sample Size: 12" x 27"

Carpet Number And Code *	Original Sample Weight In Grams	Weight Of Soiled Carpet In Grams	Weight After Cleaning	Percentage Soil Removed	Percentage Soil Remaining
		100% estron			
1 L-E-A-1	373.7	408.5	406.3	2.8%	6.5%
3 L-E-W-L-2	574.2	622.1	621.5	0.6%	8.2%
		Wool and viscose blend			
5 B-WA-V-L-2	463.7	515.7	511.8	0.9%	10.4%
7 Mo-WA-V-2	409.3	447.3	446.5	0.3%	9.0%
		100% wool			
2 L-W-A-1	400.5	515.5	507.2	2.1%	26.6%
4 Ma-W-W-L-3	467.4	547.3	537.7	2.1%	15.0%
6 B-W-V-3	491.8	548.2	547.7	0.2%	11.3%
8 AS-W-V-3	514.9	602.3	601.5	0.4%	16.5%

* Code: 1st Letter: Manufacturer; 2nd Letter: Fiber; 3rd Letter: Weave; 4th Letter: Loop Pile; Numeral: Price group

The above Table emphasizes the inadequacy of home methods for completely removing soil from carpets. The residue of dirt and cleaning material remaining in the carpet after a home cleaning, often causes rapid resoiling[8]. In order to obtain maximum service, it is of extreme importance that carpets be cleaned professionally each year or two.

Fadeometer Test: Floor coverings have more need of color-fast dyes today than ever before. Modern architects are increasing the areas exposed to sunlight throughout our homes, particularly in the living room. Wall to wall carpeting is currently popular and the area over which carpets are laid has increased. However, modern dyestuff manufacturers have progressed in the production of colorfast dyes to such an extent that only moderate precautions should be necessary to protect floor coverings.

All carpets in this study rated either Class 3 or 4 in colorfastness to light. Three carpets satisfactorily passed the minimum test of 100 hours in the fadeometer. However, no carpet was badly faded in less than 150 hours exposure. The carpets are listed below in descending rank in their colorfastness to light:

TABLE VII
Colorfastness to Light

Carpet Number and Code*		Color	Class	Rank	Result of minimum 100 hour rating
2	L-W-A-1	green	4	1	Satisfactory
5	B-WA-V-2	brown	4	2	"
8	AS-W-V-3	green	4	3	"
1	L-E-A-1	rose	4	4	Unsatisfactory
7	Mo-WA-V-2	green	3	5	"
4	Ma-W-W-L-3	Light green	3	6	"
3	L-E-W-L-2	rose	3	7	"
6	B-W-V-L-3	grey	3	8	"

*Code: 1st Letter: Manufacturer
2nd Letter: Fiber
3rd Letter :Weave
4th Letter: Loop Pile
Numeral: Price Group

After 180 hours in the fadeometer, Carpets 1 and 3, both of 100% estron pile, began to change in color from rose to orange. After 200 hours, the faded areas were considerably lighter than the original carpets and the orange hue of the faded area clashed with the original color. Carpet 3 faded to a greater extent, however, than Carpet 1.

The four wool pile carpets turned yellow as they faded. This yellowing was particularly noticeable and undesirable in the grey carpet tested. Carpet 4, of two tones of light green was the first to yellow after 60 hours exposure to light. This is undoubtedly due to the lightness of the original color, as dark colors are known to keep their color better than lighter values[8]. However, after 200 hours, the amount of change in color in Carpet 4 was not as severe as in Carpets 3 and 6. Carpet 6, a bluish grey wool showed first signs of yellowing after 80 hours exposure in the apparatus. The faded area, after 180 hours was lighter with a tannish cast. After 200 hours the carpet was a yellow-tan instead of grey.

Carpet 7, a wool-avisco blend did not yellow; instead the faded area became a dark grey-green. However, Carpet 5, also a wool-viscose blend did not darken, but paled, retaining its original hue in a lighter value.

Resistance To Crushing Test: A carpet with a springy pile is comfortable to walk on; will not show foot prints; nor does it show a serious tendency to mat permanently under the weight of furniture. We have become accustomed to associating a thick pile with cushion-like qualities in carpeting. However, a thick pile may be stiff and unbending--due to coarse fibers or a high degree of twist in the pile yarns, or to the amount of sizing applied to the back of the carpet. Actually, a carpet's cushion-like quality is not due to the height of the pile, nor to its compressional resiliency, but rather it is due to compression (the actual work done) and recovery (work recovered). Compression is mechanical and is caused by the pressure of the load. Recovery is not mechanical, but is caused by an urge within the fiber to 'spring back' to its original position.

Data obtained from tests performed on the control samples with the compressometer suggest several points of interest concerning compression, (see Chart V, appendix). Carpets number 1, 3, and 4 were high in work accomplished; the amount (expressed in inches), in each case being more than .0330". Of these three, one was 100% wool, and two were 100% estron. These carpets were constructed of yarns with slight twist and no apparent sizing in two of them. Carpet number 6, showing the least 'springiness' was of 100% wool of highly twisted yarns with a heavily sized backing.

In determining whether or not footsteps will leave an imprint, we must know something about the ability of a carpet to 'spring back'. Data obtained from tests on the original samples show that Carpets 1, 3, and 4 were also high in recovery, (1 and 3 are 100% estron, 4 is 100% wool) while the three carpets with the lowest recoveries were of all-wool pile. Carpets 2, 6, and 8 recovered less than .0055". However, it is to be remembered that coarse wools such as carpet wool are, as a rule, stiff and unbending at first, but increase in resiliency with use.(38) The all-wool wilton carpet with the uncut pile showed the highest recovery recorded. This carpet is composed of finer-appearing fibers than the other three, and its yarn is twisted only slightly.

The thickness of a carpet is directly dependent upon its compressional resiliency. This becomes more and more apparent as the carpet begins to wear. Compressional resiliency is also indirectly one of the most important factors in determining the warmth of our floors, for thickness determines the thermal qualities of a carpet.[38] The greater the ability of carpets to maintain their initial thickness, the greater will be the volume of air entrapped in the carpet. Wool and viscose blends showed the highest percentages in compressional resiliency, regaining 26 to 28% of their original thickness. Two carpets of 100% wool were below average in compressional resiliency.

Tests on the control samples were very favorable to the synthetic and synthetic-blend carpets. However, it is to be remembered that the maximum load applied by the compressometer is only .2 pounds pressure per square inch, whereas a person walking across a carpet subjects it to 12 pounds pressure per square inch per second.[5] Furthermore, furniture resting on a carpet will cause flattening or crushing--the degree depending upon the weight of the furniture and the elapse of time.

In the compression of the original samples, there were plenty of air spaces between the tufts allowing room for the carpet pile to spread. However, after the pile has been matted, the size of the air spaces is decreased and further compression would be expected to be slower.

After the carpets had been subjected to weights for 75 hours, all of the carpets in this study showed a decrease in work accomplished with the exception of Carpet 2, (see Chart IX, appendix). This 100% wool axminster was stiff when first tested, but due to increase in the load applied and the time modulus; it began to 'unbend' and subsequently showed an increase in compression of 18.2% over its original number. Two carpets of cut pile construction showed only slight losses in work accomplished. Carpet 1 of estron, lost 1% and Carpet 8, of wool lost 6.4% respectively. Carpet 6, not only shows the least work accomplished both in initial compression and after the 75 hour test, but also showed a loss of 20.1% of its original compression after application of weights for 75 hours. The high twist in the pile yarns, and the above average amount of sizing in the backing may account for its low compression readings. However, neither of these factors satisfactorily explain the loss of approximately one-fourth its original ability to 'compress'. This carpet is constructed with pile loops of uneven height. One explanation for its low compression value may be due to the fact that initially only the high pile was affected by the pressure of the compressometer, whereas after 75 hours under pressure, both the high and low pile was reflected(thus increasing the carpet density) in its compression reading. After 300 hours under weights, this carpet had regained so much of its original compressional ability, ~~so~~ that instead of a 25.0% loss, there was only an approximate 10% loss, (see ChartVIII, carpet 6, appendix). Carpet 2, an axminster wool, continued to gain in compression. This fact suggests that carpets made of coarse stiff fibers will, within certain limitations, become more and more 'springy'. All four of the carpets containing synthetic fibers showed increasing losses in their ability to compress, (see Chart IX, appendix). After 300 hours under weights the loss range was 25.0 to 46.3%. Wool carpet number 8 of velvet construction likewise lost 28.3% of its compression value. All carpet with 25 or more percent loss in compression showed evidences of matting.

In order to ascertain the reason for the matting mentioned above, the amount of 'work regained' during each test must be taken into consideration. This is dependent upon two conflicting factors. The scaly surface of the wool fibers might become entangled under the pressure of the load thereby causing matting. On the other hand, it would seem logical that if no matting took place, the upward push of one fiber against another would hasten the recovery of the pile.

After weights had been applied for 75 hours, it was found that all carpets containing synthetic fibers showed a loss in work recovered, ranging from 26.2% to 62.2% of their initial ability to compress, (see Chart X, appendix). Carpets of all-wool showed gains in work recovered from 2.2% to 90.9%. It is evident then, that no interference in compressional recovery was due to an entangling of the wool fibers under pressure. As the synthetic fibers are comparatively smooth and rod-like, matting through interlocking could not have taken place. Therefore it would seem that the initial resiliency of the synthetic fibers had been strongly affected by the application of weights for 75 hours.

Table IX, page 61, shows that after 300 hours, each of the four synthetic carpets lost from 47.5% to 81.2% of their original recovery. Significantly, three of the four woolen carpets retained (or increased) their ability to recover from crushing. Carpet 2, a wool axminster which showed the lowest original reading in 'recovery', showed the highest reading after being weighted for 300 hours. Due to the fact that the fibers used in this carpet were stiff and coarse, resiliency would be expected to increase as the load increased. Moreover, its low density of 35 tufts per square inch reduced any opportunity for the fibers to entangle under the load.

TABLE IX

Recovery From Compression

Carpet Number And Code*	Control Recovery In Inches	Recovery After 300 Hours In Inches	Gain or Loss In Percent
	100% Wool		
2 L-W-A-1	.0044"	.0119"	+ 170.4%
4 Ma-W-A-L-2	.0099"	.0102"	3.3%
6 B-W-V-L-3	.0057"	.0059"	0.1%
8 AS-W-V-3	.0053"	.0039"	-24.5%
	Blends of Wool and Avisco		
5 B-WA-V-L-2	.0080"	.0042"	-47.5%
7 Mo-WA-V-2	.0073"	.0025"	-65.7%
	100% Estron		
1 L-E-A-1	.0091"	.0027"	-66.6%
3 L-E-W-L-2	.0081"	.0017"	-81.2%

* Code: 1st letter: Manufacturer; 2nd letter: Fiber; 3rd letter: Weave; 4th letter: pile Loop; Numeral: Price Group

Carpet 8 (100% wool velvet construction) lost 24.5% of its original ability in 'recovery from compression' after 300 hours. Visual signs of matting were more evident than in other wool carpets. This carpet pile was of two-ply yarns with only slight twist in the singles of the yarn. Its density, height of pile, and weight were above the average of the other carpets tested. However, there are two possible reasons for the loss of more than one-fourth its original ability in recovery from pressure. As the density is high, matting might have been caused by the interlocking of the wool fibers; or the weak structure of the backing might have caused a slight shift of the fibers from an up-right position. This carpet was the easiest to dissect of the eight carpets tested. The pile almost fell out, suggesting that the back was not too firmly woven. The backing shows no apparent sizing, the stuffer yarns are paper, and there are only two shots to hold the tufts in place. This carpet was the only one to show wear due to loss of tufts in the abrasion pre-testing.

A comparison of the rate and extent of recovery (following the terminal pressure of 300 hours) was possible through readings taken at specified intervals. The compression figures are summarized below in Table X:

TABLE X
A Comparison of Compression Numbers at Specified Intervals

Carpet Number and Code	Compression After 300 Hours	Compression After Weights Removed For 1 hour	4 hours	24 hours	48 hours	Percentage Gain Or Loss Over Control
1 *L-E-A-1	.0238"	.0276"	.0305"	.0306"	.0309"	- 8.0%
3 *L-E-W-L-2	.0211"	.0213"	.0216"	.0218"	.0221"	-43.4%
5**B-WA-V-L-2	.0229"	.0232"	.0238"	.0260"	.0259"	-13.3%
7**Mo-WA-V-L-2	.0131"	.0181"	.0184"	.0189"	.0192"	-26.5%
2 L-W-A-1	.0337"	.0328"	.0354"	.0369"	.0378"	+44.1%
4 Ma-W-W-L-3	.0384"	.0371"	.0373"	.0379"	.0393"	- 1.0%
6 B-W-V-L-3	.0206"	.0225"	.0272"	.0266"	.0274"	+20.1%
8 AS-W-V-3	.0203"	.0191"	.0202"	.0213"	.0260"	- 6.8%

* 100% estron
** Wool-avisco blends

In one hour's time, the 100% estron axminster carpet (number 1) showed marked improvement in compression, and after 48 hours it had regained approximately its original compression number. However, Carpet 3, also of estron, showed a loss of 43.3%. In comparing the construction of the two estron carpets, Carpet number 1 has a low density number of 35 tufts per square inch; while carpet Number 3 with 54 tufts per square inch has fewer air spaces into which the fiber might be 'packed' after matting had taken place. Carpet 3 had the second highest compression number recorded in the 'control' test: It is possible that only the higher pile loops were affected by the pressure of the compressometer in the control test; whereas after weights had been applied for 300 hours, both high and low pile were reflected in the compression reading. After the weights were removed, the pile loops of which there were only an average number per square inch may have flattened to such an extent that the compression of the carpet was lessened. However, Carpet 4, an all-wool, comparable to the above estron carpet in weave, weight and density ranked high in compression throughout the series of tests, thereby suggesting that the pressure of the weights had impaired the compressional ability of Carpet 3.

It is to be noted from Table XI that three of the carpets containing synthetic fibers lost between 27.1% and 51.6% of their ability in recovery.

TABLE XI

A Comparison of Recovery Numbers at Specified Intervals

Carpet Number And Code	Control Sample Recovery Number	300 Hour Recovery Number (Zero Hour)	Recovery After Weights Removed for 48 hours	Percent Gain or Loss Over Control After 48 Hours
1* L-E-A-1	.0091"	.0017"	.0043"	-51.6%
3 *L-E-W-L-2	.0081"	.0027"	.0059"	-27.1%
5**B-WA-V-L-2	.0080"	.0042"	.0080"	0.0%
7**Mo-WA-V-2	.0073"	.0025"	.0039"	-46.8%
2 L-W-A-1	.0044"	.0119"	.0062"	+36.3%
4 Ma-W-W-L-3	.0099"	.0102"	.0089"	-10.1%
6 B-W-V-L-2	.0057"	.0057"	.0095"	+66.6%
8 AS-W-V-3	.0052"	.0039"	.0078"	+30.8%

* 100% estron
** Wool -avisco blend

Three of the 100% wool carpets gained between 36.9% and 66.7% of their ability to 'recover'. Although Carpet 4 (100% wool) lost 10% of its ability in recovery, this carpet continued to rank second. Microscopic tests showed that the pile of this carpet was of a finer grade of wool than that used in the other carpets; therefore, it was not stiff and unbending in the first tests but was immediately resilient. Perhaps, because the yarns are made from finer fibers than the others it could not be expected to withstand repeated loads with the same high compressional resiliency noted in the initial test.

According to Table XI, wool carpets tend to gain in their ability to 'spring back' after the application of pressure and synthetic carpets tend to lose their 'springiness'. It would seem logical that Carpet 5, a blend of wool and synthetic fibers would retain its original recovery number; yet this carpet showed very positive evidence of matting. A high recovery number in the 'control' test could be attributed to the uneven height of the pile. Carpet 7, also a blend of wool and synthetic fibers lost 48.5% of its original recovery number: This was expected, as this carpet also appeared very 'matted'. A detailed 'Recovery Chart' is included in the appendix, Chart X.

Compressional resiliency is a ratio between the work accomplished and the work recovered. The control test samples show slightly greater compressional resiliences for those containing synthetic fibers than those of all wool, (see Chart XI, appendix). However, terminal tests of the eight carpets in this study indicate that after wool has been given a chance to 'unbend' the percent of compressional resilience will show a definite relationship to the Density Index Number, (see Table XII, page 65).

TABLE XII

Comparison of Compressional Resiliences
And Density Index Numbers

Carpet Number And Code	Compressional Resiliences Control Test	After 48 hours	Density Index Number
1 *L-E-A-1	23.0%	14.0%	4.15
3 *L-E-W-L-2	20.4%	26.6%	9.29
5**B-WA-V-L-2	26.6%	30.8%	1 0.96
7**Mo-WA-V-2	28.0%	20.3%	7.26
2 L-W-A-1	14.9%	16.4%	4.51
4 Ma-W-W-L-3	24.9%	22.9%	7.32
6 B-W-V-L-3	25.0%	34.7%	11.13
8 AS-W-V-3	18.6%	30.0%	10.86

* 100% estron
** Wool and Avisco blend

According to the above figures, there is a definite relationship between the quality and the compressional resiliency recorded after the 'newness' of a carpet has worn off.

A certain degree of pile crushing or matting takes place on all carpets and is particularly noticeable when the carpet is woven so as to have a plush-like surface, or is of a plain color. Although weave, texture and pattern are important in reducing the appearance of crushing or matting, genuine crushing is directly dependent upon the resiliency of the fiber.

After the carpets in this study had been under the weights for 300 hours, six of them lost 15.4 to 22.3% of their original thickness due to pile-crushing. Carpets 4 and 6 did not look matted, although the former had lost 13.6% of its original thickness and the latter 6.4%. Both of

these all-wool carpets were seemingly high in resilience at the termination -------- of 300 hours, (see Table XI, appendix). Within 48 hours after weights were removed, Carpets of 100% wool and 100% estron had regained at least 95% of their original thicknesses; whereas the wool-avisco blends, (carpets 5 and 7) regained only 83.3% and 89.2%, respectively. Moreover, these carpets were matted four weeks after weights had been removed. Although Carpets 1 and 3 (100% estrons) were greatly affected by the pressure of the weights, their subsequent recovery suggests that the affect was not permanent, and that the estron fiber is more resilient than a blend of wool and avisco fibers.

TABLE XIII

Carpet Crushing*

Carpet Number And Code	Control Thickness In Inches	Percentage Loss in Thickness						
		Hours Compressed			Hours Released			
		75	150	300	1	4	24	48
1 *L-E-A-1	.3117"	13.1%	14.6%	17.1%	14.5%	12.9%	6.5%	3.2%
3 *L-E-W-L-2	.3530"	5.4%	14.0%	15.4%	13.8%	12.0%	10.6%	5.4%
5**B-WA-V-L-2	.3700"	12.5%	13.1%	18.5%	18.0%	15.7%	12.0%	10.8%
7**Mo-WA-V-2	.3000"	14.9%	18.5%	22.3%	19.9%	19.3%	18.0%	16.7%
2 L-W-A-1	.3579"	12.3%	12.4%	19.7%	15.7%	13.2%	2.3%	0.4%
4 Ma-W-W-L-3	.3433"	6.8%	12.8%	13.6%	3.2%	1.8%	0.6%	0.4%
6 B-W-V-L-3	.3600"	0.4%	3.6%	6.3%	4.7%	1.0%	0.5%	0.0%
8 AS-W-V-3	.3600"	12.8%	15.3%	21.9%	18.8%	15.9%	15.6%	3.6%

* Crushing: Loss in Standard Thickness, due to pressure of weights, recorded as Percentage Loss in Thickness.

* 100% estron

** Wool and avisco blends

Evaluation of Carpets: A Table summarizes the investigators evaluation and ranking of each carpet on a ten point scale, (from high of 10 to low of 0) for serviceability factors and general appearance:

TABLE XIV

Carpet Rating As to Appearance And Serviceability Factors

Carpet Number And Code*	Appearance (1)	Abrasion(2)	Resiliency(3)	Ease in Vacuuming(4)	Soil Resistance(5)	Resistance to Fading(6)	Matting (7)	Total(8)
1 L-E-A-1**	3	0	4	8	10	5	8	41
2 L-W-A-1	4	1	5	7	0	9	9	40
3 L-E-W-L-2**	5	2	8	5	10	7	6	50
4 Ma-W-W-L-3	10	4	7	5	6	3	10	59
5 B-WA-V-L-2***	8	8	9	3	9	8	5	66
6 B-W-V-L-3	8	10	10	3	9	1	10	69
7 Mo-WA-V-2***	7	5	6	8	10	5	1	54
8 AS-W-V-3	10	8	9	8	6	7	3	68

(1) Appearance: Personal reaction to appearance of carpets
(2) Abrasion: One-half the number of cycles carpet withstood before becoming worn out by the action of abrasion machine.
(3) Resiliency: 3 times compressional resiliency, 48 hours after weights were removed, expressed as points on a ten-point scale.
(4) Ease in Vacuuming: Arbitarily graded during soil-retention test.
(5) Resistance to Soil Retention: Highest in resistance to soil graded 10, lowest graded 0, others calculated between 0 and 10
(6) Resistance to Fading: Based on results obtained from Fadeometer Tests.
(7) Based on percentage of original thickness regained 24 hours after weights were removed, highest regain graded 10, lowest graded 0, others calculated between 0 and 10.
(8) Total: Because of the importance to the consumer-buyer of appearance and wear-qualities of a carpet, the rating for these factors are doubled in computing the total evaluation of the carpets.

* Code: 1st Letter: Manufacturer; 2nd Letter: Fiber; 3rd Letter: Weave; 4th Letter: Loop Pile; Numeral: Price Group

** 100% estron

*** Wool-viscose blend

The over-all results of the carpets tested in this study suggest their division into three quality groups; fair, average, and high. Although there is some relationship between quality and price, this correlation si not always positive as is shown in Chart I, appendix. Carpet 4 was high in price but only average in quality. It was felt that the style value of this lovely wool carpet was the determining price factor. Carpet 5 was average in price but high in quality. The price factor is due to the fact that approximately 50% of the fibers used were viscose, which cost 42¢ per pound in September 1950, about the time that this carpet was in production, whereas wool carpet fibers were $1.05 per pound [(9)]. The high quality of Carpet 5 is attributed to its excellent construction, in which density, height of pile and weight were above average.

V. CONCLUSIONS

Considering the vast numbers of carpets on the market and the tremendous amount of thought and time that has gone into the manufacture of carpets throughout the last eight centuries, it is impertinent to suggest that the results of this small study is predictive of the wear qualities of carpets containing synthetic fibers. In fact, this study is not sufficient in its scope to be predictive of the serviceability qualities of the eight carpets tested. However, several points worthy of consideration in the purchase of carpets are suggested by the results of this study.

Surveys made in retail stores have shown that customers buying carpets are interested primarily in color, pattern and appearence; secondly, in quality and/or serviceability; and third, in price.[2] The consumer-buyer has accepted synthetic fibers in other products and is prepared to accept them in the carpet field provided the synthetic carpets offer equivalent value in appearance and serviceability in relationship to price.

The over-all test results of the carpets in this study suggest their division into three quality groups--fair, average and high quality. As each group includes a 100% wool carpet as well as one containing synthetic fibers, one cannot accurately base the over-all value on the fiber content of carpet pile.

Before the introduction of synthetics and synthetic-blends, the maximum wear value of wool pile was based primarily on density and height of pile and weight of the carpet, properly coordinated and balanced. The compactness of the tufts per square inch in the pile was considered most important. When density was equal, carpets with the highest pile were the most durable, but yarn size, type of dye, and fiber quality were also important.

Serviceability tests for this study suggest that, other factors being equal, wool fibers will wear longer than synthetic fibers. However, density, height of pile and weight of the carpets are still of major importance in determining probable serviceability. A Density Index Number based on the above factors is more predictive of the wear qualities of a carpet than the quality of the carpet fiber used. For instance, Carpet 5, a wool and viscose blend with a Density Index Number of 10.96 was abraded 8 times as many cycles before becoming worn out as Carpet 2, a 100% wool with a Density Index Number of 4.5.

However, the formulae for a Density Index Number does not present the total criteria for determining serviceability, for it does not account directly for differences in soil retention, the ability to resist crushing, or fading characteristics.

Test results showed that, as a rule, carpets with synthetic pile fibers retained less soil than the carpets of all-wool. However, twist, density, and the amount of sizing applied to the fibers and/or the backing also affected soil retention.

Difficulties encountered in vacuuming and cleaning carpets with a fluid cleaner were not due to the differences in the fibers of the pile, but rather to the construction of the carpet or to the lightness of the colors used. Carpets of uneven loop pile seemed very difficult to clean with a suction-type vacuum cleaner. Carpet 2, (100% wool axminster with a plush-like pile) showed a marked tendency to 'shade' when vacuumed against the grain of the pile. Although Carpet 1, (100% estron axminster) also constructed with a plush-like pile, did not 'shade' during vacuuming, the application of a commercial cleaner tended to give this pile a definite 'shaded' appearance. Pale colors such as light green and rose were more difficult to clean satisfactorily than the darker colors.

The wool carpets showed wide variation in resiliency. Carpet 4, a 'luxury' carpet which was very resilient at the beginning of the test, lost some of its ability to compress and 'spring back' due to the fineness of the fibers of the yarns. On the other hand, Carpet 2, which was stiff and unbending at first became increasingly resilient as the tests progressed. This carpet was constructed of coarse fibers more capable of resiliency when the load was prolonged than for short loads. Carpet 6, also fairly stiff and unbending at first, due to high twist and heavy sizing became more resilient as the fiber became accustomed to bending under a load. Only one wool carpet, number 8, showed evidence of matting. It lost 21.9% of its original thickness through the application of weights. However, after 48 hours, a regain of most of its original thickness suggested that the 'matting' was not of a permanent nature.

Carpets of synthetic fibers or synthetic-wool blends were high in compression, recovery and compressional resiliency during control tests, but after weights had been applied each of these carpets reacted differently and to approximately the same extent that the wool fibers differed from each other. The ability of carpets of estron to compress and recover seemed the most impaired by the pressure of the weights, yet 48 hours after the weights were removed these carpets were continuing to regain in resiliency, and no visual effect of matting was evident. Carpets 5 and 7 (wool-avisco fibers), at first did not seem to be as seriously affected by the weights has had the estron carpets, but eight weeks after the weights had been removed, these carpets were still very 'matted'. Although Carpet 5 had recovered 90.1% of its original thickness and Carpet 7, 85.0%, it seemed possible that these carpets were permanently 'crushed', (to a certain extent) by a load of 2.3 pounds per square inch for a period of 300 hours (approximately 12 days).

Analysis of results of this study indicated that the pile-crushing characteristic of the synthetic fibers is its most significant adverse factor, and that fibers of viscose are more subject to matting than fibers of estron. However, certain construction factors conceal matting. Patterns in design, achieved either through combining colors or use of uncut and cut pile or different heights of uncut pile or twist in the yarns tend to minimize the appearance of crushing. Therefore, the consumer-buyer who wants plush-like carpeting should avoid the synthetics.

Carpets tested in the fadeometer were insufficient in number to give an accurate comparison of the color characteristics and permanency of carpet yarns when subjected to accelerated sunlight. However, it was observed in this study that carpets of light colors do not hold their color as well as those of darker hues. This point is affirmed by Heuer[(8)], who states that this is due to the small amount of coloring used in the lighter colors. While all of these carpets were fairly sunfast, only three passed the minimum test of 100 hours in the fadeometer. Two of these carpets were all-wool, the other a wool-avisco blend. Carpet 6, one of the finest carpets tested showed the greatest amount of fading. It was felt that this was due to the color--as light grey seems to be more susceptible to color change than positive colors of darker values. The estron carpets faded badly after 150 hours, the color itself actually changing from rose to orange. However, there seemed to be no significant differences in the colorfastness of the synthetic and the wool carpets.

The factor of cost has a definite relationship with the quality of the carpet. Carpets of low price were found to be below average in over-all quality. With two exceptions, carpets of medium price were 'average' in quality and the high priced carpets were 'high-quality'. Carpet 4 was high in price but only average in quality. It was felt that the style value of this lovely wool carpet was the determining price factor. Carpet 5 was average in price but high in quality. The price factor was due to the fact that approximately 50% of the fibers used were viscose at $.42 per pound (January 1951 figure)[27], costing less than one-half the $1.05 per pound of carpet wool (September 1950 figure)[9].* The high quality of this carpet was due to the high grade of construction in which density, height of pile, and weight of fiber were above average.

The need for further study on carpets of synthetic fibers is obvious. There is relatively little information on the serviceability of these carpets. With increased use of synthetic carpets there is a definite need for a clearer understanding of its advantages and limitations in consumer use. A laboratory study such as this one is but indicative of one type of research which could be done. Further investigations of carpets should include a serviceability study in which the carpets are subjected to normal

* Six months later, in March 1951, the price of wool was $2.24[39]

use for a period of years. Several studies in which larger samplings of carpets than those used in this study is also recommended. Another phase of study in carpets should include those made of nylon, vinyon and other synthetic fibers as orlon and dynel.

Consumers, purchasing carpets today should have some knowledge of the significance of carpet construction as well as an understanding of the comparative cost of carpet construction and fibers. In addition to this information, a consumer should be able to rely on an informative label attached to the carpet under consideration. Such a label would include the following: name of the manufacturer; number of tufts per square inch; size of yarns; the fiber content of the pile and backing yarns; type of weave; height of the pile; and weight of carpet per square yard. The colorfastness of the carpet should be designated by the number of hours of accelerated sunlight required to fade the carpet. Functional finishes for resistance to moths and fire should also be stated.

Because so many new fibers, fiber blends, and methods of construction are possible in the future, both technological and consumer research must continue so that today's consumer-buyer may purchase the carpeting that she wants and needs with few or no compromises required.

VI. SUMMARY

Statistics show that the carpet industry has been facing a downward trend for the last thirty years.[37][39] For some time, the manufacturers have been looking for some way in which a less expensive carpet of good quality would be available for the market, thus enabling them to obtain a larger share of the consumer's dollar. Rayon has been able to accomplish very fine results in other textile fields, and it has been felt that it could conceivably accomplish a similar result in the carpet field.

For years wool has been considered the finest possible fiber for carpet wools in spite of the instability of the foreign markets and the continual fluctuation in price per pound. However, there are several unfavorable properties possessed in varying degrees by different carpet wools which must be overcome by the manufacturer by careful blending with other wools. These properties include the presence of excessive amount of kempy fibers; uneven dyeing properties; shedding; and wide variation in the different carpet wools in wear-resistance, resiliency and torsional rigidity.

Rayon fibers produced in the United States provide not only a domestic source of supply but a market in which price is not as fluctuant as those from which carpet wool are secured. Of course, it is not a perfect fiber, it needs greater resiliency, more torsional rigidity, and crimp, Rayon technology has made remarkable progress and it is not unreasonable to except that eventually carpet fibers can be produced to specifications, so to speak, in size, length, brightness and crimp. They will, no doubt, be able to overcome to a limited extent some of the adverse characteristics of synthetic carpet pile.

An evaluation of selected types of all-synthetic, and wool and synthetic blends with wool carpeting was conducted through laberatory experiments on eight carpets purchased in Lansing, Michigan in March 1951. The carpets representing five different manufacturers were of 100% estron, 100% wool, and wool-avisco blends. Two carpets each of axminster weave; wilton construction with loop pile; velvet weave with loop pile, and two of velvet construction with a cut pile were studied. Each pair consisted of one carpet with synthetic pile fibers and one all-wool pile.

The carpets were purchased from three price groups; $6.50 to $7.50 per square yard, $9.50 to $10.95 per square yard, and $12.50 to $14.95 per square yard. Correlation between price and quality was found to be positive for all but two of the carpets.

Specification tests included microscopic and chemical analysis for fiber content; dissection of carpets for construction analysis; and performance testing for light fading; compressional resiliency and thickness. A comparison of dirt retention, abrasion resistance and compressional recovery were modified to the available instruments for testing.

Laboratory tests to determine the abrasive quality of the carpets suggested that, other factors being equal, wool fibers will give longer wear than some of the synthetic fibers. However, density, height of pile and weight of the carpets are of major importance in determining probable serviceability. A density index number based on the above factors is more predictive of wear qualities of a carpet than the type of fiber used.

Tests for 'soil retention' showed that, as a rule, carpets of synthetic pile retained less dirt than the carpets of all-wool. However, twist, density, freedom from scales, uniformity of size, and the amount of sizing applied to the fibers and/or the backing affect soil retention to a greater degree than the 'type' of fiber.

Analysis of the results of the pile-crushing test indicated that the low-resistance to crushing of the synthetic fibers is their most significant adverse factor, and that viscose fibers are more subject to matting than estron fibers. It is suggested that synthetic pile carpets are most satisfactory in textured patterns, multicolors or tone on tone so that genuine matting is not so evident.

Carpets tested in the fadeometer for fastness to light were insufficient in number to provide an accurate comparison of color change or permanency of color when carpets were subjected to accelerated sunlight. However, there was no significant difference in the colorfastness to light of the synthetic, wool or blends.

It was felt that carpets of good construction, purchased from reliable manufacturers, at medium or somewhat higher prices will be satisfactory in appearance and serviceability in use regardless of the fiber used.

LITERATURE CITED

Literature Cited

1. American Society for Testing Materials, Committee D-13 A.S.T.M., Standards on Textile Materials. Philadelphia, Penn. ASTM., October 1946, pp. 68-89, pp 870-875, p 77, p 43.

2. American Viscose Coporation: Things You Should Know About the New Man-made Carpet Fibers. Leaflet Number 149, Consumer Service Section of American Viscose Corporation, New York, New York. 4 pp.

3. Ashcroft, A. G. Carpet Yarns Newest Triumph In Science. Alexander Smith & Sons Carpet Company, Yonkers, New York, Mimeographed Bulletin, Spring, 1951. 6 pp.

4. Backer, Stanley. The Relationship Between the Structural Geometry of a Textile Fabric and Its Physical Properties. Textile Research Journal. Volume 21 (July 1951), pp 453-467.

5. Barach, J. L. Dynamic Studies of Carpet Resilience, Textile Research Journal. Volume 19 (June 1949) , pp 355-362.

6. Barach, J. L., and Rainard, L. W. Effect of Crimp on Fiber Behavior. Part II , Addition of Crimp to Wool Fibers and Its Effect on Fiber Properties. Textile Research Journal. Volume 20 (May 1950) pp. 308-16.

7. Beckwith, O. P., and Barach, J. L. Notes on the Resiliency of Pile Coverings, Textile Research Journal. Volume 17 (June 1947)

8. Better Buymanship Pamphlet. Floor Coverings, Pamphlet Number 10. Household Finance Corporation. January 1950, 31 pp.

9. Carpets Go Synthetic. Business Week, September 2, 1950,p 56.

10. Dillon, M. E. Resilience of Fibers and Fabrics. Textile Research Journal. Volume 17 (April 1947), pp 207-13.

11. Dilts, Madge E., Carpets and Rugs. The Hoover Company, North Canton Ohio. 1939.

12. Federal Standard Stock Catalogues: Superintendent of Documents, Washington D. C.

DDD-C-51a, March 27, 1942
DDD-C-51 January 9, 1934
DDD-C-61a January 9, 1934
DDD-C-61b March 18, 1937
DDD-C-71a July 3, 1934

13. Finch, Rogers B. Interfiber Stress and Its Transmission: Part I: Measurement of the Contact Area Between Fibers Under Pressure. Textile Research Journal, Volume 21 (June 1951) p 375.

14. Gonsalves, V.E. Theoretical Considerations and Measurements with Regard to the Longitudinal Abrasion of Rayon Filaments. Textile Research Journal. Volume 20 (January 1950) page 28-42.

15. Hartsuch, Bruce E. Introduction to Textile Chemistry. John Wiley & Sons, Inc. 1950. 387 pp.

16. Hildreth, Howard. What About Rayon Carpets? Reprint from Mohawk Carpet Mills Pow-wow. September 1950. 4 pp.

17. Hoffman, R. M. Generalized Concept of Resilience. Textile Research Journal. Volume 18 (march 1948), p 141.

18. James Lees Carpet Company. Technical Bulletin: Cellulose Acetate--A man-made Fiber. Mimeographed material from Product Development Division. James Lees & Sons Carpet Company, Bridgeport, Penn.

19. Matthews, J. Merrit. Textile Fibers John Wiley and Sons, Inc. 1935, p. 77.

20. Millson, H. E., and Turl, L. H., Studies on Wool Dyeing: The Influence of the Cuticle in the Dyeing of Wool. American Dyestuff Reporter, October 2, 1950. pp. 647-56

21. Morahan, J. M., Rug and Carpet Yarns: Use of Rayon and Synthetic Fibers. Rayon and Synthetic Textiles. Volume 31 (August 1950) pp. 26-28.

22. Morahan, J. M. Synthetic Fibers Dig In On The Carpet Front. Rayon and Synthetic Textiles. Volume 32 (February 1951) pp 32-3/

23. Platt, Milton. Mechanics of Elastic Performance of Textile Materials. Part III. Some Aspects of Stress Analysis of Textile Structure Continuous Filament Yarns. Textile Research Journal. Volume 20 (January 1950) pp 1-15.

24. Platt, Milton. Mechanics of Elastic Performance of Textile Materials. Part IV. Some Aspects of Stress Analysis of Textile Structure Staple Fiber Yarns. Textile Research Journal (August 1950) p 519-537.

25. Platt, Milton. Mechanics of Elastic Performance of Textile Materials Part VI. Influence of Yarn Twist on Modulus of Elasticity. Textile Research Journal Volume 20, (October 1950) pp 665-667.

26. Rainard, L. W., and Abbot, D. Effect of Crimp on Fiber Behavior. Part I: The Determination of Fiber Irregularities and the Concepts of the Single-Fiber Bulking Capacity. Textile Research Journal. Volume 20 (May 1950) pp 301-7

27. Rayon and Synthetic Textile Survey: What's New in Staple Fibers. Rayon and Synthetic Textiles, Volume 32 (September 1951) p 60.

28. Royer, G. L. A Review of Textile Coloring and Finishing Research. American Dyestuff Reporter. December 11, 1950.

29. Schiefer, H.F. Notes on Disintegration of Wool in Abrasion Tests. Textile Research Journal. Volume 19, (1949) page 822.

30. Schiefer, H. F. Wear Testing of Carpets. Research Paper RP 640. United States National Bureau of Standards Journal of Research Volume 12, February 1934, pp 155-166.

31. Schiefer, H. F. Wear Testing of Carpets. Research Paper RP 1505. United States National Bureau of Standards Journal of Research Volume 29, (November 1942) pp. 333-379

32. Schwartz. Edward R. Yarn Structure. Textile Research Journal Volume 21 (March 1951) page 125.

33. Skinkle, John H. Textile Testing. Chemical Publishing Co. New York City (1940) 267 pp.

34. Prices of Rayon Filament and Staples, Rayon and Synthetic Textiles Volume 32 (Januardy 1951) p 60.

35. Smith, Robert E. Rayon Staple and Wool Blends Produce New Possibilities For Carpet Trade. Textile Age, August 1950.

36. Study Shows Kraftcord Yarns Improve Carpet Appearance. Retailing Daily. April 28, 1947. Fairchild News Service. New York City.

37. Truitt, Joseph A. The Carpet Trade Needs Rayon--Is Rayon Ready? Rayon Textile Monthly January 1940 pp 33-37, February 1940 pp 101-102.

38. Von Bergen, Werner, and Mauersberger, Herbert R. American Wool Handbook. Textile Book Publishers (1948) 1055 pp.

39. Wool's Battle with the Synthetics. Fortune Volume XLV (May 1952) pp 128-133

40. Yarn Acceptance: What Carpet Producers Think of Synthetics as a Permanent Raw Material. Rayon and Synthetic Textiles. Vol. 31 (September 1950) pp. 95-6.

APPENDIX

CHART I

Carpet Code, Quality and Price Data

Carpet Number	Manufacturer	Fiber	Weave	Loop Pile	Price P.S.Y.	Quality
1	Lees	Estron	Axminster	cut pile	$6.50	Low
Code:	L----	E----	A----	----	---1*	
2	Lees	Wool	Axminster	cut Pile	$7.50	Low
Code:	L----	W---	A----	----	---1*	
3	Lees	Estron	Wilton	loop	$10.95	Medium
Code:	L----	E---	W----	L----	---2*	
4	Masland	Wool	Wilton	Loop	$14.95	Medium
Code:	Ma----	W----	W----	L----	---3*	
5	Bigelow	Wool-Avisco	Velvet	Loop	$10.50	High
Code:	B----	WA----	V----	L----	---2*	
6	Bigelow	Wool	Velvet	Loop	$12.50	High
Code:	B----	W----	V----	L----	---3*	
7	Mohawk	Wool-Avisco	Velvet	Cut Pile	$9.50	Medium
Code:	Mo---	WA----	V----	-----	---2*	
8	Alexander-Smith	Wool	Velvet	Cut Pile	$13.95	High
Code:	AS----	W----	V----	-----	---3*	

* Price Range:
1. Low
2. Medium
3. High

CHART II

Chemical Analysis of Carpet Pile Fibers *

Carpet No and Code	Weight of Pile in Grams	Weight of Residue in Grams	Loss in Weight Attributed to Loss of Fibers or Sizing	Percentage Weight of Residue
Potassium Hydroxide Test				
1 L-E-A-1	4	3.9525	sizing	98.8%(rayon)
3 L-E-W-L-2	4	3.8624	do	94.5%(rayon)
5 B-WA-V-L-2	4	2.2412	Wool Fibers	56.0%(rayon & sizing)
7 Mo-WA-V-2	4	2.0036	do	50.0%(rayon)
2 L-W-A-1	4	No residue	do	----
4 Ma-W-W-L-3	4	do	do	----
6 B-W-V-L-3	4	do	do	----
8 AS-W-V-3	4	do	do	----
Acetone Test				
1 L-E-A-1	2	No residue	estron fibers	----
3 L-E-W-L-2	2	No residue	estron fibers	----
5 B-WA-V-L-2	2	2.0340	------	100%(wool & viscose)
7 Mo-WA-V-2	2	1.9862	------	100%(wool & viscose)
Sulphuric Acid Test				
5 B-WA-V-L-2	2	.7197	viscose fibers	35.9% (wool)
7 Mo-WA-V-2	2	.8943	viscose fibers	44.7%(wool)

Summary: Composition of Pile Fiber

1 L-E-A-1	98.8% estron, 1.2% sizing
3 L-E-W-L-2	94.5% estron, 5.5% sizing
5 B-WA-V-L-2	56.0% viscose and sizing , 8.1% sizing, 35.9% wool
7 Mo-WA-V-2	50.0% viscose 5.3% sizing, 44.7% wool
2 L-W-A-1	100% wool and sizing
4 Ma-W-W-L-3	100% wool and sizing
6 B-W-V-L-3	100% wool and sizing
8 AS-W-V-3	100% wool and sizing

* Averages of three tests

Code: 1st letter: Manufacturer
2nd letter: Fiber
3rd letter: Weave
4th letter : Loop pile
Number: Price Group

CHART III

Specification Analysis of Weights

Carpet Number And Code	Weight In Ounces Per Running Yard	Weight In Ounces Per Square Yard		Pile Weight In Percent	Weight in Grams Per Square Inch		Weight In Grains Per Turt
		Total	Pile		Pile	Backing	
1 L-E-A-1	33.0735	44.0980	16.2637	36.9%	.3555	.6257	.157
2 L-W-A-1	35.0322	46.7097	15.1520	32.4%	.3312	.6896	.145
3 L-E-W-L-2	49.1582	65.5443	37.0611	56.5%	.8101	.6216	.231
4 Ma-W-W-L-3	46.1148	61.4864	30.4916	50.6%	.6665	.6165	.190
5 B-WA-V-L-2	43.4042	57.8723	34.8594	60.2%	.7618	.4773	.184
6 B-W-V-L-3	45.6000	60.8001	36.7822	60.4%	.8036	.5158	.195
7 Mo-WA-V-2	42.5464	56.7285	28.3643	50.0%	.6200	.6182	.149
8 AS-W-V-3	50.9870	67.9827	36.3884	53.3%	.7954	.6821	.191

*Code:

1st Letter: Manufacturer
2nd Letter: Fiber
3rd Letter: Weave
4th Letter: Weave-Loop Pile
Numeral: Price Group

CHART IV

Density Index Numbers*

Carpet No. and Code	Weight Per Tuft in Grains	Tufts per Square Inch	Height of Pile in Inches	Density Index Number
1 L-E-A-1	.157	35	.1885	4.15
2 L-W-A-1	.145	35	.2065	4.51
3 L-E-W-L-2	.231	54	.1862	9.29
4 Ma-W-W-L-3	.190	54	.1785	7.32
5 B-WA-V-L-2	.184	64	.2323	10.96
6 B-W-V-L-3	.195	64	.2230	11.13
7 Mo-WA-V-2	.149	64	.1907	7.27
8 AS-W-V-3	.191	64	.2221	10.86

* Formula: 4(weight per tuft in grains x tufts per square inch x height of Pile).

CHART V

Standard Thickness and Compressional Resiliency

Carpet No. and Code	(a) Standard Thickness In Inches	(b) Compression Index Number	(c) Compression In Inches	(d) Recovery In Inches	(e) Compressional Resiliency
			Carpets containing Synthetic Fibers		
1 L-E-A-1	.3117"	.026	.0335"	.0079"	23.5%
3 L-E-W-L-2	.3530"	.074	.0391"	.0081"	20.4%
5 B-WA-V-L-3	.3700"	.038	.0300"	.0080"	26.6%
7 Mo-WA-V-2	.3000"	.057	.0260"	.0073"	28.0%
			Carpets of 100% wool		
2 L-W-A-1	.3579"	.043	.0268"	.0044"	14.9%
4 Ma-W-W-L-3	.3433"	.070	.0398"	.0099"	24.9%
6 B-W-V-L-3	.3600"	.042	.0228"	.0057"	25.0%
8 AS-W-V-3	.3600"	.052	.0279"	.0052"	18.6%

(a) Standard Thickness: Thickness at 0.1 pounds pressure per square inch.

(b) Compression Index Number: Difference between thickness at 0.15 pounds pressure per square inch and thickness at 0.05 pounds pressure per square inch, divided by the standard thickness

(c) Compression: The amount of work done due to pressure of 0.2 pounds per square inch, expressed in .0000"

(d) Recovery: The amount of work recovered after release of .2 pounds pressure per square inch to pressure of .01 pounds per square inch.

(e) Compressional Resiliency: Relationship between Compression and Recovery expressed as a percentage.

CHART VI

Results of Wear Test*

Carpet No. and Code		Density Index Number	Average Weight of Samples in Grams	Wear of Carpets Expressed In Cycles Required to Show: First Sign Wear	Backing	Complete Breakdown	Weight of Samples After Test (Grams)	Percentage Loss In Weight
1	L-E-A-1	4.15	12.6561	700	862	1,250	11.8045	6.6%
2	L-W-A-1	4.51	12.7032	1,009	1,250	2,500	12.0185	6.2%
3	L-E-W-L-2	9.29	20.4144	1,250	2,500	4,948	17.7396	15.0%
4	Ma-W-W-L-3	7.32	15.7819	1,524	5,150	8,162	14.0426	11.0%
5	B-WA-V-L-2	10.96	15.7333	4,562	11,000	16,425	13.3613	15.1%
6	B-W-V-L-3	11.13	15.9162	6,235	17,467	20,000+	13.8100	13.2%
7	Mo-WA-V-2	7.27	15.5823	2,534	5,233	9,280	14.2987	8.2%
8	AS-W-V-3	10.86	18.6737	5,028	11,248	15,500	15.7187	15.7%

* Average of three abrasions for each carpet

Code: 1st letter: Manufacturer; 2nd letter: Fiber; 3rd letter: Weave; 4th letter: Loop pile; Number: Price Group

CHART VII -a

Dirt Retention Data
(Tests 1 through 4)

Carpet No	1	3	5	7	2	4	6	8
Code	L-E-A-1	L-E-W-L-2	B-WA-V-L-2	Mo-WA-V-2	L-W-A-1	Ma-W-W-L-3	B-W-V-L-3	AS-W-V-3
Fiber	100% estron		Wool and viscose		100% wool			
Weight of Sample (12" x 27") in grams*	375.4	574.9	464.3	411.3	401.9	467.4	493.0	515.2
Test 1								
Weight of sample (grams)	373.7	574.2	463.7	409.3	400.5	467.4	491.8	514.9
Total Weight **	378.9	580.7	473.2	408.3	413.3	477.3	501.5	523.0
Percentage gain in Wt.	1.4%	1.1%	2.5%	-0.02%	3.1%	2.1%	1.9%	1.7%
***Total percentage gain	1.4%	1.1%	2.5%	0.0%	3.1%	2.1%	1.9%	1.7%
Test 2								
Weight of sample(grams)	378.9	580.7	473.2	408.3	413.3	477.3	501.5	523.0
**Total Weight in grams	383.6	586.5	468.3	412.4	421.5	485.0	505.8	530.6
Percentage gain in Wt.	1.2%	1.0%	0.6%	0.4%	2.1%	1.6%	0.9%	1.1%
***Total Percentage Gain	2.6%	2.1%	3.1%	0.4%	5.2%	3.7%	2.8%	2.8%
Test 3								
Weight of sample(grams)	383.6	586.5	468.3	412.4	421.5	485.0	505.8	530.6
**Total Weight in grams	386.5	590.2	484.1	417.2	431.0	494.3	511.9	538.0
Percentage gain in Wt.	0.8%	0.7%	1.3%	1.5%	2.4%	1.1%	1.2%	1.3%
***Total Percentage Gain	3.4%	2.8%	4.4%	1.9%	7.6%	4.8%	4.0%	4.6%
Test 4								
Weight of Sample(grams)	386.5	590.2	484.1	417.2	431.0	494.3	511.9	538.0
** Total Weight in Grams	389.4	593.9	490.0	423.9	440.4	503.7	517.9	545.3
Percentage Gain in Wt.	0.7%	0.6%	1.2%	1.9%	2.4%	2.9%	1.3%	1.5%
***Total Percentage Gain	4.1%	3.4%	5.6%	3.8%	10.0%	7.7%	5.3%	6.1%

* Weight of Sample before vacuuming to remove lint

** Weight of Sample after cleaning with vacuum

*** Total gain in weight over original sample weight, expressed as a percentage

CHART VII -b

Soil Retention Data
(Tests 5 Through 8)

Carpet No.	1	3	5	7	2	4	6	8
Code	L-E-A-1	L-E-W-L-2	B-WA-V-L-2	Mo-WA-V-2	L-W-A-1	Ma-W-W-L-3	B-W-V-L-3	AS-W-V-3
Fiber	100% estron		WOOl and avisco		100% wool			
Weight Control Sample*	373.7	574.2	463.7	409.3	400.5	467.4	491.8	514.9
Test 5								
Weight of Sample (grams)	389.4	593.9	490.0	423.9	440.4	503.7	517.9	545.3
**Total Weight in grams	391.0	597.0	492.8	426.5	450.3	511.1	524.1	552.6
Percentage Gain in Wt.	0.7%	0.5%	0.5%	0.4%	2.4%	0.7%	1.3%	1.4%
***Total Percentage Gain	4.8%	3.9%	6.1%	4.2%	12.4%	9.4%	6.6%	7.4%
Test 6								
Weight of Sample(grams)	391.0	597.0	492.2	426.5	450.3	511.1	524.1	552.6
**Total Weight in Grams	396.5	601.3	494.4	429.9	460.2	515.5	527.7	559.8
Percentage Gain in Wt.	0.6%	0.8%	0.7%	0.8%	2.5%	0.9%	1.2%	1.4%
***Total Percentage Gain	5.4%	4.7%	6.6%	5.0%	14.9%	10.3%	8.0%	8.8%
Test 7								
Weight of Sample(grams)	396.5	601.3	494.4	429.9	460.2	515.5	527.7	559.8
**Total Weight in Grams	397.8	604.2	498.6	433.1	463.9	524.6	532.0	566.9
Percentage Gain in Wt.	1.0%	0.2%	1.3%	0.8%	0.9%	0.9%	0.1%	1.4%
***Total Pereentage Gain	6.4%	4.9%	7.9%	5.8%	15.8%	12.2%	8.1%	10.2%
Test 8								
Weight of Sample(grams)	397.8	604.2	498.6	433.1	463.9	524.6	532.0	566.9
**Total Weight in Grams	401.9	608.0	501.5	436.9	477.6	533.3	535.8	593.9
Percentage Gain in Wt.	1.4%	0.9%	0.2%	0.4%	3.2%	1.8%	0.5%	1.3%
***Total Percentage Gain	7.8%	5.8%	8.1%	6.2%	19.0%	14.0%	8.9%	11.5%

*Weight of Sample after lint had been removed by vacuuming
**Weight of Sample after soil was applied and removed by vacuuming
***Total Gain in Weight over Control Sample, Expressed as Percentage Gain

CHART VII-b

Soil Retention Data
(Tests 5 Through 8)

Carpet No.	1	3	5	7	2	4	6	8
Code	L-E-A-1	L-E-W-L-2	B-WA-V-L-2	Mo-WA-V-2	L-W-A-1	MaW-W-L-3	B-W-V-L-3	AS-W-V-3
Fiber	100% estron		Wool and avisco		100% wool			
Control Weight of Sample*	373.7	574.2	463.7	409.3	400.5	467.4	491.8	514.9
Test 5								
Weight of Sample(grams)	389.4	593.9	490.0	423.9	440.4	503.7	517.9	545.3
**Total Weight	391.0	597.0	492.2	426.5	450.3	511.1	524.1	552.6
Percentage gain in Wt.	0.7%	0.5%	0.5%	0.4%	2.4%	0.7%	1.3%	1.4%
***Total Percentage Gain	4.8%	3.9%	6.1%	4.2%	12.4%	9.4%	6.6%	7.4%
Test 6								
Weight of Sample(grams)	391.0	597.0	492.2	426.5	450.3	511.1	524.1	552.6
**Total Weight	396.5	601.3	494.4	429.9	460.2	515.5	527.7	559.8
Percentage Gain in Wt.	0.6%	0.8%	0.7%	0.8%	2.5%	0.9%	1.2%	1.4%
***Total Percentage Gain	5.4%	4.7%	6.6%	5.0%	14.9%	10.3%	8.0%	8.8%
Test 7								
Weight of Sample(grams)	396.5	601.3	494.4	429.9	460.2	515.5	527.7	559.8
**Total Weight	397.8	604.2	498.6	433.1	463.9	524.6	532.0	566.9
Percentage Gain in Wt	1.0%	0.2%	1.3%	0.8%	0.9%	0.9%	0.1%	1.4%
***Total Percentage Gain	6.4%	4.9%	7.9%	5.8%	15.8%	12.2%	8.1%	10.2%
Test 8								
Weight of Sample (grams)	397.8	604.2	498.6	433.1	463.9	524.6	532.0	566.9
**Total Weight	401.9	608.0	501.5	436.9	477.6	533.3	535.8	593.9
Percentage Gain in Wt	1.4%	0.9%	0.2%	0.4%	3.2%	1.8%	0.5%	1.3%
***Total Percentage Gain	7.8%	5.8%	8.1%	6.2%	19.0%	14.0%	8.9%	11.5%

* Weight of Sample after lint had been removed by vacuuming
** Weight of Sample after soil was applied and removed by vacuuming
***Total Gain in Weight over Control Sample, Expressed as Percentage Gain.

CHART VII --C

Soil Retention Data
(Test 9 Through 12)

Carpet Number	1	3	5	7	2	4	6	8
Code	L-E-A-1	L-E-W-L-2	B-WA-V-L-2	Mo-WA-V-2	L-W-A-1	Ma-W-W-L-3	B-W-V-L-3	As-W-V-3
Fiber	100% estron		Wool and viscose			100% wool		
Weight of Control Sample*	373.7	574.2	463.7	409.3	400.5	467.4	491.8	514.9
Test 9								
Weight of Sample(grams)	401.9	608.0	501.5	436.9	477.6	533.3	535.8	573.9
**Total Weight in Grams	403.2	610.5	504.6	439.1	487.6	535.7	537.7	580.7
Percentage Gain in Wt.	0.3%	1.3%	0.5%	0.9%	2.6%	0.6%	0.6%	0.7%
***Total Percentage Gain	8.1%	6.3%	8.6%	7.1%	21.6%	14.6%	9.5%	12.2%
Test 10								
Weight of Sample(grams)	403.2	610.5	504.5	439.1	487.6	535.7	537.7	580.7
**Total Weight in Grams	405.3	613.2	507.6	441.1	497.6	537.4	540.8	586.4
Percentage Gain in Wt.	0.6%	0.4%	0.8%	0.6%	2.6%	0.3%	0.8%	1.6%
***Total Percentage Gain	8.7%	6.7%	9.4%	7.7%	24.2%	14.9%	10.3%	13.8%
Test 11								
Weight of Sample(Grams)	405.3	613.2	507.6	441.1	497.6	537.4	540.8	586.4
**Total Weight in Grams	406.8	615.8	508.8	442.6	503.8	540.6	542.2	591.4
Percentage Gain in Wt.	0.1%	0.5%	0.3%	0.4%	1.6%	0.7%	0.4%	1.1%
***Total Percentage Gain	8.8%	7.2%	9.7%	8.1%	25.8%	15.6%	10.7%	14.9%
Test 12								
Weight of Sample(grams)	406.8	615.8	508.8	442.6	503.8	540.6	542.2	591.4
**Total Weight in Grams	408.2	618.2	510.9	444.0	509.4	542.3	544.5	595.4
Percentage Gain in Wt.	0.4%	0.4%	0.5%	0.3%	1.3%	0.6%	0.4%	0.9%
***Total Percentage Gain	9.2%	7.6%	10.2%	8.4%	27.1%	16.2%	11.1%	15.8%

* Weight of Sample in Grams after lint had been removed by vacuuming
**Weight of Sample after soil was removed by vacuuming
***Total Gain in Weight over Control Sample, expressed as percentage gain

CHART VII --D

Soil Retention Data
(Tests 13 through 15)

Carpet Number	1	3	5	7	2	4	6	8
Code	L-E-A-1	L-E-W-L-2	B-WA-V-L-2	Mo-WA-V-2	L-W-A-1	Ma-W-W-L-3	B-W-V-L-3	AS-W-V-3
Fiber	100% estron		Wool and avisco			100% wool		
Weight of Control Sample*	373.7	574.2	463.7	409.3	400.5	467.4	491.8	514.9
Test 13								
Weight of Sample(grams)	408.2	618.2	510.9	444.0	509.4	542.3	544.5	595.4
**Total Weight in Grams	408.4	620.4	513.5	445.9	511.9	544.3	546.6	598.7
Percentage Gain in Wt.	0.1%	0.4%	0.5%	0.5%	0.7%	0.3%	0.4%	0.4%
***Total Percentage Gain	9.3%	8.0%	10.7%	8.9%	27.8%	16.5%	11.1%	16.2%
Test 14								
Weight of Sample(grams)	408.4	620.4	513.5	445.9	511.9	544.3	546.6	598.7
**Total Weight in Grams	408.5	621.4	515.7	446.7	514.1	545.9	547.9	601.1
Percentage Gain in Wt.	0.0%	0.2%	0.5%	0.2%	0.5%	0.3%	0.3%	0.6%
***Total Percentage Gain	9.3%	8.2%	11.2%	9.1%	28.3%	16.8%	11.4%	16.8%
Test 15								
Weight of Sample(grams)	408.5	621.4	515.7	446.7	514.1	545.9	547.9	601.1
**Total Weight in Grams	408.2	622.1	516.2	447.3	515.5	547.3	548.2	602.3
Percentage Gain In Wt.	0.0%	0.1%	0.1%	0.2%	0.4%	0.3%	0.1%	0.1%
***Total Percentage Gain	9.3%	8.3%	11.3%	9.3%	28.7%	17.1%	11.5%	16.9%

* Weight of Sample in Grams after lint had been removed by vacuuming
**Weight of Sample after soil was removed by vacuuming
***Total Gain in Weight over Control Sample, expressed as percentage gain

CHART VIII--Carpet 8

Compressional Resiliency and Standard Thickness of Carpets Subjected To Weights* for Specified Intervals**

Carpet 8--100% wool

Code	Pitch###	Wires###	Density***	Weight in Grams per Square Inch		Height of Carpet in Inches		Density Index
				Total	Pile	Total Thickness	Pile	Number
AS-W-V-3	8	8	64	1.486	.7954	.3600"	.2211"	10.86

Compression and Thickness

	Control Sample	Hours Compressed			Hours Released After 300 Hour Compression			
		75	150	300	1	4	24	48
Compression: (1)	.0279"	.0256"	.0203"	.0203"	.0191"	.0202"	.0213"	.0260"
Recovery: (2)	.0052"	.0060"	.0051"	.0039"	.0044"	.0057"	.0060"	.0078"
Compressional Resiliency(3)	18.6%	27.3%	25.1%	19.2%	23.0%	28.2%	28.1%	30.0%
Compression Index: (4)	.052	.053	.046	.038	.046	.044	.041	.046
Standard Thickness: (5)	.3600"	.3140"	.3050"	.2810"	.2920"	.3026"	.3037"	.3470"
Loss in Thickness: (6)		12.8%	15.3%	21.9%	18.8%	15.9%	15.6%	3.6%

* 2.3 pounds per square inch
**Average of five readings
\#\#\# Per inch
*** Per square inch

(1) Compression: the amount of work done due to pressure of 0.2 pounds per square inch expressed in .0000"
(2) Recovery: The amount of work recovered after release of 0.2 pounds pressure per square inch to pressure of 0.01 pounds per square inch
(3) Compressional Resiliency: Ratio between compression and recovery expressed as a percentage
(4) Compression Index: Difference in thickness at .05 pounds pressure and 0.15 pounds pressure divided by standard thickness
(5) Standard Thickness: Thickness at 0.1 pounds pressure per square inch
(6) Loss in Thickness: Change in Standard thickness expressed as percent loss.

CHART IX

Compression in Inches**

Carpet Number And Code *		Control	Hours Compressed 75	150	300	Hours Released after 300 Hour Compression 1	4	24	48
1	L-E-A-1	.0335"	.0331"	.0256"	.0238"	.0276"	.0305"	.0306"	.0309"
3	L-E-W-L-2	.0391"	.0281"	.0277"	.0211"	.0213"	.0216"	.0218"	.0221"
5	B-WA-V-L-2	.0300"	.0254"	.0254"	.0229"	.0232"	.0238"	.0260"	.0259"
7	Mo-WA-V-2	.0260"	.0183"	.0181"	.0181"	.0181"	.0184"	.0189"	.0192"
2	L-W-A-1	.0268"	.0317"	.0326"	.0337"	.0328"	.0354"	.0369"	.0378"
4	Ma-W-W-L-3	.0398"	.0323"	.0344"	.0384"	.0371"	.0373"	.0379"	.0393"
6	B-W-V-L-3	.0228"	.0182"	.0180"	.0206"	.0225"	.0272"	.0266"	.0274"
8	AS-W-V-3	.0279"	.0256"	.0203"	.0203"	.0191"	.0202"	.0213"	.0260"

Percentage Gain or Loss Over Control Compression

1	L-E-A-1	.0335"	- 1.0%	-23.6%	-28.9%	-17.3%	- 8.9%	- 8.7%	- 8.0%
3	L-E-W-L-2	.0391"	-28.1%	-29.2%	-46.3%	-45.5%	-45.0%	-44.2%	-43.4%
5	B-WA-V-L-2	.0300"	-18.0%	-18.0%	-25.0%	-22-2%	-20.6%	-13.3%	-13.3%
7	Mo-WA-V-2	.0260"	-29.7%	-29.8%	-29.8%	-30.4%	-29.2%	-27.9%	-26.5%
2	L-W-A-1	.0268"	+18.2%	+21.6%	+22.0%	+22.4%	+31.9%	+37.2%	+44.1%
4	Ma-W-V-L-3	.0398"	-18.2%	-13.3%	- 3.5%	- 6.7%	- 6.2%	- 4.7%	- 1.0%
6	B-W-V-L-3	.0228"	-20.1%	-21.0%	- 9.6%	- 1.0%	+19.3%	+16.6%	+20.1%
8	As-W-V-3	.0279"	- 8.3%	-28.3%	-28.3%	-31.5%	-28.3%	-23.7%	- 6.8%

* Code: 1st letter: Manufacturer
2nd Letter: Fiber
3rd Letter: Weave
4th Letter: Loop Pile
Number: Price Group

** Average of 5 Readings

CHART X

Recovery in Inches*

Carpet Number and Code**	Control	Hours Compressed 75	150	300	Hours Released After 300 Hour Compression 1	4	24	48
1 L-E-A-1	.0091"	.0034"	.0021"	.0017"	.0017"	.0020"	.0041"	.0043"
3 L-E-W-L-2	.0081"	.0044"	.0042"	.0027"	.0039"	.0035"	.0054"	.0059"
5 B-WA-V-L-2	.0080"	.0059"	.0052"	.0042"	.0062"	.0062"	.0075"	.0080"
7 Mo-WA-V-2	.0073"	.0040"	.0033"	.0025"	.0023"	.0038"	.0038"	.0039"
2 L-W-A-1	.0044"	.0084"	.0097"	.0119"	.0111"	.0109"	.0083"	.0062"
4 Ma-W-W-L-3	.0099"	.0101"	.0102"	.0102"	.0075"	.0070"	.0069"	.0089"
6 B-W-V-L-3	.0057"	.0052"	.0056"	.0057"	.0061"	.0068"	.0087"	.0095"
8 AS-W-V-3	.0052"	.0060"	.0051"	.0039"	.0044"	.0057"	.0060"	.0078"

Percentage Gain or Loss Over Control Recovery

1 L-E-A-1	.0091"	-62.6%	-76.9%	-81.2%	-81.2%	-78.0%	-54.9%	-51.6%
3 L-E-W-L-2	.0081"	-45.6%	-48.1%	-66.6%	-51.8%	-56.8%	-33.3%	-27.1%
5 B-WA-V-L-2	.0080"	-26.2%	-34.7%	-47.5%	-22.5%	-22.5%	- 6.3%	+ 0.0%
7 Mo-WA-V-2	.0073"	-45.2%	-54.8%	-65.7%	-54.8%	-47.9%	-47.9%	-46.8%
2 L-W-A-1	.0044"	+90.9%	+120.4%	+170.4%	+152.2%	+147.7%	+88.6%	+36.3%
4 Ma-W-W-L-3	.0099"	+ 2.2%	+ 2.7%	+ 2.7%	-24.2%	-29.4%	-30.3%	-10.1%
6 B-W-V-L-3	.0057"	- 8.8%	- 1.7%	----+--	+ 7.0%	+19.3%	+52.6%	+66.6%
8 AS-W-V-3	.0052"	+15.4%	- 1.9%	-25.0%	-15.3%	+ 9.6%	+15.3%	+30.8%

*Averages of Five Readings

**Code: 1st Letter: Manufacturer; 2nd Letter: Fiber; 3rd Letter: Weave; 4th Letter: Loop Pile; Number: Price Group

CHART XI

Compressional Resiliency in Percent*

Carpet Number And Code **	Control	Hours Compressed			Hours Released After 300 Hour Compression			
		75	150	300	1	4	24	48
1-L-E-A-1	23.0%	10.3%	8.9%	7.3%	6.1%	6.5%	13.4%	14.0%
3-L-E-W-L-2	20.4%	15.2%	11.4%	12.6%	18.0%	16.9%	25.0%	26.6%
5 B-WA-V-L-2	26.6%	21.6%	20.6%	18.3%	27.3%	26.0%	28.0%	30.8%
7 Mo-WA-V-2	28.0%	21.6%	12.0%	13.5%	12.7%	19.9%	21.2%	20.3%
2 L-W-A-1	14.9%	24.0%	29.6%	35.2%	36.9%	30.7%	22.5%	16.4%
4 Ma-W-W-L-3	24.9%	31.0%	29.3%	26.2%	20.2%	18.7%	18.2%	22.9%
6 B-W-V-L-3	25.0%	28.6%	31.1%	27.6%	27.1%	25.0%	32.7%	34.7%
8 AS-W-V-3	18.6%	27.3%	25.1%	19.2%	23.0%	28.2%	28.1%	30.0%

* Average of five readings

**Code: 1st Letter: Manufacturer
2nd Letter: Fiber
3rd Letter: Weave
4th Letter: Loop Pile
Number: Price Group

PLATE I
CARPET PHOTOGRAPHS

Carpet 1

Code: L-E-A-1
Price: $6.50 per square yard
Weave: Axminster
Fiber: 100% estron

Density: 35 tufts per square inch
Weight: 44.1 ounces per square yard
Thickness: .3319 inches

Carpet 2

Code: L-W-A-1
Price: $7.50 per square yard
We$_a$ve: Axminster
Fiber: 100% wool

Density: 35 tufts per square inch
Weight: 46.7 ounces per square yard
Thickness: .3583 inches

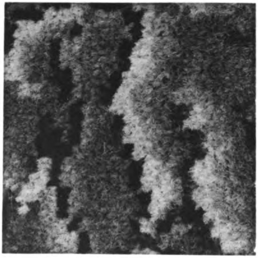


PLATE II
CARPET PHOTOGRAPHS

Carpet 3

Code: L-E-W-L-2
Price: $10.50 per square yard
Weave: Wilton, un-cut pile
Fiber: 100% estron

Density: 54 tufts per square inch
Weight: 65.5 ounces per square yard
Thickness: .3533 inches

Carpet 4

Code: Ma-W-W-L-3
Price: $14.95 per square yard
Weave: Wilton, un-cut pile
Fiber: 100% wool

Density: 54 tufts per square inch
Weight: 61.5 ounces per square yard
Thickness: .3433 inches

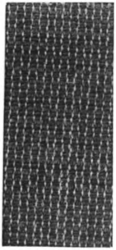


PLATE III
CARPET PHOTOGRAPHS

Carpet 5

Code: B-WA-V-L-2
Price: $10.50 per square yard
Weave: Velvet, un-cut pile
Fiber: Wool and Avisco blend

Density: 64 tufts per square inch
Weight: 57.9 ounces per square yard
Thickness: .3700 inches

Carpet 6

Code: B-W-V-L-3
Price: $12.50 per square yard
Weave: Velvet, un-cut pile
Fiber: 100% wool

Density: 64 tufts per square inch
Weight: 60.8 ounces per square yard
Thickness: .3600 inches

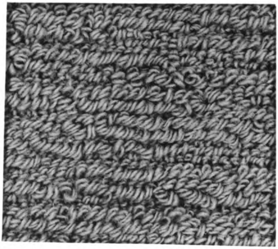
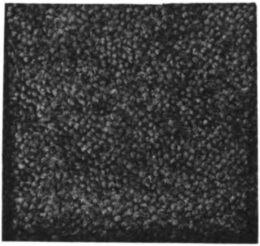


PLATE IV
Carpet Photographs

Carpet 7

Code: Mo-WA-V-2
Price: $9.50 per square yard
Weave: Velvet
Fiber: Wool and Avisco Blend

Density: 64 tufts per square inch
Weight: 56.7 ounces per square yard
Thickness: .3000 inches



Carpet 8

Code: AS-W-V-3
Price: $13.95 per square yard
Weave: Velvet
Fiber: Wool and Avisco Blend

Density: 64 tufts per square inch
Weight: 68.0 ounces per square yard
Thickness: .3600 inch

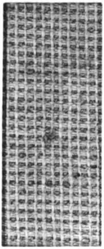
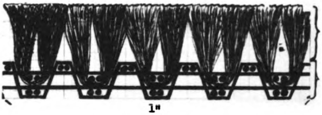


PLATE V

CARPET WEAVES

Carpet 1 – Axminster

Pile: Estron
3-Shot: Paper
Stuffer: Cotton
Warp: Cotton
Pitch: 7
Rows: 5



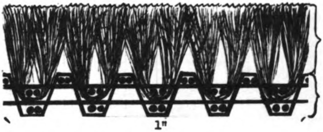
1"

Pile Height
.1885"

Backing Height
.1370"

Carpet 2 -Axminster

Pile: Wool
3-Shot: Jute
Stuffer: Cotton
Warp: Cotton
Pitch: 7
Rows: 5



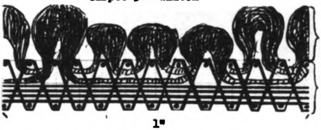
1"

Pile Height
.2165"

Backing Height
.1418"

Carpet 3- Wilton

Pile: Estron
2-Shot: Cotton
Stuffer: Jute
Warp: Cotton
Pitch: 9
Rows: 6



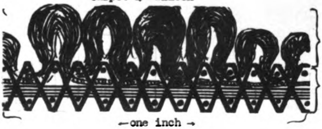
1"

Pile Height
.1862"

Backing Height
.1668"

Carpet 4 -Wilton

Pile: Wool
2-Shot: Jute
Stuffer: Jute
Warp: Cotton
Pitch: 9
Rows: 6



←one inch→

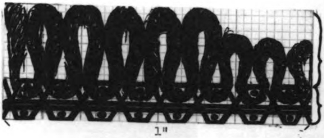
Pile Height
.1785"

Backing Height
.1648"

PLATE VI
CARPET WEAVES

Carpet 5 Velvet

Pile: Wool and Avisco
2-Shot: Jute
Stuffer: Cotton
Warp: Rayon
Pitch: 8
Rows: 8



Pile Height .2323"
Backing Height .1377"

1"

Carpet 6 Velvet

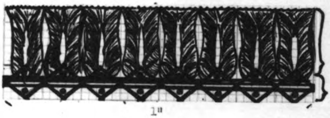
Pile: Wool
2-Shot: Jute
Stuffer: Cotton
Warp: Cotton
Pitch: 8
Rows: 8

Pile Height .2230"
Backing Height .1370"

1"

Carpet 7 Velvet

Pile: Wool and Avisco
2-Shot: Jute
Stuffer: Paper
Warp: Cotton
Pitch: 8
Rows: 8

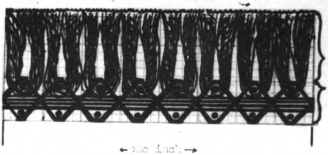


Pile Height .1940"
Backing Height .1060"

1"

Carpet 8 Velvet

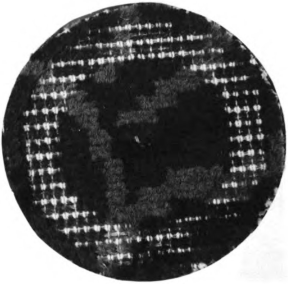
Pile: Wool
2-Shot: Jute
Stuffer: Paper
Warp: Cotton
Pitch: 8
Rows: 8



Pile Height .2221"
Backing Height .1379"

← one inch →

PLATE VII
AXMINSTER CARPETS ABRADED TO 1250 CYCLES



Carpet number 1

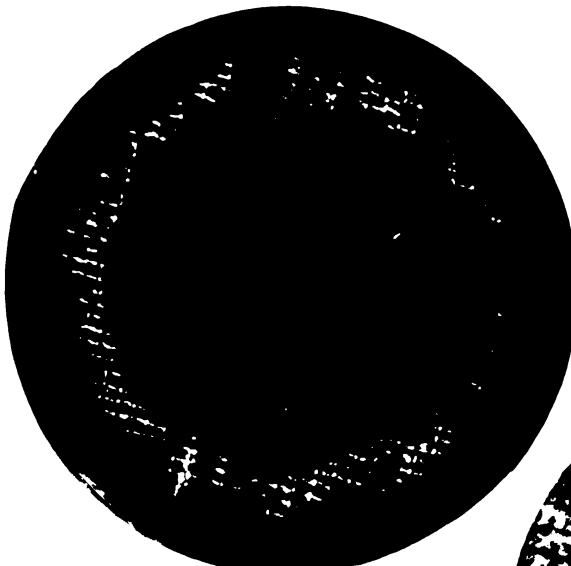
Code: L-E-A-1
Price: $6.50 per square yard
Density: 35 tufts per square inch
Density Index number: 4.15
Fiber: 100% estron

Carpet number 2

Code: L-W-A-1
Price: $7.50 per square yard
Density: 35 tufts per square inch
Density Index Number: 4.15
Fiber: 100% wool

PLATE VIII

SAMPLES ABRADED TO 4500 CYCLES

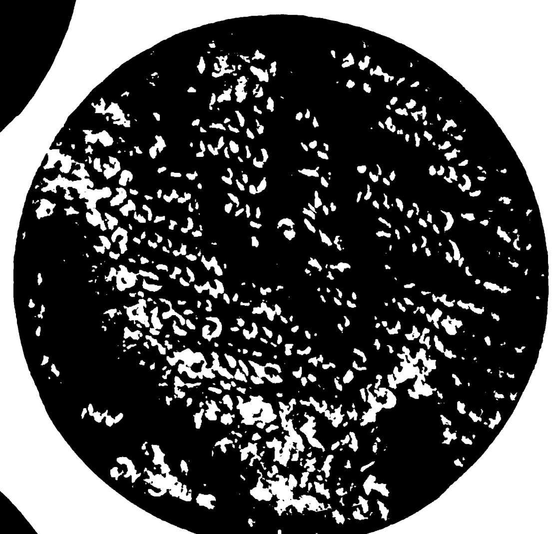


Carpet number 3

Code: L-E-W-L-2
Price: $10.50 per square yard
Fiber: Estron
Construction: Wilton, un-cut pile
Density: 54 tufts per square inch
Density Index number: 9.29

Carpet number 4

Code: Ma-W-W-L-3
Price: $14.95 per square yard
Fiber: 100% wool
Construction: Wilton, un-cut pile
Density: 54 tufts per square inch
Density Index Number: 7.32

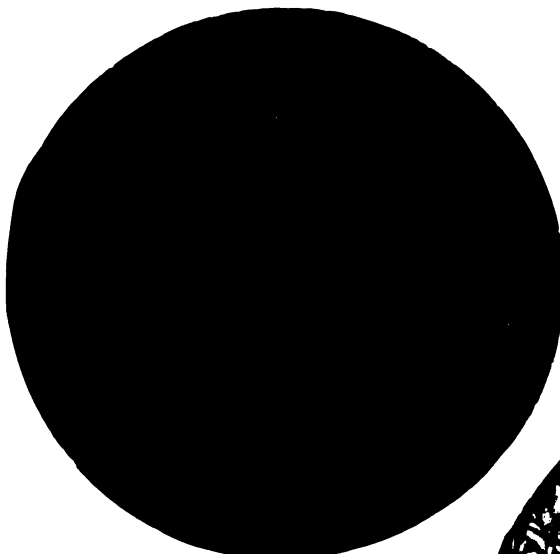


Carpet number 7

Code: Mo-WA-V-2
Price: $9.50 per square yard
Fiber: Wool-Avisco Blen d
Construction: Velvet
Density: 64 tufts per square inch
Density Index Number: 7.27

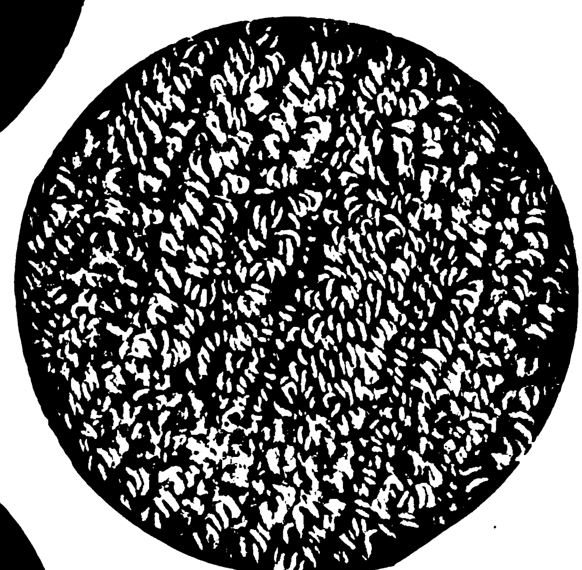
PLATE IX

SAMPLES ABRADED TO 9000 CYCLES



Carpet number 5

Code: B-WA-V-L-2
Price: $10.50 per square yard
Fiber: Wool and Avisco Blend
Weave: Velvet
Density: 64 Tufts per square inch
Density Index number: 10.96



Carpet number 6

Code: B-W-V-L-3
Price: $12.50 per square yard
Fiber: 100% wool
Weave: Velvet
Density: 64 Tufts per square inch
Density Index number: 11.13

Carpet number 8

Code: AS-W-V-3
Price: $13.95 per square yard
Fiber: 100% wool
Weave: Velvet
Density: 6 4 tufts per square inch
Density Index number: 10.86

52
16
8
12
.88

132
238
837