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Title COMPARATIVE PERFORMANCE OF POLYPROPYLENE AND NYLON HOSIERY USING WEAR AND LABORATORY TESTS

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The purpose of this study was to compare the performance of hosiery made from a new fiber, polypropylene, with the performance of hosiery made from a better known fiber, nylon, and to get some indication of consumer reaction to a new textile product.

Information was obtained through two wear tests and selected laboratory tests using different brands of hosiery with both fiber types represented. Two questionnaires were used as part of the wear tests. The first obtained information about the subjects and about some of their opinions concerning hosiery wear in general. The second questionnaire obtained information about the subjects' opinions concerning the hosiery worn in the wear tests. Thirty subjects participated in the first wear test with each wearing one pair of hosiery made of each fiber. Ten subjects participated in the second wear test, six of whom had also been part of the first

test.

The performance of the hosiery was checked by considering the number, severity and position of faults which occurred in relation to the number of days worn and by measuring to find the amount of stretch found in the worn hosiery. Laboratory tests were conducted to verify certain information obtained about the hosiery during the wear tests as well as to obtain further information about the hosiery.

The questionnaires were analyzed by using percentages of the number responding to each part of each question. In this way, a general picture of the majority could be made to find out something about the subjects as a group and about their opinions of the hosiery.

The wear life of the hosiery as shown by the number of days worn was related to the number of total faults found in the test hosiery. In addition, each type of fault, snags, runs, and abrasion marks, was considered. The two fiber types of hosiery were compared by testing to find if the differences between means were significant using F ratios. An additional check was made for covariance between the number of runs and the total days worn, and between the number of abrasion marks and the total days worn.

All hosiery increased in width and decreased in length during the wear periods. The average amounts of dimensional change were analyzed by comparing the mean differences of the two fiber types of hosiery. The results were verified in the laboratory using a stretch and recovery test under controlled conditions. The differences in the means found in the laboratory test were checked for significance using F ratios. The rates of recovery were plotted on a time graph.

An evaluation of the degree of fading was made by a panel of judges using a ranking system. The amount of, and the deviation from linear regression was found. Hosiery of both fiber types were washed in the laboratory and used as control groups to check with hosiery worn and washed by the subjects.

Four laboratory tests were conducted to help describe the hosiery used in the study and to supply further information as to the differences in performance of hosiery made of polypropylene and of nylon. The yarn numbers and the course and wale counts were found. Yarn breaking strengths and the percents of elongation were analyzed by using a t test. Standard deviations checked the amounts of variation from the means. The same types of analyses were done to compare the two fiber types of hosiery as to the differences found in the bursting strengths of the knee and toe areas of the hosiery. In addition the F ratios were also found.

COMPARATIVE PERFORMANCE OF POLYPROPYLENE AND NYLON HOSIERY USING WEAR AND LABORATORY TESTS

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CHAPTER I

INTRODUCTION AND REVIEW OF LITERATURE

Fibers found in nature had been used to create textiles long before written records were kept, and fabrics of a quality superior to our own have been found in ancient tombs. However, it is only in the last half-century that man-made fibers have become available. The first man-made fibers were formed from certain fiber-forming substances found in cotton and wood pulp. Later, chemicals from a wide variety of raw materials were used to develop new fibers. As a result of technological advances man can now produce fibers with almost any desired combination of properties (27).

Polypropylene, unique in several ways, is one of the latest newcomers in the list of fibers used for apparel fabrics. It was the first synthetic polymer to be promoted on the market before it actually existed as a fiber (16). No other polymer in history has received so much study and evaluation in such a short time. Its low cost potential has encouraged further research to seek many possible end-uses through developing various forms of the fiber. It was introduced on the fiber market almost simultaneously as monofilament, continuous multifilament, staple fiber, and bulked continuous filament yarns (24).

Fiber producers are optimistic. The output of monofilament polypropylene fiber is expected to go from ten million pounds in 1960 to 40 million pounds in 1965 in United States' markets alone (37). However, trade observers generally agree that polypropylene fabrics will have a hard time obtaining consumer acceptance (33). The market is already heavily penetrated by other synthetic fabrics and any new fiber will have to displace another in fabrics in order to gain acceptance (5).

One such possibility for the use of polypropylene fiber is to replace nylon in making sheer hosiery. Research over a two year period by the General Foods Chemical Company resulted in the introduction of 14-denier women's hosiery made with "Gerfil", a monofilament polypropylene yarn. This hosiery was introduced to the public late in May of 1963 in department stores in New York and other large cities in different sections of the nation (35). As there was little advertising accompanying them, the general public has not had time or enough information to become aware of this new product. The hosiery is still considered largely experimental as far as consumer acceptance is concerned (34).

This study has been prompted by interest in the new fiber and its use in hosiery, since it was the first fiber belonging to the olefinic generic class to be introduced into the sheer hosiery industry since the first nylon was introduced (34). The purpose of this investigation of polypropylene hosiery as compared with nylon hosiery was to analyze the performance of each under the same conditions of normal wear and care by a selected group of women.

Historical Survey of Fiber Development

Wallace H. Carothers began his fundamental research on polymers in 1928. From the long-chain polymers which he developed, nylon, the first true synthetic, was only one of many resulting fibers with a commercial value (28). Two years later Staudinger disclosed the nature of the long-chain molecules. His explanation of the properties needed by fiber-forming materials furthered research in the entire textile field (41). Ten years later the polymerization of ethylene was accomplished and a low density fiber, a forerunner of polypropylene, was developed from the fiber-forming polymer (20).

The development of propylene as a polymer which could be made into a fiber with even greater potential than that of fibers formed from ethylene became possible as a result of another basic scientific discovery. In 1954, Professor Guilio Natta of Milan, Italy, found a way of making a highly ordered polymer from propylene with much improved properties. This new polypropylene polymer had a new spacial arrangement of the monomer which he termed "isotactic" to distinguish it from two other possible structures. The resulting isotactic polypropylene is a fiber-forming polymer which can be further modified to produce fibers with a wide range of utility (15).

Fiber Formation and Properties

While faulty construction can produce a poor fabric from a good fiber, there is no known technique to produce a good fabric from a poor fiber (36). Much is determined by the basic properties of the fiber. The properties of fibers govern, in part, the utility of the fabrics (7). Thus the choice of the basic monomer units and the conditions of polymerization and fiber formation are the controlling factors for the mechanical properties of fibers (15) which form the basis for a good fabric.

The chemical structure of the monomer is basic in providing the properties found in a fiber-forming polymer (40). However, since different types of structures may occur in different fibers composed of the same polymer, there are possibilities for varying fabric properties by varying the physical structures of fibers (22). The properties of a fiber are a result of more than the properties of the polymer used. The method of producing the fiber also imparts certain characteristics. The amount of crystallinity and the degree of orientation to the fiber axis are important factors which are different for different fibers, even those from the same monomer. These factors can be varied by changing the method of fiber production (15).

It is possible to obtain almost any mechanical property in fibers by modification of any or all of the following: the monomer, the intermolecular forces, the morphological structural features of the fiber-forming polymer, or the fiber itself (7). Fabrics designed for specific end-uses have a better chance of being adequate for the purpose if a fiber is chosen which has the necessary and desirable properties (26).

Polypropylene Fiber

Polypropylene fibers, derived from propylene, belong to the generic classification of olefin. The Federal Trade Commission Rules define "olefin" as a

> . . . manufactured fiber in which the fiber forming substance is any long chain synthetic polymer composed of at least 85% by weight of ethylene, propylene, or other olefin units (27, p. 21).

Because the double bond is on the first carbon atom of the unit structure, polypropylene is an alpha olefin (16). Natta (15) found that isotactic polypropylene formed a better textile fiber than any of the other known olefins. In its structural form the branches lie in the same direction, projecting from one side of a linear chain (15).

Polypropylene fiber, like polyethylene and nylon, is produced by melt extrusion, cooled, then drawn to orient the crystals to the fiber axis (16, 24). Its structure can be controlled in much the same way as can other synthetic fibers (18). To control the properties of polyethylene fiber (47), the liquid polymer is rapidly cooled to room temperature. It solidifies in a state of disorder. This is the so-called amorphous state. Then, if this is heated to a certain temperature, crystallization occurs and an unoriented, partially crystalline polymer is formed. The degree of crystallization, which controls the mechanical properties, depends upon the temperature and time of this heat treatment. Stretching the unoriented polymer produces fibers of varying crystallinity and orientation to the fiber axis. The exact values of these qualities depend upon the amount of stretch and the temperature of the stretching process (47).

Thus it has been possible to produce a fiber with a great potential from polypropylene by the introduction of the isotactic form and by controlling fiber formation resulting in a strong, resilient, lively fiber with a melting point high enough to be used as a textile fiber (16). The isotactic structure of polypropylene is responsible for a fiber with a higher melting point than fibers made from other olefins (15). A greater orientation of the crystals makes possible higher strength obtained through the cold drawing process (15). As polypropylene is related chemically to the paraffins it is hydrophobic and comparatively chemically inert (16). In strength, low density, and chemical inertness, polypropylene compares favorably with nylon (16).

Polypropylene is made from a low cost raw material which produces a low density fiber giving it a high cover power. Therefore, more fabric can be produced from each pound of fiber (37). However, its resiliency is not as good as that of nylon although better than that of the polyesters (33). The yarn can ultimately recover almost all original deformation from extensions as high as ten percent; but above that, there is an increasing amount of permanent set (32). Because polypropylene is thermoplastic, fabric can be heat-set to shape which tends also to make it wrinkle resistant (8). Fabric with good dimensional stability (33) and, high resistance to abrasion, chemicals, molds and insects, has also been demonstrated. It is the lightest of all fibers and yet, may rival wool as a "warm" fabric (8).

Polypropylene, as a hydrocarbon related to the paraffins, is nonpolar and so lacks dye sites common to other fibers (33). Its moisture regain is nil and it is inert to most chemicals. These properties created the problem of finding fast dyes (16). In the development of nylon, dyes were found which made use of the amide and terminal amine groups which bind the dye in the fiber (19). Nylon also has some moisture regain and will react to more chemicals than will the olefins (19).

It was found that fast dyes could be developed if the polypropylene fiber were modified (43). Modification was done (a) by mixing other polymers or chemicals with it; (b) by chemically attaching amines and acids to the polymer; or (c) by using metallo-organic compounds, which were added as stabilizers, yet also provided dye sites (43). This method of modifying polypropylene by the use of certain additives while the polymer was in solution was a less costly and an easy way. However, this limited the kinds of dye that could be used (19).

Other ways have been found to modify the fiber so that common dyes and dye methods can be used. The United States Rubber Company has achieved a dyeable fiber by use of a unique type of dye receptor system which allows water soluble dyes to penetrate the fiber. This also increases moisture regain (19). Chemore Corporation claims that the fiber's textile properties are not altered by their dyes. They have found ways to use acid, premetalized, chrome, vat, and reactive dyes, all with a wide color range (30). National Allied Chemical Company developed a dye for fibers modified by metallo-organic compounds. The dye was fixed when chelated with metal compounds present in the modified fiber (2).

Knitting of Hosiery

Consumers are interested only in the performance of a garment as a whole not in the fiber (25). They demand quality in appearance, in comfort, ease of maintenance and durability. It is the task of the textile industry to select the proper fiber of those available and build a fabric construction suitable for further manufacturing of goods for consumer use (26).

Knitting is especially suited to the demands made upon fabric by hosiery wearers; and fabric used for this purpose must be highly extensible in all directions. Hosiery must be elastic for good fit, have a high recovery from strains, and feel just loose enough for comfort (12).

The production of knitted fabric by machine has been practiced for more than 350 years and yet there is still much art in designing knitted fabric (38). The Consumer Service Division of the United States Testing Company defines knitting as:

> . . . the looping of one yarn or one system of yarns together to make a fabric. A row of loops running lengthwise of the fabric is known as a "wale". A row of loops running across the fabric is referred to as a "course" (45, p. 46).

Weft knitting where the interloops are formed across the fabric is most commonly used in hosiery (45). Gauge is the measure of the closeness of stitch; and denier is the unit used to express the diameter of the yarn (8). These terms are used to accurately describe the fabric in full fashioned hosiery where the shape is obtained by increasing or decreasing the number of stitches where needed. With seamless hosiery, the shape is obtained by heat setting which distorts some of the stitches. When making equivalent gauge comparisons, full fashioned to seamless hosiery, the latter will give wide variations. Full fashioned hosiery has the same gauge all the way down while seamless hosiery is stretched in the welt and closer together in the ankle (46).

Hosiery made on a single bank of needles has a jersey fabric construction. The machine determines the length of stitch but beyond this the qualities possessed by the fabric are fixed by the yarn itself (38). With the use of a heat setting process, synthetic thermoplastic fibers can be used to make seamless hosiery which will hold a shape. This is an important finishing process performed after the hosiery is made. It involves breaking the interchain forces, rearranging the chains which make up the fibers, and forming new forces to keep the configuration. The success of the treatment depends upon the basic fiber properties. Both nylon and polypropylene fibers are thermoplastic and will retain the new shapes with varying degrees of success (41; 48).

CHAPTER II

METHODS AND PROCEDURE

The performance of hosiery made from nylon and polypropylene was compared on the basis of results obtained from wear and laboratory tests. The main objective of the wear tests was to compare the performance of a new product, polypropylene hosiery, with the performance of a better-known product, nylon hosiery, under conditions of actual wear and care by a selected group of people who normally wear hosiery daily. The two objectives of the laboratory tests were to verify some of the results shown in the wear tests, and to give further information about the hosiery that could not be obtained in actual wear.

Before the wear tests were begun the hosiery used in the study were examined in the laboratory to obtain a description of the yarns, of the size of the hosiery as measured in six areas, and of the construction of the hosiery.

The first wear test extended over a period of six weeks during the months of April and May. The second wear test could not take place until June and July as the hosiery were not available until that time. The wear period for the second wear test was shortened to four and one-half weeks which still allowed for the same amount of wear except for a small percent of hosiery which were recalled before they were worn out. With this modification, the same procedure was followed with both wear tests.

The following laboratory tests were conducted: breaking strength and elongation of yarns, bursting strength of the knee and toe areas, the stretching and recovery of the hosiery fabric, and fading to hand laundry. Samples of both worn and new hosiery were used in all laboratory tests with the exception of the stretch and recovery test. Worn hosiery were omitted from this test because the amount of stretching was determined by measuring the hosiery before and after the wear tests. Standard conditions of relative humidity and temperature were maintained for all laboratory tests with the exception of the course and wale counts and the determination of the amount of fading to laundry.

Two brands of hosiery were selected because of availability and were obtained directly from the hosiery manufacturers. The brands, differentiated by the terms Group I and Group II in this study, each contained matched pairs of hosiery, one pair made of each fiber, which were comparable as to style, construction, and size. The two different fiber types of hosiery are termed fiber A for nylon and fiber B for polypropylene. Table I gives the numbering systems and the fiber designations used in the wear tests.

Table I

NUMBERING SYSTEMS AND FIBER DESIGNATIONS USED IN THE WEAR TESTS

First Wear Test		Second Wear Test	
Group I	Numbers	Group II	Numbers
Subjects	1 to 30	Subjects	43 to 52
Fiber A*	1A to 30A	Fiber A	43A to 52A
Fiber B**	1B to 30B	Fiber B	43B to 52B

* Fiber A designates hosiery made of nylon
** Fiber B designates hosiery made of polypropylene

The subjects who wore the hosiery during the wear tests were given numbers to correspond with the numbers of the pairs of hosiery assigned to them. In Group I the numbers ranged from 1 through 30; in Group II the numbers ranged from 43 through 52.

Table II lists the hosiery by number which were used in the laboratory tests. Categories from 1 to 16 were set up to include four single stockings; a new fiber A, a new fiber B, a worn fiber A, and a worn fiber B. Categories 1 to 12 included hosiery from Group I; categories from 13 to 16 included hosiery from Group II.

The new nylon and polypropylene hosiery are listed in order of ascending numbers with "A" to indicate nylon and "B" to indicate polypropylene. These new hosiery served as controls. The worn nylon and polypropylene hosiery are listed in order of the number of days worn during the wear tests. They were chosen through a process of stratified random sampling. The strata used were the number of days worn; and the pair from each strata was chosen by random selection. One single stocking was selected from the pair in such a way that half of the total worn stockings would contain runs while the other half would not.

Table II

CATEGORIES, FIBER DESIGNATIONS, AND HOSIERY USED IN LABORATORY TESTS

Category	New Fiber A	New Fiber B	Worn Fiber A			Worn Fiber B		
Group I	No.	No.	No.	Days Worn	Cond. runs	No.	Days Worn	Cond. runs
1	31A	31B	3A	1	none	6B	1	none
2	32A	32B	17A	2	none	9B	2	none
3	33A	33B	5A	4	run	19B	4	run
4	34A	34B	6A	5	run	22B	5	run
5	35A	35B	9A	6	run	1B	6	run
6	36A	36B	21A	7	run	10B	7	run
7	37A	37B	30A	8	run	12B	8	run
8	38A	38B	13A	9	run	14B	9	run
9	39A	39B	23A	10	none	4B	10	none
10	40A	40B	20A	15	none	20B	15	none
11	41A	41B	14A	15	none	15B	15	none
12	42A	42B	2A	17	none	2B	18	none
Group II								
13	53A	53B	46A	3	runs	45B	3	runs
14	54A	54B	50A	6	none	48B	5	none
15	55A	55B	43A	10	runs	49B	9	runs
16	56A	56B	44A	17	none	44B	17	none

As the yarns were unraveled during laboratory testing, visual observation indicated that all hosiery in both Group I and II were made on two-feed knitting machines. All hosiery were circular knit and heat-set to shape.

Group I contained six dozen pairs of hosiery, three dozen of each fiber, nylon and polypropylene. The nylon hosiery were described as dress sheer, 400 needle, plain heel and reinforced toe. The polypropylene hosiery were described as dress sheer. The style and construction were the same for hosiery made from both fibers. The hosiery were seamless with the heel and toe areas shaped showing fashion marks. The reinforced toe area was seamed to the foot area on the underside with a loop closure. The color, "Beige Mist", was listed for all hosiery in this group. However, the color of the polypropylene hosiery was of a darker shade than was the nylon hosiery. Thirty pair of each fiber type of hosiery were given numbers. The nylon numbers ranged from 1A to 30A; the polypropylene numbers ranged from 1B to 30B (Table I). Six pair of hosiery made from each fiber were separated into individual stockings and numbered for use in laboratory tests. The numbers of the nylon hosiery ranged from 31A to 42A; the numbers of the polypropylene hosiery ranged from 31B to 42B (Table II). Sizes ranged from $8\frac{1}{2}$ to $10\frac{1}{2}$ medium length with the exception of two pair, one of each fiber, which were $8\frac{1}{2}$ short.

Group II contained two dozen pairs of hosiery, one dozen of each fiber with two colors represented, "Suntan" and "Burnish Taupe". The style and construction were similar to those in Group I except for two bands of run-resistant knitting, one found at the top of the reinforced toe area and the other between the welt and the after-welt. The sizes ranged from 9 medium to 11 tall. Ten pair of each fiber type of hosiery were given numbers. The numbers for nylon hosiery ranged from 43A to 52A; and the numbers for polypropylene hosiery ranged from 43B to 52B (Table I). Two pair of each fiber type to be used in laboratory tests were separated into single stockings and numbered (Table II). The numbers for nylon hosiery ranged from 53A to 56A; the numbers for polypropylene hosiery ranged from 53B to 56B.

Wear Tests

Group I

The wearers were selected from university personnel and students with the addition of two homemakers. An attempt was made to select people who varied as to the amount of daily activity ranging from sedentary to very active. Thirty people participated in the first wear test. Each participant, designated as subjects, was given a number to correspond with the numbers on the pairs of hosiery of each fiber type worn. The numbers ranged from 1 to 30 with each subject wearing both the "A" and "B" hosiery (Table I).

Each subject was asked to wear and care for the hosiery in their usual manner. It was felt that this would give a more normal wear test than if wear and care were restricted (6). However, one precaution given was to take care so as to minimize snagging as the hosiery were hung to dry. The hosiery were to be worn once before washing and were to be washed after each wearing. The two pair of hosiery, one made of each fiber, were to be worn on alternate days unless one pair had to be discarded because of an unsightly run. In that case, the remaining pair was worn every day. After a period of ten days, which allowed five days of wear for each pair, the hosiery were collected and examined over a black surface for obvious snags and for runs. They were then returned for further wear if they were still in good condition. The test then continued without further examination of the hosiery until the pairs were discarded because of visible runs or until the end of the six weeks time period allowed for the test. Each subject kept a record of the days each pair was worn, and if known, the origin and reason for each fault that the subject considered serious.

Two questionnaires were used during the wear period. The first asked questions about the subjects seeking information as to: occupation, amount of activity during an average day, the most and least common reasons for stocking wear, the area in a stocking which usually wore out first, types of shoes usually worn, hosiery buying habits, and the preferred size and length of hosiery (Appendix A-1). The second questionnaire asked questions about the two pairs of hosiery worn in the test. The information asked for was: how well the hosiery fit the subject, words which could be used to describe the hand, and whether the wearer would buy hosiery made from either or both of the fibers (Appendix B-1).

Before the wear tests and again after, each individual stocking was measured to the nearest eighth of an inch. The width was measured in four places: the instep, the ankle, the calf, and the welt. The length of the foot was measured from the tip of the toe to the top of the reinforced area of the heel. The overall length was measured from the bottom of the foot just behind the reinforced area of the heel to the top of the welt through the center of the stocking. In order to insure accuracy at the second measuring after the wear tests, all hosiery were turned right side out and washed in a mild neutral detergent, allowed to line-dry with as few wrinkles as possible. Any remaining wrinkles were pressed out with a warm iron using an up and down movement of the iron to avoid stretching the pressed area.

Two records were made of faults which occurred during the wear tests. The first, made after a ten-day wear period which allowed each pair to be worn five days, recorded the runs and the obvious snags which were plainly seen over a dark surface. The second record was a complete tabulation of all faults found in each individual stocking at the completion of the wear tests. The hosiery were examined on a flat black stocking form of thin cardboard divided into numbered sections. In this way a single layer of fabric could be inspected using a magnifying glass to locate very small faults that would otherwise be missed. The length of each snag was measured in centimeters, and placed into the following categories: pricks, 0.1 to 0.9 centimeters, 1.0 to 2.9 centimeters, 3.0 centimeters and over, and holes which were of the same size as those in the first two categories but were round in appearance. Abrasion marks were also counted and noted as to whether or not they were the cause of a run. All faults were listed as to the number of the area in which they occurred (Figure 1). An arrow showing the origin of a run and the direction it ran was also indicated by area.

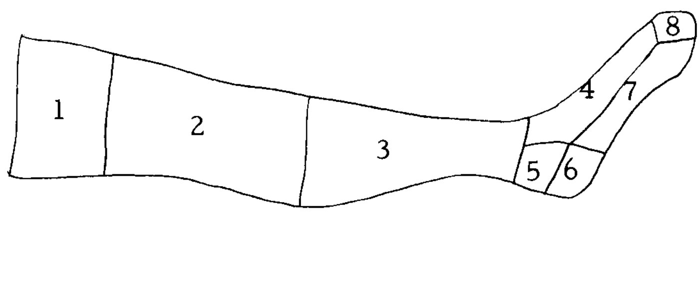

Figure 1

DIVISIONS INDICATING THE EIGHT AREAS OF THE HOSIERY

The black cardboard stocking form was divided into eight areas to facilitate tabulating the faults according to areas (Figure 1). Area 1 included both the welt and the after welt; areas 2 and 3 indicated the top and bottom of the panel; area 4 indicated the instep and the top of the foot; area 5 marked the heel above the reinforced area where the rim of a shoe would come; areas 6 and 8 indicated the reinforced areas of the heel and toe respectively; and area 7 indicated the sole of the foot.

Group II

Ten subjects were selected to take part in the second wear test. Six of these had participated in the first wear test. Except for having a smaller number, the second group was comparable to the first group as to occupations and kinds of daily activity. The instructions, questionnaires and procedure were treated the same as far as it was possible to do so. Because the hosiery sizes included both medium and tall, personal preferences as to hosiery length desired by the subjects were taken into account. Another change in procedure was to attempt to limit the number of maximum days worn to fifteen. As the second brand of hosiery was not available until a later date, the only other change in procedure was the time of year the second wear test was conducted. The first wear test took place in the months of April and May, while the second wear test did not take place until June and July. The hosiery were examined after a ten-day wear period and again at the end of the wear test, following the same procedures as in the first test.

Laboratory Tests

Laboratory tests were selected and conducted using both worn and new hosiery to obtain further information on the properties of hosiery made of two fibers, polypropylene as compared to nylon. There are two main reasons for the choice of specific tests. First, to obtain facts about the hosiery which help describe them, and second, to verify or help explain some of the findings of the wear tests. The yarn numbers and the course and wale counts were determined in order to describe in some detail the differences in yarn and fabric construction. All other laboratory tests were designed to help explain the findings of the wear tests as well as to furnish a further description of the performance of the hosiery.

The procedures recommended by Committee D-13 of the American Society for Testing Materials were followed for the laboratory tests wherever possible (3). Two exceptions were the fading to laundry test and the hosiery stretch test. The procedures for these were devised to obtain information for which adequate instructions and equipment were not available. However, in all tests, with the exception of the course and wale counts, standard conditions of relative humidity of 65 $\pm$ 2 percent and a temperature of $70^{\circ} \pm 2^{\circ}$ F. were maintained (3).

The tests for bursting strength in the knee and toe areas, and the tests of yarn breaking strength and elongation were both performed on worn hosiery as well as on new hosiery made of both fibers. Only new hosiery were used for all other laboratory tests. The tests for yarn numbers and for course and wale counts were made to describe the hosiery used in the study. The fading to laundry and the hosiery stretch tests were made to explain some of the findings of the wear tests, thus only new hosiery were included. The amount of fading in the laboratory test was compared to the amount of fading in the hosiery actually worn. As the hosiery were measured before and again after wearing to reveal the amount of stretch, a laboratory test for stretch was set up under controlled conditions to demonstrate the differences in the amount of stretch of the two fiber types.

Yarn Number and Description

Tests to provide a description of the yarns were determined by a visual examination of both Group I and II yarns under a broadfield microscope. Because the yarns of all hosiery used were of a monofilament type with no twist, the only test deemed necessary was the determination of the yarn numbers. This was determined by using the Suter Twist Counter to measure the lengths of the yarn (3, p. 429) and the Universal Yarn Numbering Balance to obtain a direct reading of the denier. Five yarns were taken from each new stocking and the readings averaged together. Thus, Group I provided 60 yarn samples of each fiber type which yielded 12 readings; and Group II provided 20 yarn samples of each fiber type which yielded four readings (Table II).

Each specimen was unraveled as it was placed between the jaws, set 45 centimeters apart, of the Suter Twist Counter. The center of the yarn was placed under a specified amount of tension by a tensioning bar with a 0.3 gram weight attached. The yarn was removed from the machine by cutting with a razor blade as close to the jaws as possible.

The Universal Yarn Numbering Balance was used to weigh each yarn sample after it was measured. With the beam locked, the yarn was placed on the hook inside the weighing chamber. After the beam was unlocked the scale pointer was rotated until the balance pointer and the balance line coincided. The scale pointer then indicated a number which, when multiplied by two, yielded the yarn number expressed as denier.

Course and Wale Count

Using a Suter Yarn Counter equipped with a pointer, the number of wales and courses per inch were recorded (3, p. 102). Each stocking was placed on a black cardboard stocking form so that only one layer of fabric was seen. Four counts, two in the ankle area and two in the calf area, were made in each new stocking (Table II, p. 14). A count was made in the two areas to find the amount of distortion necessary to shape the hosiery in the ankle.

Yarn Breaking Strength and Elongation

A Scott Inclined Plane Tester, model IP-2, was used to measure yarn breaking strength and elongation. The tests were run with a 250-gram weight load according to the standard procedure (3, p. 578-589). The stress-strain curves were recorded automatically on the tensilgram. In addition, a record was made of the number of grams of weight and number of inches elongation at break. Five specimens of yarn from the calf area of each stocking, both worn and new (Table II, p. 14) were unraveled as each was set into the machine.

Bursting Strength

A Scott Breaking Strength Tester, Model J, of the pendulum type was used with the Ball Burst attachment to measure bursting strength. As near as was possible, standard procedures were followed (3, p. 102-3). A steel ball was forced up against the fabric until rupture. A record was made of the number of pounds of force required to rupture the hosiery fabric.

Two specimens were cut from the knee area and one specimen from the toe of each single stocking, both new and worn, listed in Table II, page 14. Standard procedures were followed for bursting the knee area. However, because the toe does not lie flat, the method of placing the toe specimens into the Ball Burst attachment was modified. The foot area of the stocking was slashed up to the reinforced toe area. The specimen was then spread over one ring and held under tension to flatten it as much as possible until the other ring could be placed and the specimen holder set under the pressure bar of the attachment. The area which would normally be subjected to wear by the big toe was placed directly in the center of the rings in the pathway of the steel ball. Any extra fabric which would interfere with the upward path of the steel ball was cut away before the specimen holder was placed in the machine.

Elasticity of Hosiery - Stretch Test

A modified procedure using a Scott Breaking Strength Tester, Model J, of the pendulum type was used to stretch a double thickness of fabric in the calf area of each new stocking listed in Table II, page 14. The methods devised were set up empirically after experimentation and pretesting. The area stretched was as far away from the cut edge of the knee area as possible to prevent runs from occurring during the stretching process. As the area towards the ankle was not cut away, the problem of runs did not occur there. To prepare the fabric, the hosiery was first soaked in distilled water for 30 minutes, stirring occasionally. The specimens were line dried, and then placed under standard conditions of humidity and temperature for 24 hours.

Each specimen was placed without tension, on a flat surface to be measured. Across the width of the hosiery a distance of 2.7 inches was measured and marked with colored tape. The machine was equipped with three-inch jaws set three inches apart which provided some tension before the stretching process was carried out. This tension was allowed because a well-fit stocking is under some tension when it is first placed on the leg. The machine was adjusted so that the lower jaw would stop at a distance of four and one-half inches, then return. This allowed a total of 66.7 percent stretch to be applied.

Each specimen was stretched and relaxed for 12 minutes or the equivalent of 52 $\pm$ 2 times. Upon being removed from the machine, each specimen was measured immediately to the nearest tenth of an inch, measured again after a relaxation period of 15 minutes and again after four hours. A fourth measurement was taken after the specimen had been washed and line dried for one hour.

Fading to Laundry

A specimen for a laundry test was cut from each new stocking of Group I listed in Table II, page 14, by measuring down two inches from the afterwelt. This provided a sample which contained sheer fabric as well as the heavier fabric of the welt. These were placed into the 12 categories and each specimen was washed the same number of times as were the hosiery in the same category worn by the subjects in the wear test. Hosiery from Group II, Table II, page 14, were not included in this test as the two different initial colors made judgments as to the amount of fading more complicated and unreliable.

To evaluate, four groups of hosiery, each group containing 12 single stockings, were ranked from one to 12 on the basis of fading by four judges working independently. The four groups so ranked were: worn fiber A hosiery, worn fiber B hosiery, new fiber A hosiery, and new fiber B hosiery. The last two groups listed were washed in the laboratory using warm water and a neutral detergent, and served as control groups. The first two groups were washed by the subjects during the wear test. As the hosiery were being ranked, the judges were not forced into making a decision if one stocking was not noticeably different from another. If there did not seem to be a difference, both stockings were given the same medium rank. The ranks were then placed in a table which listed the stockings in order of the number of times they were washed.

CHAPTER III

ANALYSIS OF DATA

The following is the order in which the data will be discussed: description of the hosiery, findings from the questionnaires, results of the two wear tests, and results of the laboratory tests.

The hosiery used in the study were divided into two groups, each group contained hosiery of a different brand. Within each brand of hosiery both fiber types, nylon and polypropylene, were represented. Throughout the discussion of the data, the fiber types have been designated by "A" for nylon hosiery and "B" for polypropylene hosiery. The two brands were used in separate wear tests and were designated as Group I and Group II.

Description of Hosiery

The mean weights of the yarn samples, expressed as denier, place fiber A and fiber B of both brands in a medium weight range. The results of the yarn analysis are summarized in Table III. The yarn numbers range from 17.2 to 19.0 denier. In Group I the yarn number was slightly larger for fiber B yarns while the reverse was true in Group II where fiber A yarns were slightly larger.

Table III

ANALYSIS OF HOSIERY CHARACTERISTICS

Fiber Area	Denier	Course Count	Area Difference	Wale Count	Area Difference	Ratio* Course:Wale
Group I						
A Calf	17.2	52.6	4.7	39.1	31.6	4:3
A Ankle		47.9		70.7		2:3
B Calf	19.0	48.2	8.1	36.1	25.4	4:3
B Ankle		40.1		61.5		2:3
Group II						
A Calf	18.3	46.4	4.5	38.1	34.0	4:3
A Ankle		41.9		72.1		2:3
B Calf	17.7	49.5	5.0	36.0	26.9	4:3
B Ankle		45.0		62.9		2:3

* ratio: approximate

The analyses of the course and wale counts are summarized in Table III. The two counts made, one in the calf area and one in the ankle area, showed a wide variation for both the wale and course counts. This variation was probably due to the distortion introduced during the process of shaping the hosiery. In the shaping process the normal ratio of courses to wales is changed. The difference between the counts made in the two areas is a measure of distortion. In the table, brackets enclose the two counts used to calculate the difference. These ranged from 4.7 to 8.1 courses per inch and from 25.4 to 34.0 wales per inch. Because the ranges were wide, the conclusion was reached that the combined counts from the ankle and calf areas could not be used to obtain a true measure of the course to wale count ratio.

However, as the calf area has less distortion than any other, the course and wale count could be used as a more accurate measure of the ratio. Thus, the approximate ratio of 4:3 is a more reliable description of this factor than is the approximate ratio of 2:3 found in the ankle area.

Description of Subjects

Results of Questionnaire I

Information about the subjects who took part in the wear tests, and about some of their opinions and preferences was obtained by analyzing the responses made to various items in Questionnaire I (Appendix A-1). The kinds of information about the subjects included: an indication of the amount of daily activity, the types of shoes usually worn, the weight and style of hosiery preferred, the size and length of hosiery usually worn, and the importance of the listed guide points in buying hosiery. Opinions were also expressed concerning the areas of hosiery most often affected by faults, and the most and least common causes of faults in hosiery wear.

The subjects who took part in both of the wear tests could be characterized in general as being moderately active (Appendix A-2).

The majority indicated that they spent most of the day sitting at work and that at times their activities involved kneeling or bending. A smaller but still significant percent checked walking as an important activity for about half of their day. On the other hand, very little time was spent sitting at rest.

The types of shoes worn by the subjects in both wear tests were, for the most part, shoes having from one to two inch heels, with a smaller number wearing flat heels (Appendix A-3). These shoes were most commonly a closed heel and toe style. High heels were worn only at times.

Hosiery of a medium weight and of seamless construction was the most common type preferred, with more sheer hosiery being worn at times (Appendix A-4). Size preferences ranged from size $8\frac{1}{2}$ to 11 with 85 percent wearing medium length (Appendix A-6).

Most of the subjects checked the shin and calf area as being most often affected by hosiery faults and checked the ankle area as least often affected (Appendix A-7). A smaller number checked the knee area as also being a common place for hosiery faults to occur. Thus, most faults occur in the panel of the stocking. Furniture roughness and strain from kneeling or bending were the causes of most faults while garter strain and shoe rubbing were of lesser importance (Appendix A-8). Of all the possible reasons for hosiery faults listed, damage caused by washing the hosiery was checked as being the least common cause.

The fact that a high percent of the subjects indicated that kneeling or bending was a part of their daily activities only at times and also that this same activity was one of the most common reasons for hosiery faults would indicate that kneeling and bending place a great strain upon hosiery.

The subjects who participated in the wear tests were moderately active. Their shoes were of a closed heel and toe style with most of the heels being from one to two inches high. The most common type of hosiery was seamless and of a medium weight and length, with sizes ranging from $8\frac{1}{2}$ to 11. In the opinion of most, the shin and calf area were most vulnerable to hosiery faults; and furniture roughness and strain from kneeling or bending were the most common causes of faults. It was felt that the least amount of damage occurred while the hosiery were being washed.

Results of Questionnaire II

The survey made of the opinions of the subjects concerning the test hosiery provided information as to: the fit of the test hosiery, which of the descriptive adjectives listed could be used to describe the hand of the hosiery, and whether or not similar hosiery types made of either of the two fibers would be purchased if found in a future market (Appendix B-1).

A high percent of the responses to the question as to how well the test hosiery fit the subjects, fell into the "normal" range of the scale (Appendix B-2). A smaller percent of the responses indicated that some areas did not fit as well as expected. The length of leg, and the widths of the ankle and thigh areas of Group I were checked most often as being at fault. The general trend to find the length too short was true for both fiber types of hosiery. For hosiery made of fiber A, the thigh had a tendency to feel too tight; and for hosiery made of fiber B the ankle area had a tendency to feel too loose. For the most part, hosiery in Group II fit the subjects better than those of Group I, as the only areas reported most at fault were the ankle and calf areas in fiber B hosiery which were in some cases too loose.

The hand of the hosiery was surveyed by asking for opinions concerning which words in a selected list of adjectives could be used to describe the hosiery worn in the wear tests (Appendix B-3). Using 74 percent as an arbitrary dividing point, five words could be used to describe fiber A type hosiery: silky, soft, smooth, pliable, and elastic. Only one word, springy, received a high enough percent acceptance to indicate that it might be used to describe fiber B type hosiery. Equally significant are the words which were checked by a high percent of the subjects as not applying to either of the two fiber types of hosiery. These were: boardy, hard, oily, sticky, cold, moist, limp, dry, stiff, and tight.

Customer acceptance for similar types of hosiery, if found in a future market, was surveyed (Appendix B-4). Fiber A was found to have greater acceptance than did fiber B hosiery. Eighty-nine percent of Group I and 90 percent of Group II indicated that they would buy fiber A hosiery, while only 48 percent of Group I and 70 percent of Group II indicated that they would buy fiber B hosiery.

Wear Test - Group I

The findings of the wear test are discussed by first considering the performance of the two fiber types of hosiery, nylon and polypropylene, as to the length of wear life. Two analyses were made of the number of days worn, one using the total number of days actually worn, and the other using a 15 day maximum wear period. Second, the two fiber types of hosiery were compared as to the number of snags and runs found after an initial wear period of five days for each pair. Third, the total number of faults, which occurred during the entire test period, was used to compare the performance of the two fiber types of hosiery. The total number of faults was then broken down into the specific categories of snags, runs, and abrasion marks. Fourth, the hosiery types were compared as to the amount of dimensional change which took place during the test period.

Wear Life of Hosiery

Hosiery made of fiber A were worn an average of 10.87 days as compared to an average of 6.40 days for fiber B (Table IV). Two sources of variation were considered in the evaluation of the difference between these two mean values; the two fiber types, and the subjects were both found to cause the significant difference. However, the differences in the performance of the two fiber types were more influential in affecting the wear life than were the actions of the subjects (Appendix C-2).

Some subjects were able to continue the wear test beyond 15 days for one pair of hosiery because of failure of the other pair early in the wear test. Other subjects discontinued wearing the hosiery after a 15-day wear period for both fiber types even though neither pair had failed. Because of this a second analysis was run using a 15-day maximum limit for all hosiery worn longer than this. The average number of days for fiber A hosiery was thus reduced to 9.23 as compared to 6.30 for fiber B. Again both sources of variation were found to have significance but the variation caused by the subjects was more important during the shorter length of time (Appendix C-2).

The conclusions drawn were that there was a significant difference in the amount of time hosiery made of the two fiber types were worn, Fiber A being the most durable; and that as the wearing period increased this advantage for fiber A increased; with the differences caused by the subjects becoming less important.

Table IV

MEAN WEAR CHARACTERISTICS - DAYS WORN, FIVE-DAY CHECK FOR RUNS AND SNAGS FOR GROUP I

	Fiber A		Fiber B	
Wear Characteristic	Total	Mean	Total	Mean
Total Days Worn	326	10.87	192	6.40
15 Day Maximum	277	9.23	189	6.30
5 Day Check - Snags	496	16.53	256	8.53
5 Day Check - Runs	8	0.27	17	0.57

Initial Five-Day Wear Period Check

After each pair of hosiery had been worn five days a count of the snags found in each pair yielded an average of 16.53 snags for each pair of fiber A hosiery and only 8.53 snags for fiber B hosiery (Table IV). This was almost twice as many snags for fiber A type. When the two sources of variation, the fiber types and the subjects, were analyzed to find the F ratios (Appendix C-2), it was found that both sources were causes of the significant difference between the two fiber types, although the subjects were less important sources of variation.

A count of the runs was also made after the five-day wear period. Fiber A hosiery contained an average of eight runs compared to the average of 17 found in fiber B hosiery (Table IV). It was evident that after the initial five-day wear period that although fiber B hosiery had only half as many snags as did fiber A, they contained over twice as many runs which caused more hosiery made of fiber B to be discarded during this period.

Total Number of Faults

A count made of the total number of faults found at the end of the wear test included all snags, runs and abrasion marks. An analysis was made testing three sources of variation: the fiber types, the areas where the faults occurred in each fiber type, and the areas where the total faults in both fiber types occurred. The count of faults was then broken down into the three types: snags, runs, and abrasion marks. Each type was analyzed as to the variation introduced by the subjects as well as to the differences due to the two fiber types. Snags were listed according to their sizes to test for differences in severity. Additional analysis was made of both runs and abrasion marks to find out if there were covariance with the number of days worn.

The mean values for the total number of faults, for snags, for runs, and for abrasion marks are found in Table V. Three mean values are given for each: the average number for each day worn, the average number for each subject, and the average number for each subject for each day worn.

Table V

MEAN VALUES FOR FAULTS PER DAY AND PER SUBJECT FOR GROUP I

Type of Fault	Fiber	Total	Total/Days	Total/Subj.	Per Subj. Per Day
Total Faults	A	2432	7.46	81.07	0.25
	B	605	3.15	20.17	0.10
Snags	A	2352	7.22	78.40	0.24
	B	536	2.79	17.87	0.09
Runs	A	41	0.12	1.37	0.004
	B	42	0.22	1.40	0.007
Abrasion Marks	A	39	0.12	1.30	0.004
	B	27	0.14	0.90	0.005

The average number of faults for each subject was 81.07 for fiber A as compared with 20.17 for fiber B hosiery. These faults were acquired at an average rate of 7.46 for each day for fiber A and a rate of 3.15 for fiber B. Thus, on an average, each subject acquired about four times as many faults in fiber A hosiery as they did in fiber B hosiery, and the faults were acquired about twice as fast. The average number of faults for each subject for each day worn was 0.25 for fiber A which was two and one-half times as many as the average of 0.10 for fiber B.

By eliminating the number of days worn as a factor and calculating the F ratios, it was found that the difference between the number of faults found in each fiber type hosiery was highly significant. Thus, fiber B was much more resistant to faults than was fiber A (Appendix C-1).

The faults were placed into categories according to the areas where they were found (Figure 1, page 19). After eliminating the number of days worn as a factor, the average number of faults found in each area was calculated for each fiber type (Table VI). An analysis of variance indicated significant variation between the areas. Most of the faults occurred in the panel area. There was significant variation in the number of faults as the two fiber types were compared (Appendix C-2). Figure 2 graphically pictures the differences between the fiber types. Fiber A not only had more faults than did fiber B in all areas except for areas six and eight, but also showed a trend towards having a greater proportion of faults in the foot areas.

The number of snags were counted and placed into five categories according to their size. The means for the two fiber types were calculated from the total number and a test for significance made.

Fiber A hosiery contained an average number of snags per subject of 78.40 as compared to an average of 17.87 snags in fiber B hosiery which makes over four times as many in fiber A for each

Table VI

MEAN NUMBER OF FAULTS BY AREA FOR GROUP I

Fiber \ Area	1	2	3	4	5	6	7	8
A	1.28	3.50	2.02	0.76	0.55	0.02	0.62	0.04
B	0.32	2.06	0.99	0.17	0.10	0.01	0.12	0.09

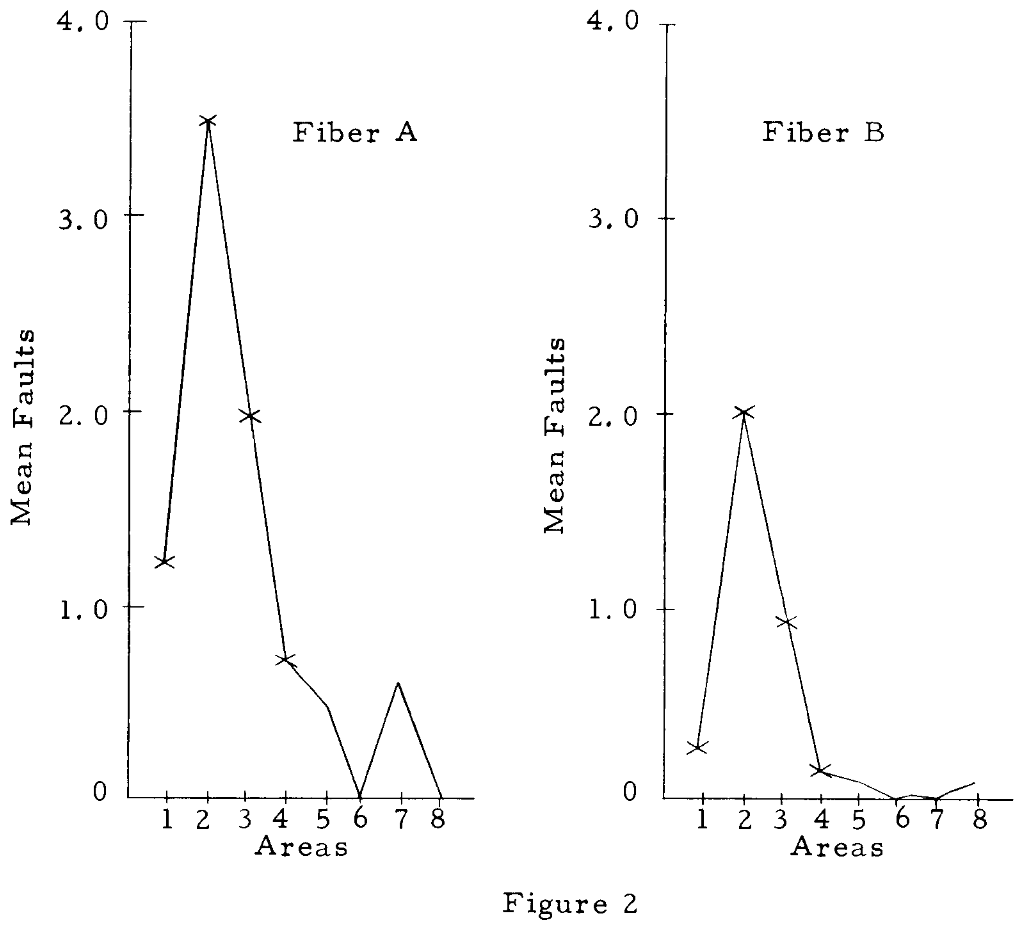

Figure 2

DISTRIBUTION OF FAULTS BY AREA FOR GROUP I subject. However, when the number of days worn was also taken into consideration the difference was reduced so that fiber A contained only two and one-half times as many snags for each day worn (Table V). The test for significance indicated that the difference between the snagging of the two fiber types was important with fiber B being the more resistant (Appendix C-2). The amount of variation introduced by the subjects who wore the hosiery was not found to be important.

To compare the two fiber types of hosiery as to the sizes of the snags, the count of snags in the five categories were changed to percents (Table VII). Most of the snags found in all hosiery ranged from pricks up to 0.9 centimeters. With one exception,as the size of the snags increased the number found in the hosiery decreased. Fiber B hosiery contained ten percent in the category of small round "holes". Otherwise, both fiber types showed the same relative pattern (Figure 3).

The average of 1.37 runs for each subject found in fiber A hosiery as compared with 1.40 runs for each subject in fiber B hosiery does not indicate the true difference in performance of the two fiber types of hosiery. The averages of the number of runs for each day worn have more meaning. It was found that fiber B contained 0.22 runs for each day as compared to 0.12 runs for fiber A hosiery (Table V), which is almost twice as many runs found in fiber B

Table VII

PERCENT OF SNAGS BY SIZE FOR GROUP I

Size / Fiber	Pricks	Cm. 0.1-0.9	Cm. 1.0-2.9	3 Cm. over	Hole Snag
A	34.0	51.3	11.2	3.2	0.3
B	28.0	45.7	13.1	3.2	10.0

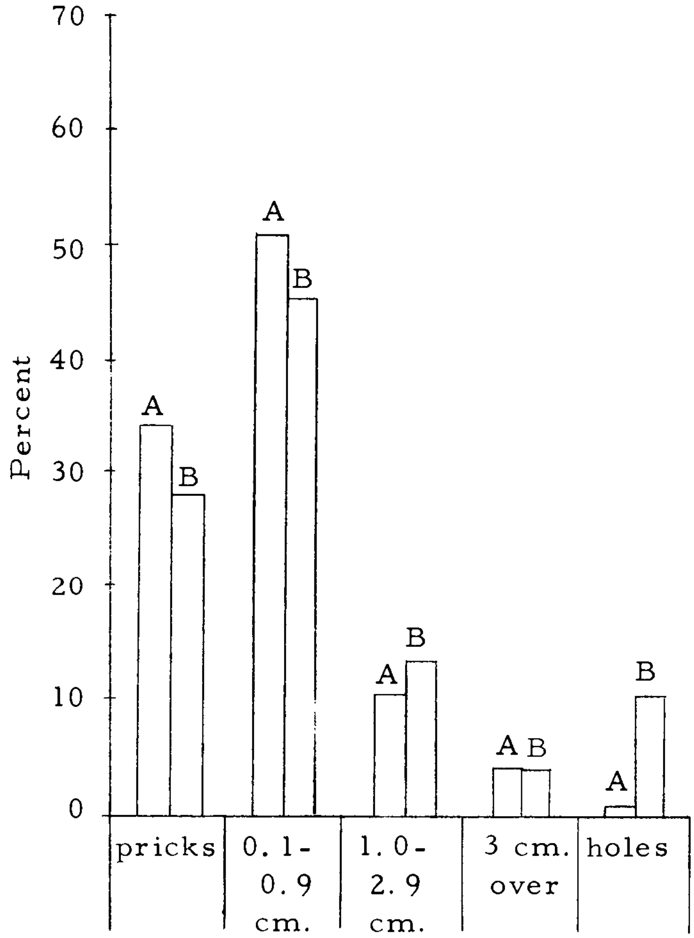

Figure 3

PERCENT OF SNAGS BY SIZE FOR GROUP I

hosiery.

Since the hosiery were discarded when one stocking of a pair developed a run, the number of runs in relation to the number of days worn was checked by an analysis of covariance. It was found that neither the subjects nor the difference between the two fibers were important. The differences in the actual number of days worn indicated that fiber A hosiery were more durable than fiber B hosiery but a probable increase in the number of days worn would not necessarily increase the differences in performance of the two fiber types (Appendix C-3).

Abrasion marks found in each fiber type of hosiery were counted and it was found that fiber A had an average of 1.3 abrasion marks for each subjects as compared to 0.9 abrasion marks for fiber B (Table V). This difference between the two fiber types was not found to be significant although the variation caused by the subjects was significant (Appendix C-2).

Because fiber A hosiery were worn for a greater number of days an analysis of covariance was made to check the relationship between the occurrence of abrasion marks and the number of days worn. It was found that with increased number of days worn, there was no corresponding increase in the number of abrasion marks. However, the differences among the subjects were significant (Appendix C-3).

Measurement of Stretching During Wear

By visual observation a noticeable amount of stretching was noted for the hosiery after a period of wear. For fiber A hosiery much of the stretch was recovered after washing; fiber B hosiery retained most of this stretch resulting in hosiery which was wider and shorter than fiber A hosiery at the end of the wear test. The differences in the widths and lengths of hosiery of the two fiber types are found in Table VIII. The figures in the table are expressions of eighths of an inch, thus, three inches becomes the figure 24. These transposed numbers are used in the following discussion, and will be termed units.

Table VIII

DIFFERENCES IN UNITS OF MEASUREMENT OF AREAS OF HOSIERY BEFORE AND AFTER THE WEAR TEST FOR GROUP I

	Fiber A			Fiber B		
	After	Before	Difference	After	Before	Difference
Width of						
Foot	25.9	24.5	1.4	30.2	28.4	1.8
Ankle	25.4	24.1	1.3	31.5	26.6	4.9
Calf	44.7	43.9	0.8	46.7	45.3	1.4
Thigh	54.7	52.4	2.3	56.1	51.3	4.8
Length of						
Foot	78.6	79.2	-0.6*	74.8	75.9	-1.1
Overall	244.9	246.2	-1.3	219.2	226.8	-7.6

* Negative signs indicate a decrease in length

The ankle and thigh areas showed the greatest contrast as the widths of hosiery made of the two fiber types were compared. The amount of stretch retained in the ankle area for fiber A hosiery was 1.3 units as compared with 4.9 units for fiber B hosiery. This means that fiber B hosiery retained five-eighths of an inch stretch while fiber A hosiery retained only one-eighth inch stretch. The difference was not quite as great in the thigh areas as 2.3 units of stretch in fiber A hosiery are compared with 4.8 units of stretch in fiber B hosiery. Thus, fiber A retained two-eighths of an inch as compared to five-eighths inch for fiber B.

A corresponding decrease in overall length was found as -1.3 units for fiber A hosiery are compared to -7.6 units for fiber B; which means that the average length of fiber A hosiery decreased only one-eighth of an inch while fiber B hosiery decreased almost one inch.

All hosiery tended to increase in width and decrease in length when worn. However, fiber B hosiery had a greater tendency to stretch in width and decrease in length than did fiber A hosiery. These conclusions were further supported by visual observation. When the hosiery was placed on a flat surface, fiber B hosiery showed a definite tendency to retain the shape of the wearer's leg. This was the most noticeable in the knee area where there was a pronounced curve after the hosiery were worn.

Wear Test - Group II

The findings of the second wear test will be discussed in the same order and in the same manner as was the first wear test. The two tests were not compared because of the difference in the number of subjects, and the difference in time of year the test was conducted. There were many similarities in the findings, however, there were also many differences. The differences may be due to the difference in the brands used or they may be due to other unknown variables.

Wear Life of Hosiery

Hosiery made of fiber A were worn an average of 8.5 days for each subject as compared with 10.1 days for fiber B hosiery (Table IX). When the two sources of variation, the subjects and the two fiber types, were evaluated, it was found that the influence of the subjects was significant while differences between fiber types were not important (Appendix C-4).

The test was stopped after a 15-day wear period whether the hosiery were still in good condition or not with the exception of hosiery worn by one subject. Thus, one pair of each fiber type hosiery was worn 17 days instead of the 15 day maximum. To determine if this variation changed the results a second analysis was made using a 15 day maximum wear period. It was found that the results were the same (Appendix C-4).

There was a significant difference as to the average number of days worn due primarily to the influence of the subjects but not due to the difference in the fiber types of hosiery.

Table IX

MEAN WEAR CHARACTERISTICS - DAYS WORN, FIVE-DAY CHECK FOR RUNS AND SNAGS FOR GROUP II

	Fiber A		Fiber B	
Wear Characteristic	Total	Mean	Total	Mean
Total Days Worn	85	8.5	101	10.1
15 Day Maximum	83	8.3	99	9.9
5 Day Check - Snags	290	29.0	92	9.2
5 Day Check - Runs	2	0.2	3	0.3

Initial Five-Day Wear Period Check

After a five-day wear period for each pair of hosiery a count made of the number of snags yielded an average of 29.0 for fiber A hosiery as compared with 9.2 for fiber B hosiery (Table IX). This was over three times as many for fiber A hosiery. When the two sources of variation, the subjects and the two fiber types, were analyzed to find the F ratios (Appendix C-4), it was found that the type of fiber was important in making the difference between the means significant.

A count of the runs, also made after the five-day wear period, yielded an average of two runs for fiber A hosiery as compared with three runs for fiber B hosiery (Table IX). The difference between the two fiber types is too small to be of significance.

Total Number of Faults

A count made of the total number of faults found at the end of the wear test included all snags, runs and abrasion marks. The analysis of data found in the second wear test was made in the same way as was the analysis of data obtained in the first wear test. Again, the total number of faults was broken down for further analysis into the three types of faults: snags, runs, and abrasion marks.

The mean values for the total number of faults, for snags, for runs, and for abrasion marks are found in Table IX. Three mean values are given for each: the average number for each day worn, the average number for each subject, and the average number for each subject for each day worn.

The average number of faults for each subject was 133.0 for fiber A hosiery as compared with 37.9 for fiber B hosiery. These faults were acquired at a rate of 15.65 for each day for fiber A and a rate of 3.75 for fiber B hosiery. Thus, on an average, each subject acquired about three and one-half times as many faults in fiber A hosiery as they did in fiber B hosiery and these were acquired about five times as fast. The average number of faults for each subject for each day was 1.57 for fiber A which was four times as many as the average of 0.38 for fiber B.

Table X

MEAN VALUES FOR FAULTS PER DAY AND PER SUBJECT FOR GROUP II

Type of Fault	Fiber	Total	Total/Days	Total/Subj.	Per Subj. Per Day
Total Faults	A	1330	15.65	133.0	1.57
	B	379	3.75	37.9	0.38
Snags	A	1310	15.41	131.0	1.54
	B	352	3.48	35.2	0.35
Runs	A	10	0.12	1.0	0.012
	B	12	0.12	1.2	0.012
Abrasion Marks	A	10	0.12	1.0	0.012
	B	15	0.15	1.5	0.015

By first eliminating the number of days worn as a factor, and by calculating the F ratios, it was found that the difference between the number of faults found in each fiber type hosiery was highly significant. Thus, fiber B hosiery were found to be much more resistant to faults than were fiber A hosiery (Appendix C-4).

The faults were placed into categories according to the areas where they were found (Figure 1, p. 19). After eliminating the number of days worn as a factor, the average number of faults found in each area was calculated for each fiber type (Table XI). An analysis of variance indicated a significant amount of variation between the areas. Most of the faults occurred in the panel area. There was also a significant variation in the number of faults as the two fiber types were compared (Appendix C-4). Figure 4 graphically pictures the differences between the fiber types. Fiber A not only had more faults than did fiber B in all areas except for areas six and eight, but also showed a difference between areas two and three, with a greater number of faults occurring in area three, the calf and ankle areas.

Fiber A hosiery contained an average number of snags for each subject of 131.0 as compared to an average of 37.9 for fiber B hosiery which makes about three and one-half times as many snags in fiber A hosiery for each subject. The mean number of snags for each day show four times as many snags for fiber A occurring for each day worn (Table X). The test for significance indicated that the difference in the amount of snagging of the two fiber types was very important with fiber B being more resistant. However, there was also some significant variation introduced by the differences in subjects (Appendix C-4).

To compare the two fiber types of hosiery as to the sizes of the snags, the count of snags in the five categories were changed to

Table XI
MEAN NUMBER OF FAULTS BY AREA FOR GROUP II

Fiber \ Area	1	2	3	4	5	6	7	8
A	0.62	5.75	8.46	2.06	0.96	0.05	1.59	0.0
B	0.08	2.21	2.21	0.56	0.74	0.0	0.43	0.02

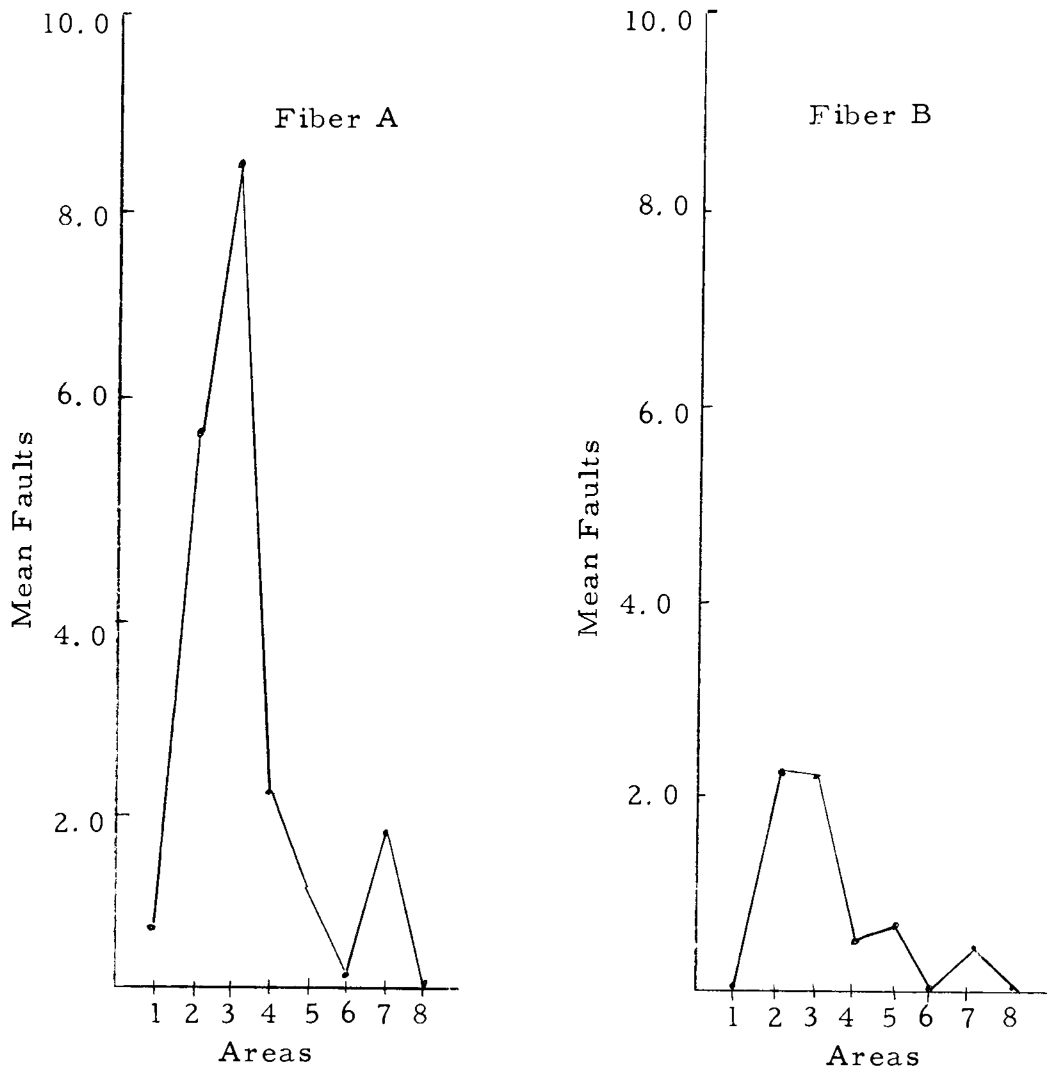

Figure 4
DISTRIBUTION OF FAULTS BY AREA FOR GROUP II

percentages (Table XII). Most of the snags found in all hosiery ranged from pricks up to 0.9 centimeters. As the size of snags increased, the number found in the hosiery decreased. Both fiber types show approximately the same pattern (Figure 5).

The average of 1.0 runs for each subject found in fiber A hosiery was compared with 1.2 runs for each subject in fiber B hosiery (Table X). When the number of days was also considered, there was no real difference in the performance of hosiery made of the two fibers as far as this type of fault was concerned. As the number of runs are directly related to the the number of days the hosiery can be worn, they are also a measure of durability.

Since the hosiery were discarded when one stocking of a pair developed a run, the number of runs in relation to the number of days worn was checked by an analysis of covariance (Appendix C-5). It was found that any variation in the number of runs was not due to the difference in the number of days worn but to variation introduced by the subjects. However, because of the time limit of 15 days placed on the wear test, the results are not conclusive. For a more accurate evaluation, it would have been desirable to continue the test until all hosiery were discarded.

Abrasion marks found in each fiber type of hosiery were counted and it was found that fiber A had an average of 1.0 abrasion mark for each subject as compared to 1.5 abrasion marks

Table XII

PERCENT OF SNAGS BY SIZE FOR GROUP II

Size / Fiber	Pricks	cm. 0.1-0.9	cm. 1.0-2.9	3 cm. over	Holes
A	23.6	65.0	10.4	2.1	0.002
B	30.3	58.4	8.2	1.1	2.000

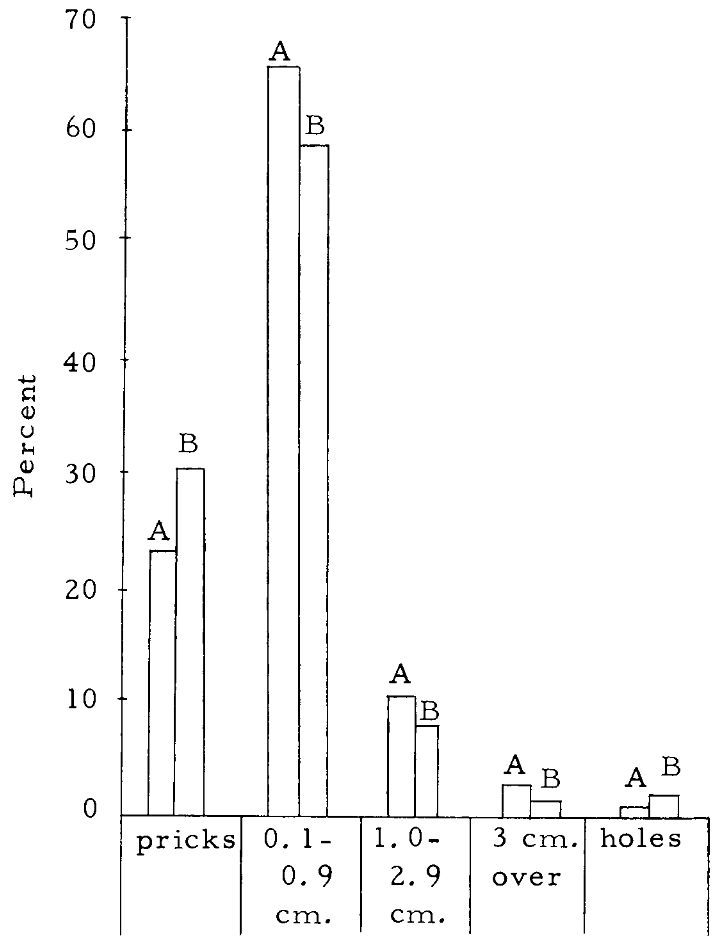

Figure 5

PERCENT OF SNAGS BY SIZE FOR GROUP II

for fiber B (Table X). This difference between the two fiber types of hosiery was not found to be significant (Appendix C-4).

Measurement of Stretching During Wear

Visual observation revealed a noticeable amount of stretching for the hosiery after a period of wear. For fiber A hosiery much of the stretch was recovered after washing; fiber B hosiery retained most of this stretch resulting in hosiery which was wider and shorter than fiber A hosiery at the end of the wear test. The differences in the widths and lengths of hosiery of the two fiber types are found in Table XIII. The figures in the table are expressions of eighths of an inch, thus, three inches becomes the figure 24. These transposed numbers are used in the following discussion, and will be termed units.

Table XIII

DIFFERENCES IN UNITS OF MEASUREMENT OF AREAS OF HOSIERY BEFORE AND AFTER THE WEAR TEST FOR GROUP II

	Fiber A			Fiber B		
	After	Before	Difference	After	Before	Difference
Width of						
Foot	24.3	21.7	2.6	32.4	26.7	5.7
Ankle	22.7	22.2	0.5	32.2	25.4	6.8
Calf	43.1	42.0	1.1	47.9	44.1	3.8
Thigh	56.1	56.0	0.1	60.9	55.3	5.6
Length of						
Foot	73.6	76.4	-2.8*	75.3	82.4	-7.1
Overall	253.3	259.5	-6.2	220.4	256.7	-6.3

*Negative signs indicate a decrease in length

The ankle and thigh areas showed the greatest contrast when the widths of hosiery made of the two fiber types were compared. The amount of stretch retained in the ankle area for fiber A hosiery was 0. 5 units as compared with 6. 8 units for fiber B hosiery. This means that fiber B hosiery retained seven-eighths of an inch stretch while fiber A hosiery retained only one-sixteenth inch stretch. The difference in the thigh areas was about as great, as 0. 1 units of stretch in fiber A hosiery were compared with 5. 6 units of stretch in fiber B hosiery. Thus, fiber A hosiery retained almost no stretch as compared to seven-eighth inch stretch in fiber B hosiery.

A decrease in the lengths of the foot areas was found to be -2. 8 units for fiber A hosiery as compared to -7. 1 units for fiber B hosiery which means that the foot area of fiber A hosiery decreased in length about three-eighths of an inch in contrast to a decrease in the length of foot area of fiber B of seven-eighths of an inch. There was little difference in the amount of decrease in overall length as the two fiber types of hosiery both decreased about six-eighths of an inch.

All hosiery tended to increase in width; however fiber B increased to a greater degree along the entire panel of the hosiery than did fiber A hosiery. Fiber B also showed a greater amount of shrinkage in the length of the foot. These conclusions were supported by visual observation. As the hosiery were examined on a flat surface after the completion of the wear test, it was noted that hosiery made of fiber B definitely retained the shape of the wearer's leg. This was most noticeable in the knee area where the greatest amount of strain occurred.

Laboratory Tests

Four laboratory tests were conducted to verify some of the results from the wear tests and to obtain further information about the hosiery used in the study. The results are discussed in this order: the stretch and recovery test, fading to laundry evaluation, the breaking strength and elongation of yarns, and a test of the bursting strengths of the knee and toe areas. Table II, page 14, lists the hosiery by number which were used in the laboratory tests.

The first test, evaluating the amount of stretch and recovery, included only new hosiery of both brands made of the two fibers, nylon and polypropylene. Worn hosiery were not used because information about the amount of permanent deformation due to stretching was obtained from the wear tests through measurements taken before and after wear. The terms fiber A and fiber B were used to designate nylon and polypropylene hosiery respectively; and Group I and Group II were used to designate the two brands used in the study.

The other three tests included both new and worn hosiery. The terms: new A, worn A, new B, worn B, were used to designate the new and worn hosiery made of nylon and polypropylene respectively. Again the brands were designated by Group I and Group II except for the fading to laundry test.

The worn hosiery included in the laundry test were samples drawn from the hosiery worn in the first wear test only. New hosiery made of the two fiber types found in Group I were washed under controlled conditions in the laboratory for a specified number of times.

Stretch and Recovery Test

The percent of stretch retained and the rate of recovery from the stretching process (Table XIV, Figure 6), varied as hosiery made of the two fibers were compared.

Fiber A hosiery in Group I retained only 16.3 percent stretch when measured immediately after the stretching process, while fiber B of the same brand retained 29.6 percent stretch. After each period of relaxation the percent stretch became less for both fiber types until, after being washed, fiber A hosiery retained three percent as compared to 16.7 percent stretch for fiber B hosiery. These figures clearly indicated that under the same laboratory conditions and treatment, fiber A hosiery had more resiliency than did fiber B hosiery. This result substantiates the findings of the wear tests which demonstrated that there was more permanent deformation

TABLE XIV

MEASUREMENTS OF THE PROPERTY OF STRETCH AT DIFFERENT INTERVALS OF RELAXATION

	FIBER A				FIBER B			
	First measure	15 min. period	4 hour period	After washing	First measure	15 min. period	4 hour period	After washing
Group I								
Stretch in inches	0.44	0.30	0.24	0.08	0.80	0.64	0.50	0.45
Percent stretch	16.3	11.0	8.9	3.0	29.6	23.7	18.5	16.7
Percent difference*		5.2	2.2	5.9		5.9	5.2	1.8
Group II								
Stretch in inches	0.47	0.27	0.24	0.04	0.75	0.60	0.50	0.45
Percent stretch	17.4	10.0	8.9	1.5	27.8	22.2	18.5	16.7
Percent difference*		7.4	1.1	7.4		5.6	3.7	1.8

*Percent difference - the difference in percent between intervals showing rate recovery

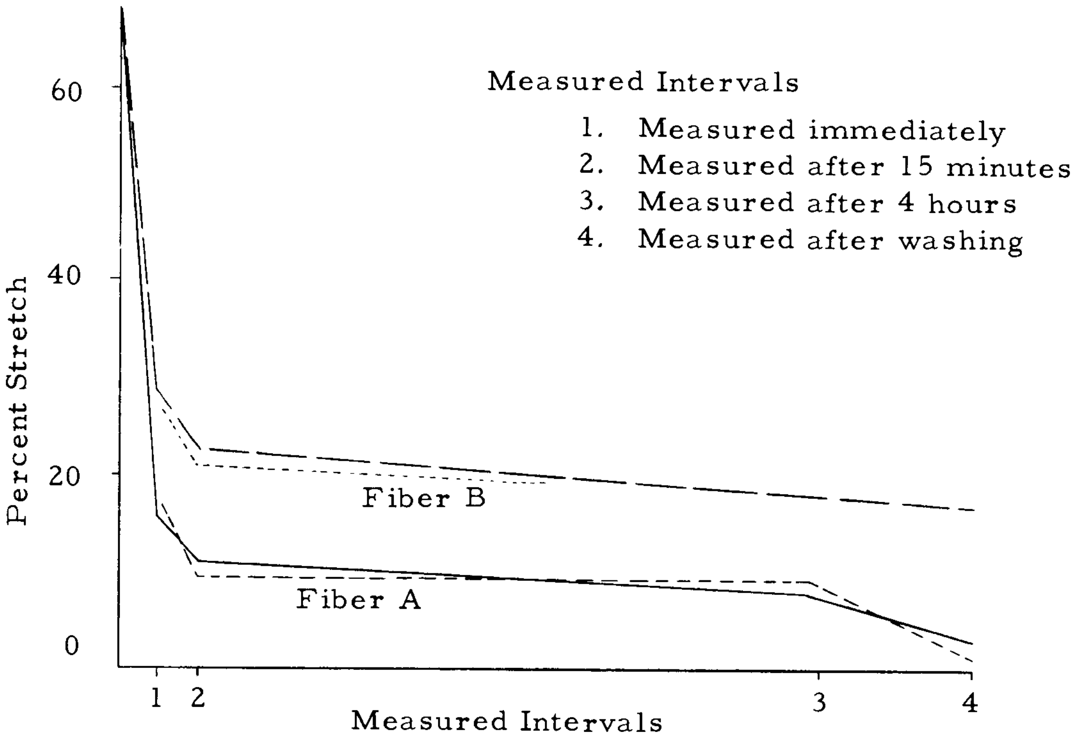

Figure 6

PERCENT OF STRETCH MEASURED AT DIFFERENT INTERVALS OF TIME when hosiery made of fiber B were worn than was the case when hosiery of fiber A were worn. The same results were found to be true when Group II hosiery were tested even though there were minor variations in the figures as shown in Table XIV.

Figure 6 graphically plots the rate of recovery based on time intervals. The first measurement was made immediately after the hosiery fabrics were released from the machine; the fabrics were allowed to relax for 15 minutes after which a second measurement was taken. A four-hour time period under standard laboratory conditions allowed a longer period which showed continued recovery. The last time period of about one hour after the hosiery had been washed, as plotted on the graph, showed a combination of the effects of additional time plus the relaxing effects of washing.

During the first relaxation period of 15 minutes fiber A hosiery recovered 5.2 percent of the stretch as compared to 5.9 percent recovery by fiber B hosiery. The rate was then reduced for fiber A hosiery as there was only a 2.2 percent recovery over the four-hour period. The rate was also reduced for fiber B hosiery but not as greatly as shown by the 5.2 percent recovery over the four-hour period. After a one-hour period following the washing process, the rate of recovery increased for fiber A as an additional 5.9 percent of the stretch was recovered. The rate for fiber B hosiery, however, over this same time period and after washing, remained about the same as shown by the 1.8 percent recovery after the one-hour period. Figure 6 shows graphically the rates of recovery by taking into consideration the different lengths of the time intervals.

For both fiber types, the recovery rate was rapid at first, then declined over a period of four hours with fiber B maintaining a faster rate of recovery than fiber A hosiery. After washing, however, fiber B hosiery continued at about the same rate of recovery over a one-hour period while the rate increased sharply for fiber A hosiery. This indicates that during the washing process, fiber A hosiery relaxed and recovered almost all original stretch while little effect from washing was noted for fiber B hosiery. About the same results were noted for the hosiery in Group II. The dotted lines for each fiber type of hosiery on Figure 6 represent the rates of recovery for hosiery in Group II. As can be noted from the graph, there was very little variation from the results of Group I.

The amount of stretch retained by the hosiery after the washing process was assumed to show permanent deformation even though some additional recovery could have occurred if they had been allowed to rest over a longer period of time. Fiber A hosiery in Group I retained three percent stretch as compared to 16.7 percent for fiber B. In Group II, fiber A retained 1.5 percent stretch as compared to 16.7 percent for fiber B hosiery. These differences in the percentages of stretch retained were found to be statistically significant (Appendix C-4). These are illustrated in Figure 6 by noting the distances between the trend lines.

Fading to Laundry

As part of the procedure of the previous test, hosiery of both fiber types were soaked in distilled water for one-half hour and allowed to line-dry. By visual observation it was noted that there were different degrees of fading and some changes in hue in the group of fiber B hosiery. By contrast, there was no visible fading in the group of fiber A hosiery. The main objective of the laundry test was to determine the relationship between the number of times the hosiery were washed and the amount of fading.

Hosiery placed in four categories, new A, worn A, new B, and worn B, were analyzed to find the relationship between the number of times washed and the degree of fading as ranked by a panel of judges. The worn hosiery were washed from two to 19 times during the wear test. New hosiery of both fiber types were washed the same number of times in the laboratory to serve as control groups. It was found that for all four groups the amount of fading varied from the expected amount based on the number of times washed (Table XV).

A further analysis was made to determine whether or not there was a linear relationship between the ranks assigned by the

Table XV

SIGNIFICANT DIFFERENCES OF MEAN RANKS OF THE EFFECTS OF REPEATED WASHINGS ON THE AMOUNT OF FADING

Source of variation	Degree of Fading		A - New		A - Worn		B - New		B - Worn	
			Mean Square	F ratio	Mean Square	F ratio	Mean Square	F ratio	Mean Square	F ratio
Judges	3		0	--	0	--	0	--	0	--
Washings	11		2.13	4.70**	1.84	3.20**	2.49	7.35**	2.50	7.56**
Linear Reg. on Rank		1	2.98	6.58**	0.09	1.51	0.35	1.02	0.10	0.30
Deviation from L. Reg.		10	2.04	4.52**	2.02	3.51**	2.71	7.99**	2.74	8.28**
Error	33		0.45	--	0.58	--	0.34	--	0.33	--

** F ratio is significant to the 0.01 level judges as to the amount of fading and the number of times the hosiery were washed. Only one group, new A hosiery, showed such a relationship; however, the amount of deviation from this linear regression was more than could be expected. The other three groups proved to be non-linear and showed significant amounts of deviation from the expected relationship. It was concluded that there was little or no relationship between the amount of fading and the number of times the hosiery were washed. The results are graphically pictured in Figure 7. Diagram number 1 represents what could be expected if the amount of fading were dependent entirely upon the number of times the hosiery were washed. The ranks assigned to this diagram are in the same order as the number of times the hosiery in each group were washed. The trend line is linear with very little variation.

The other four diagrams illustrate for each hosiery group, the relationship of the degree of fading to the number of times the hosiery were washed (Figure 7). The ranks are average ranks given by the panel of judges. None of the groups, with the exception of new A hosiery, show a diagram with a trend line; and even diagram 2, new A, showed more deviation than would be expected if there were a relationship between fading and the number of times washed.

Yarn Breaking Strength and Elongation

Yarn samples from four categories of hosiery: worn A, new A, worn B, and new B, were tested for breaking strength expressed in grams, and percent elongation at break.

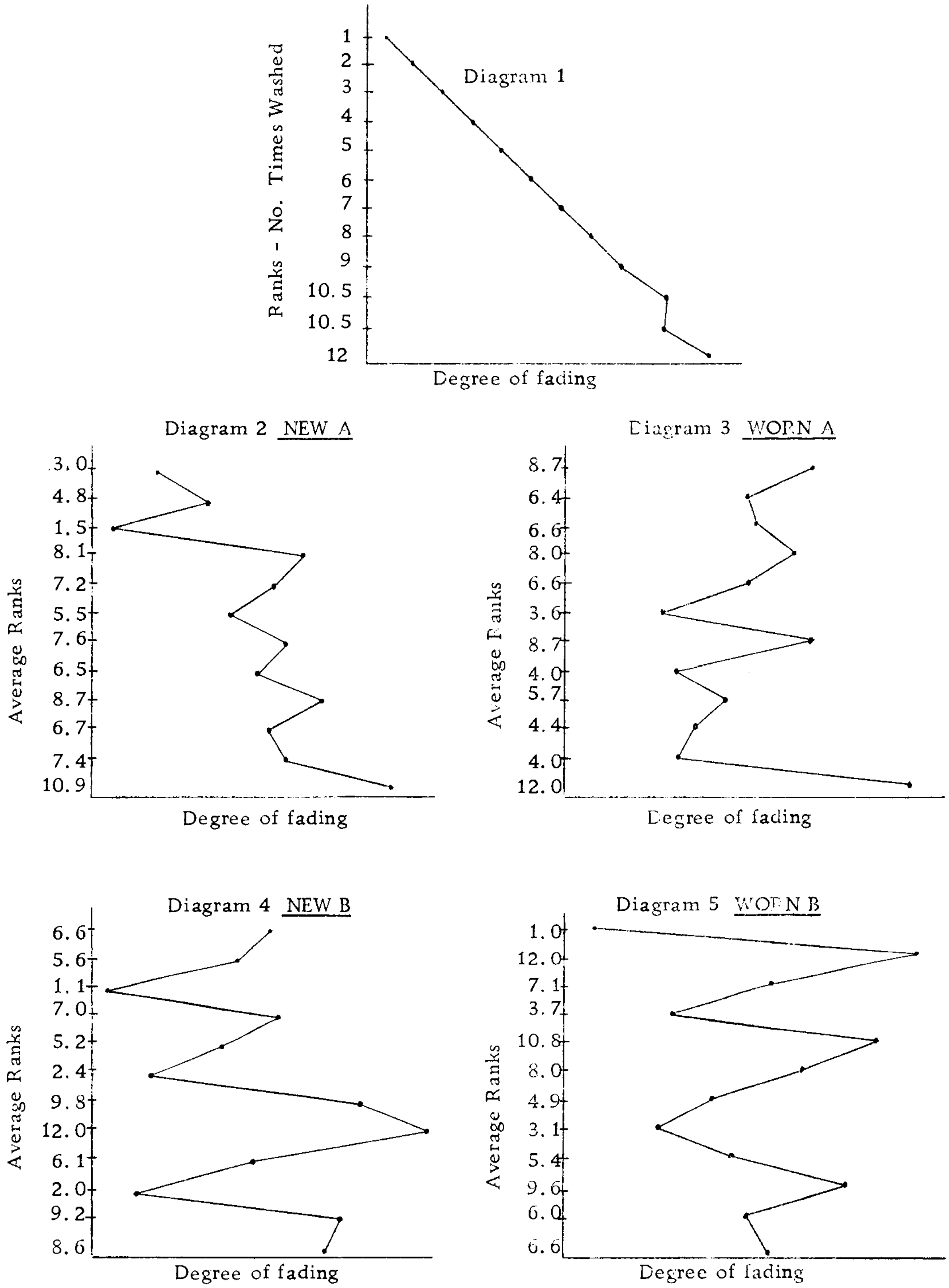

Figure 7

EFFECTS OF REPEATED WASHINGS ON THE AMOUNT OF FADING

A significant difference was found between the mean breaking strengths as fiber A and B yarns in both Group I and II were compared, which indicated that fiber A yarns were the stronger. When the means of the worn yarns of both fiber types were each compared to the means of new yarns of the same fiber type, no significant differences were found, with one exception. The mean breaking strength of yarns made of new fiber A was significantly stronger than that of worn fiber A, in Group II (Table XVI, Table XVII).

When the means of the percent elongation of yarns made of fiber A and fiber B were compared, the percent elongation of fiber A was found to be significantly greater than that of fiber B, with one exception. There was no significant difference between the means when worn fiber A and worn fiber B in Group II were compared. When yarns of worn hosiery were compared to yarns of new hosiery of the same fiber types, new fiber B yarns were found to have a significantly higher percent elongation than did worn fiber B yarns. However, there were no significant differences when the new and worn yarns of fiber A were compared (Table XVI, Table XVII).

Thus, yarns made of fiber A were stronger than those made of fiber B and fiber A yarns had a greater percent elongation than did fiber B yarns with the exception of worn fiber A and worn fiber B yarns in Group II. Wear did not affect the strength of yarns of either fiber type with the exception of fiber A in Group II where new fiber A yarns were found to be stronger than worn fiber A yarns. Also, wear did not affect the percent elongation when new and worn yarns made of fiber A were compared. However, the yarns of worn fiber B were found to have a lower average percent elongation than did new fiber B yarns.

Table XVI

MEANS AND STANDARD DEVIATIONS OF BREAKING STRENGTH AND ELONGATION OF YARNS

Hosiery Groups	Breaking Strength Grams	Breaking Strength S. D.	Percent Elongation Grams	Percent Elongation S. D.
Group I				
Worn A	88.64	3.5	34.5	3.0
New A	87.33	3.3	34.0	3.0
New B	82.70	5.6	27.8	2.4
Worn B	80.87	9.0	24.1	3.2
Group II				
New A	92.38	4.1	39.1	1.5
Worn A	85.07	2.5	34.8	2.1
New B	82.92	5.1	32.6	1.5
Worn B	77.07	5.0	30.9	1.9

Note: bars indicate no significant differences

Table XVII

SIGNIFICANT MEAN DIFFERENCES IN BREAKING STRENGTH AND ELONGATION OF YARNS

Hosiery Groups	Breaking Strength Difference of Means Grams	Breaking Strength t-values	Elongation Difference of Means Grams	Elongation t-values
Group I				
Worn A - Worn B	7.77	2.79**	10.4	8.39**
Worn A - New A	1.31	0.94	0.5	0.41
Worn B - New B	-1.83	0.60	-3.7	3.31**
New A - New B	4.63	2.49*	6.2	5.60**
Group II				
Worn A - Worn B	8.00	2.84*	1.7	1.41
Worn A - New A	-7.31	3.02*	02.2	1.83
Worn B - New B	-5.85	1.64	-8.2	6.76**
New A - New B	9.46	2.90*	4.3	3.29*

* Significant to the 0.05 level
** Significant to the 0.01 level

The typical stress-strain curves in Figure 8 show an average amount of variation as fiber B is compared to fiber A. The rate of elongation for fiber A, as shown by the unbroken line, is greater during about the first half of the curve giving a more concave or S shaped curve. This indicates that there was a greater amount of stretch during the first part of the strain period. The rate of elongation for fiber B, as shown by the broken line, was more constant over the entire strain period. This produces a slightly convex curve.

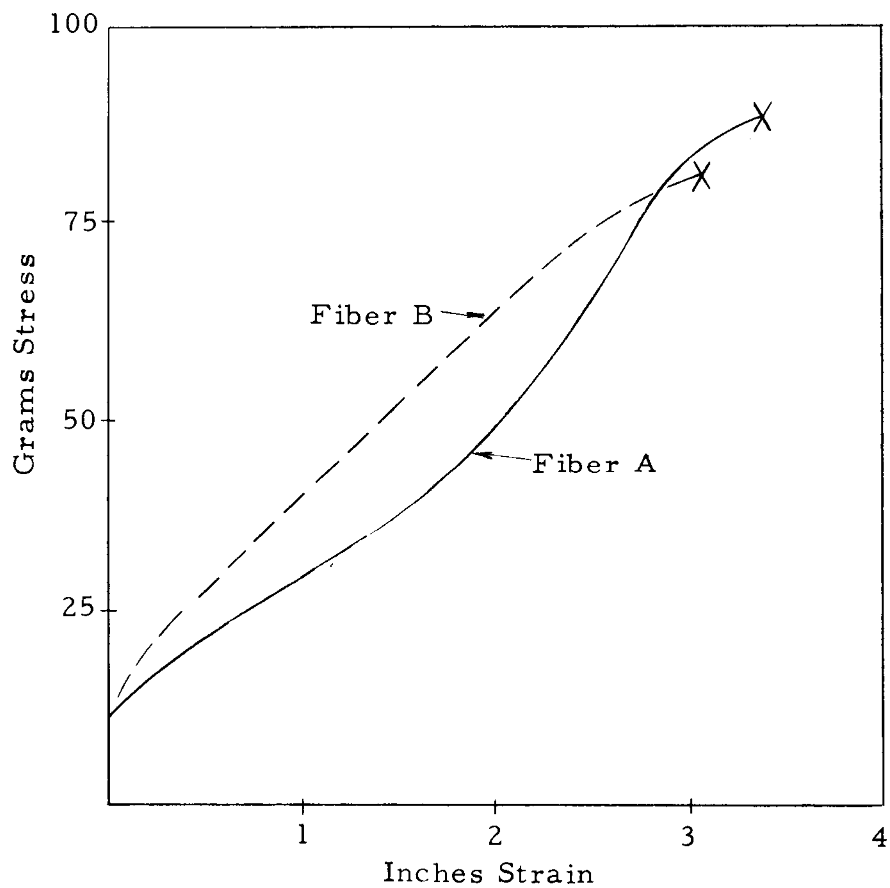

Figure 8

TYPICAL STRESS-STRAIN DIAGRAM FOR FIBERS A AND B YARNS

Bursting Strength of Hosiery

When the average number of pounds needed to burst the knee areas of hosiery in Group I were compared, it was found that neither the differences between fiber types nor the differences between new and worn hosiery were great enough to be significant. When the average bursting strengths of hosiery found in Group II were compared, the knee areas in fiber B hosiery were found to be stronger than those of fiber A. Again, there was no significant differences when worn hosiery were compared to new hosiery of the same fiber type (Table XVIII, Appendix C).

When the average number of pounds needed to burst the toe areas of hosiery in both Group I and II were compared, there were no significant differences between the fiber types. However, it was found that the toe areas in Group II made of new fiber B were stronger than those made of worn fiber B; otherwise, there were no significant differences as new and worn hosiery were compared (Table XIX).

The standard deviation values ranged from 7.2 pounds to 15.3 pounds for the bursting strength means of the toe areas in Group I and from 6.3 pounds to 15.5 pounds for the toe areas in Group II. The wide ranges indicate that there was too much variation in the results of the test of bursting strength in the toe areas to be reliable. Much of this variation was due to the difficulty in controlling the method of placing the toe areas into the machine. The rings used to hold the fabric firmly were designed to test only fabrics which could be placed on a flat surface (Table XVIII).

Table XVIII

MEANS AND STANDARD DEVIATIONS OF THE BURSTING STRENGTHS OF THE KNEE AND TOE AREAS OF THE HOSIERY

Hosiery Groups	Knee Areas		Hosiery Groups	Toe Areas	
	Pounds	S. D.		Pounds	S. D.
Group I					
Worn B	14. 1	0. 7	New B	31. 9	15. 3
New A	14. 0	0. 7	Worn B	31. 3	11. 4
Worn A	13. 8	1. 4	Worn A	26. 0	7. 2
New B	13. 4	2. 0	New A	23. 8	9. 1
Group II					
Worn B	15. 2	3. 8	New B	62. 5	13. 0
New B	14. 8	2. 8	New A	44. 9	6. 3
Worn A	10. 4	2. 4	Worn B	44. 8	13. 9
New A	8. 8	1. 6	Worn A	39. 6	15. 5

Note: bars indicate no significant difference

Table XIX

SIGNIFICANT MEAN DIFFERENCES OF THE BURSTING STRENGTHS OF THE KNEE AND TOE AREAS

Hosiery Groups	Bursting Strength - Knees Difference of Means Pounds	Bursting Strength - Knees Difference of Means t-values	Bursting Strength - Toes Difference of Means Pounds	Bursting Strength - Toes Difference of Means t-values
Group I				
Worn A - Worn B	-0.3	0.96	5.3	1.36
Worn A - New A	-0.2	0.95	2.2	0.66
Worn B - New B	0.7	1.60	-0.6	0.11
New A - New B	0.6	1.36	-8.1	1.57
Group II				
Worn A - Worn B	-4.9	3.12**	-5.1	0.49
Worn A - New A	1.6	1.47	-5.3	0.63
Worn B - New B	0.4	0.30	-17.8	2.43*
New A - New B	-6.0	5.20**	-17.6	1.86

* Significant to the 0.05 level
** Significant to the 0.01 level

SUMMARY AND CONCLUSIONS

Since modern technology in the field of textiles has produced fibers and fabrics of such a wide variety of properties and uses, it has become necessary to do continuous research into consumer use and acceptance of new textiles. The aim of this study was to compare the performance of hosiery made from a new fiber, polypropylene, with the performance of hosiery made from a better known fiber, nylon. The comparison between hosiery of the two fiber types was made by evaluating the results of two wear tests using hosiery of two different brands, each containing matched pairs of hosiery, one of each fiber type, and by evaluating the results of selected laboratory tests.

The 36 subjects who participated were moderately active, wore shoes of a closed heel and toe style with one to two inch heels. The majority preferred hosiery of a seamless construction and of medium weight similar to the test hosiery. The test hosiery was acceptable to the majority who reported that the hosiery fit them well. Even though the nylon hosiery used in the wear tests were preferred over the polypropylene hosiery, there was some indication that there could be a more limited market for the latter.

There was some agreement to the use of such adjectives as silky, soft, smooth, pliable, and elastic to describe the nylon hosiery used in the wear test but only for one word, springy, was there enough agreement so that it could be used to describe polypropylene hosiery. This would indicate that the hand of the polypropylene hosiery is harder to evaluate than is the hand of nylon hosiery, as very few subjects found the hand of polypropylene unpleasant. Most indicated that such words as boardy, hard, oily, sticky, cold, moist, limp, dry, stiff, or tight could not be used to describe either fiber type of hosiery.

The findings of the second wear test, using a different brand of hosiery with both fiber types represented, were not compared to the findings of the first wear test. A difference in the number of subjects and a difference in the time of year the tests were conducted introduced too many variables to make any comparisons reliable. Differences in the performance of the hosiery may have been due to actual differences between the two brands or they may have been due to other unknown variables.

During the first wear test using one brand of hosiery with both fiber types of hosiery represented, the nylon hosiery proved to be more durable. After a five-day check, even though polypropylene hosiery contained half as many snags, they also contained twice as many runs. This trend continued until, at the end of the test period, even though two and one-half times as many total faults were found in the nylon hosiery, they were worn one and one-half times longer than the polypropylene hosiery. The polypropylene hosiery were much more resistant to snagging than were the nylon hosiery but could not be worn as many days because runs occurred oftener.

During the second wear test polypropylene hosiery were worn a lesser number of days than were the nylon hosiery. This difference was due to the difference in the treatment given by the subjects and not due to the difference between the two fiber types. This was also shown in the trend, noted at the end of the initial five-day wear period, when there was little difference in the number of runs. During this check, three times as many faults were found in the nylon hosiery as were found in the polypropylene hosiery. Again this trend continued so that at the end of the wear test the nylon hosiery contained four times as many faults as did the polypropylene hosiery. An increase in the length of the wear period might have made possible more conclusive results in the comparison of the two fiber types as to durability.

In advising consumers of the durability of polypropylene hosiery as compared to nylon hosiery, the results were not conclusive enough to either encourage or discourage purchase. The individuality of consumers, the differences between brands, the conditions of wear, and other variables influence durability to an undetermined degree not investigated in this study.

The most common reasons given by the subjects for the occurrence of faults in hosiery were furniture roughness and the strain from kneeling or bending. The shin and calf areas were felt to be the most vulnerable. This was borne out in part by the results of the tally according to the areas where the faults were found. Most faults occurred in the panel of the hosiery with a greater number found in the knee, calf, and ankle areas.

The total number of faults were broken down into the number of snags, runs, and abrasion marks. It was found that most snags were under 0.9 centimeters long. Some of these small snags in the polypropylene hosiery were found to have a characteristic round shape which was rarely observed in the nylon hosiery. The analysis of runs and abrasion marks revealed that with an increase in the number of days worn, no corresponding increase could be expected in the number of runs and abrasion marks. In relation to the numbers of runs and abrasion marks there were no real differences in the performance of the hosiery when the two fiber types were compared; the difference was due to the differences in treatment given by the subjects.

Although all hosiery tended to increase in width and decrease in length, polypropylene hosiery had a greater tendency to show permanent stretch in width with a corresponding decrease in length.

In Group I hosiery, nylon hosiery retained an average of from one-eighth inch to two-eighths inch stretch in the ankle and thigh areas as compared to five-eighths inch stretch in the polypropylene hosiery. A corresponding decrease in the average length of hosiery in the same group was one-eighth inch for nylon hosiery compared to almost one inch for polypropylene hosiery. For the hosiery in Group II, in all four areas measured for width, polypropylene hosiery retained at least three-eighths inch more stretch than did the nylon hosiery. The difference was even greater when the ankle and thigh areas of each fiber type were compared. A corresponding decrease was found in the length of the foot where the average length decreased about four-eighths inch more in the polypropylene hosiery than in the nylon hosiery. There was little difference in the amount of decrease in the overall lengths.

Under controlled conditions in the laboratory the rate of recovery and the percent of stretch retained after the stretching process, varied as the two types of hosiery were compared. The rate of recovery was rapid at first, then declined over the period of four hours with polypropylene hosiery maintaining a faster rate of recovery. Washing did not affect the rate of recovery for polypropylene hosiery but did increase the rate for nylon hosiery until almost all the stretch was recovered.

Nylon hosiery proved to be more resilient than was polypropylene hosiery as shown by the high percent recovery at the end of the stretch test, as compared to the much lower percent recovery from the stretching process shown by the polypropylene hosiery.

As shown by the results of both the wear tests and the laboratory stretch test, the customer can expect polypropylene hosiery to stretch out of shape and become looser with wear. Whether the amount of stretch would cause undesirable bagging or loss of proper fit would depend upon the individual concerned and the conditions of wear.

It was found that there was little or no relationship between the number of times the hosiery were washed and the degree of fading. This was true not only for hosiery washed by the subjects during the first wear test but also was true for new hosiery washed under controlled laboratory conditions. Only hosiery in the new nylon group demonstrated a linear trend line and even for this group, deviation from the trend line was greater than was expected. The amount of fading was dependent upon other unknown factors as well as upon the kind of care given to them. As the shade became lighter the hosiery was still acceptable to the subjects. The practice which is common to many hosiery wearers of salvaging one stocking of a pair to be matched later with another stocking would not be practical. Other than this, the fading is not an important enough fault to make consumers wary of buying the hosiery.

Yarns from the new nylon hosiery were stronger than yarns from either new or worn polypropylene hosiery. However, wear did not affect the strength as new and worn yarns from each respective fiber were compared. The one exception was that new nylon yarns were stronger when compared with worn nylon yarns taken from hosiery in the second brand tested.

The percent elongation before break was found to be greater for nylon yarns than for polypropylene yarns. The one exception was in the comparison of worn nylon yarns to worn polypropylene yarns obtained from hosiery in Group II; there was little difference in the percent elongation at break. When the new and worn yarns were compared from hosiery made of the same fiber, wear was found to affect the polypropylene yarns by decreasing the percent elongation, but did not affect the percent elongation of yarns taken from nylon hosiery.

The yarns from the nylon hosiery had a greater percent elongation and were stronger than were the yarns from the polypropylene hosiery. Wear may affect the strength of the nylon yarns to some extent but not the strength of the polypropylene yarns. Wear decreases the percent elongation at break of yarns from the polypropylene hosiery but not the percent elongation at break of nylon yarns.

The typical stress-strain curve for nylon yarns was concave or S-shaped due to a faster rate of elongation during the first part of the stress period. The rate of elongation for polypropylene yarns is more constant resulting in a convex curve.

As the bursting strengths of the knee areas were analyzed, it was found that there were no significant differences between either the new and worn hosiery nor the two fiber types. The one exception was found as nylon and polypropylene hosiery from Group II were compared. In this brand of hosiery, polypropylene hosiery was found to resist bursting with the steel ball better than did the nylon hosiery.

The results of the test of bursting strengths of the toe areas were not reliable due to excessive variation among individual samples measured. The method of placing the samples in the bursting strength machine was not effective nor could it be duplicated for each sample because of the curved shape of the toe areas.

Information gained from this study is limited in its application to statements concerning the two brands of hosiery used, hosiery of a seamless construction, and the type of subjects who wore the hosiery. Further study of hosiery which would include other brands, other types of construction, or a different type of population would be advantageous.

Research is also needed to perfect laboratory testing techniques and equipment which could be used to evaluate hosiery. The techniques should be correlated to the results from performance tests of actual wear on a large population. In this way the cost of evaluating new types of hosiery would be lessened in both time and money. Additional information and research about hosiery found on the market is needed in order to help the consumer with this phase of her clothing buying problems.

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APPENDICES

Appendix A

Questionnaire I

A-1 Questionnaire I Number____

1. What is your occupation?

2. Check kinds and amounts of activities you usually have in a day.

Activity	Most of a day	About half day	Only at times
Sitting at rest			
Walking			
Kneeling - bending			

3. Put only one ✓ for the most common reason for stocking wear for you.

   Put only one circle O for the least common reason for stocking wear for you.

   ___Furniture roughness ___Snag when washing hosiery

   ___Rough toe nails ___Shoe rubbing or cutting

   ___Rough hands or finger nails ___Strain - bending or kneeling

   ___Snag when dressing ___Garter strain

   ___Other____________________

4. Check the area which usually wears out first. Check only one.

   ___Foot ___Shin and Calf ___Thigh and welt

   ___Ankle ___Knee ___Other

5. How do you shop for hosiery? Mark each method

Method	Most of the time	Usually	Seldom	Almost never
Buy by brand name				
Buy by cost				
Buy by brand and cost				
Buy at certain stores				
Buy at any convenient store				

Appendix A-1 (Cont'd) Page 2

6. What type of shoes do you wear?

Type	Almost always	Most of the time	About half	Seldom	Rarely or never
Flats					
1" - 2" heel					
Higher heel					
Closed toe and heel					
Open toe only					
Open heel only					
Heel and toe open					

7. What are the customary types of hosiery you buy for yourself?

Type	Most of the time	About half	Seldom	Almost never
Heavy (Service Weight)				
Day time sheer				
Dressy sheer				
Seamless				
With seams				
Stretch				
Run resistant				

8. Give the hosiery size you most prefer __________.

9. Which length hosiery do you prefer:___short;___medium;___long.

Table A-2

TYPES OF DAILY ACTIVITIES OF SUBJECTS

Type of Activity	Group I N*	Group I Percent Mostly	Group I Percent Half	Group I Percent At times	Group II N*	Group II Percent Mostly	Group II Percent Half	Group II Percent At times
Sitting at rest	24	3.4	3.3	93.3	8	0	12.5	87.5
Sitting at work	28	39.3	48.3	12.2	10	20.0	70.0	10.0
Walking	29	6.9	48.3	44.8	10	0	70.0	30.0
Kneeling or bending	26	0	7.7	92.3	10	0	0	100.0

N* Number responding

Table A-3

PERCENT SUBJECTS WEARING TYPES OF SHOES

Group I								
	Number -	22	27	23	28	22	23	24
	Shoe type	Flats	1" to 2" Heel	High Heel	Closed Heel & Toe	Open Toe	Open Heel	Heel & Toe Open
Almost always		27.3	29.6	0	75.0	0	0	0
Most of the time		9.1	25.9	8.7	14.3	0	0	4.2
Half the time		22.7	11.1	21.7	3.6	0	0	4.2
Seldom		31.8	22.2	30.4	3.6	9.1	21.7	20.8
Almost never		9.1	11.1	39.2	3.5	90.9	78.3	70.8
Group II	Number -	8	10	8	8	7	7	7
Almost always		0	30.0	0	87.5	0	0	0
Most of the time		25.0	30.0	0	12.5	0	0	0
Half of the time		37.5	30.0	0	0	0	0	0
Seldom		12.5	0	50.0	0	28.6	14.3	28.6
Almost never		25.0	10.0	50.0	0	71.4	85.7	71.4

Table A-4

PERCENT SUBJECTS WEARING TYPES OF HOSIERY

		WEIGHT			CONSTRUCTION		
Group I N -	25	24	24	26	25	24	24
Hosiery Types	Service Weight	Daytime Sheer	Dress Sheer	Seamless	With Seams	Stretch	Run Resistant
Most of time	16.0	44.0	16.7	80.0	8.0	25.0	12.5
Half of time	0	24.0	20.8	11.5	8.0	4.2	16.7
Seldom	12.0	12.0	45.8	0	36.0	12.5	29.2
Almost never	72.0	20.0	16.7	7.7	48.0	58.3	41.6
Group II N -	8	9	7	7	8	7	8
Most of time	0	55.6	14.2	85.7	25.0	14.2	25.0
Half of time	0	22.2	28.6	14.3	12.5	0	12.5
Seldom	37.5	22.2	57.2	0	37.5	28.6	12.5
Almost never	62.5	0	0	0	25.0	57.2	50.0

Table A-5

METHOD OF BUYING HOSIERY BY PERCENT OF SUBJECTS

Group I N*-	28	27	24	27	27
Buy by	Brand name	Cost	Brand & Cost	Known stores	Any store
Most of the time	42.8	23.3	25.0	33.3	11.1
Usually	32.1	33.3	45.8	33.3	11.1
Seldom	7.2	23.3	12.5	23.3	20.1
Almost never	17.9	20.1	16.7	10.1	57.7
Group II N -	10	10	10	10	10
Most of the time	20.0	20.0	30.0	60.0	0
Usually	20.0	50.0	50.0	20.0	10.0
Seldom	10.0	10.0	20.0	20.0	20.0
Almost never	50.0	20.0	0	0	70.0

N* - number responding to question

Table A-6

SIZE AND LENGTH OF HOSIERY WORN BY SUBJECTS

	Percent	
Size	Group I	Group II
$8\frac{1}{2}$	7.4	0
9	25.9	10.0
10	29.7	30.0
$10\frac{1}{2}$	11.0	20.0
11	3.7	10.0
Length		
Short	14.8	0
Medium	81.5	70.0
Long	3.7	30.0

Table A-7

OPINIONS OF SUBJECTS AS TO HOSIERY AREAS MOST AFFECTED BY WEAR

	Percent	
Area	Group I	Group II
Foot	17.2	30.0
Ankle	3.5	0
Shin & Calf	48.3	60.0
Knee	20.7	10.0
Thigh	10.3	0
Other	0	0

Table A-8

	Group I N-28 Percent		Group II N-10 Percent	
Reasons for Faults	Most	Least	Most	Least
Furniture roughness	32.1	0	40.0	0
Rough toe nails	0	3.6	0	0
Rough hands or finger nails	7.1	0	10.0	0
While dressing	3.6	0	0	0
While washing	0	42.7	0	44.4
Shoe rubbing	14.4	14.4	10.0	33.3
Strain - kneel or bent	32.1	14.3	30.0	0
Garter strain	0	25.0	0	33.3
Other	10.7	0	10.0	0

Appendix B

Questionnaire II

B-1 Questionnaire I

CHART I

The rating scales below will help you judge how well your hosiery fits you. Each question has five circles which mark the steps between the two extremes. The center circle in each one marks a good fit. Place a check in the circle which most nearly tells how the hosiery fits you. One chart is for Hosiery "A", the other for Hosiery "B".

HOSIERY "A"-Rate only the pair marked "A" on this chart.

Leg is too long / Leg is too short
O____O____O____O____O

Foot is too long / Foot is too short
O____O____O____O____O

Tight around ankle / Loose around ankle
O____O____O____O____O

Tight around calf / Bags at calf
O____O____O____O____O

Tight around thigh / Loose around thigh
O____O____O____O____O

HOSIERY "B" - Rate only the pair marked "B" on this chart.

Leg is too long / Leg is too short
O____O____O____O____O

Foot is too long / Foot is too short
O____O____O____O____O

Tight around ankle / Loose around ankle
O____O____O____O____O

Tight around calf / Bags at calf
O____O____O____O____O

Tight around thigh / Loose around thigh
O____O____O____O____O

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CHART II

The words listed below are often used to describe how fabrics "feel". Consider each word and place a check in the proper column to indicate whether or not you would use that word to describe the hosiery.

TOUCH OR SQUEEZE THE HOSIERY WITH YOUR HANDS.

	"A"	"B"	NEITHER	BOTH		"A"	"B"	NEITHER	BOTH
silky					wiry				
waxy					crisp				
soft					springy				
boardy					hard				
smooth					oily				

AS YOU WEAR THE HOSIERY HOW DOES IT FEEL?

	"A"	"B"	NEITHER	BOTH		"A"	"B"	NEITHER	BOTH
soft					firm				
pliable					tight				
loose					elastic				
sticky					moist				
dry					limp				
cold					stiff				

1. Are there any other words you would use to describe HOSIERY "A"?

2. Are there any other words you would use to describe HOSIERY "B"?

COMMENTS:

Page 3

CHART III

Draw a circle around YES or NO to indicate the best answers. This is to find out if you would buy either fiber "A" or fiber "B" if they were available in the local stores.

HOSIERY "A": I would buy hosiery with fiber "A" if:

YES NO -the hosiery were of the same style as worn in the test.

YES NO -if they were not seamless.

YES NO -if they were a better color than the ones in the test.

YES NO -if they came in a heavier weight.

YES NO -if they came in a more sheer weight.

YES NO -if the hosiery fit the way I prefer.

YES NO -if they were the same style, fit as well, and if the color was as good as hosiery I now prefer--I would buy hosiery made of fiber "A".

HOSIERY "B": I would buy hosiery with fiber "B" if:

YES NO -if the hosiery were of the same style as worn in the test.

YES NO -if they were not seamless.

YES NO -if they were a better color than the ones in the test.

YES NO -if they came in a heavier weight.

YES NO -if they came in a more sheer weight.

YES NO -if the hosiery fit the way I prefer.

YES NO -if they were the same style, fit as well, and if the color was as good as hosiery I now prefer--I would buy hosiery made of fiber "B".

Table B-2
ANALYSIS OF SUBJECTS' OPINIONS OF HOW WELL THE HOSIERY FIT

	SCALE	Too long or tight 1	2	<—— Normal ——> 3	4	Too short or loose 5
				Percent		
Group I						
Fiber A -	Area					
	Leg	3.7	11.1	48.2	22.2	14.8
	Foot	0	0	81.5	11.1	7.4
	Ankle	3.7	7.4	77.8	11.1	0
	Calf	0	3.7	85.2	3.7	7.4
	Thigh	3.7	33.3	63.0	0	0
Fiber B						
	Leg	0	14.8	51.8	18.6	14.8
	Foot	3.7	3.7	85.2	3.7	3.7
	Ankle	0	7.4	51.8	18.6	22.2
	Calf	0	3.7	74.1	18.5	3.7
	Thigh	0	22.2	63.0	11.1	3.7
Group II						
Fiber A	Leg	0	20.0	70.0	10.0	0
	Foot	0	0	80.0	20.0	0
	Ankle	0	0	60.0	30.0	10.0
	Calf	0	0	80.0	20.0	0
	Thigh	0	10.0	90.0	0	0
Fiber B						
	Leg	10.0	20.0	70.0	0	0
	Foot	0	0	80.0	0	20.0
	Ankle	0	0	50.0	40.0	10.0
	Calf	0	0	60.0	40.0	0
	Thigh	0	0	80.0	10.0	10.0

Table B-3

ANALYSIS OF SUBJECTS' OPINIONS AS TO THE HAND OF THE HOSIERY

Type of Touch	Group I				Group II			
Adjectives	A	B	Neither	Both	A	B	Neither	Both
Feels to Hands								
silky	95.0	26.0	11.0	26.0	70.0	10.0	20.0	0
waxy	11.0	26.0	63.0	0	20.0	40.0	40.0	0
soft	95.0	48.0	7.0	40.0	80.0	30.0	20.0	30.0
boardy	0	18.0	81.0	0	0	20.0	80.0	0
smooth	89.0	48.0	7.0	48.0	100.0	60.0	0	60.0
wiry	3.0	48.0	48.0	3.0	10.0	40.0	40.0	0
crisp	11.0	44.0	52.0	3.0	10.0	70.0	20.0	0
springy	40.0	48.0	22.0	15.0	20.0	100.0	10.0	20.0
hard	0	22.0	75.0	0	0	40.0	50.0	0
oily	11.0	11.0	77.0	0	10.0	20.0	70.0	0
Feels as worn								
soft	70.0	33.0	26.0	26.0	70.0	70.0	10.0	50.0
pliable	77.0	40.0	18.0	33.0	90.0	70.0	0	80.0
loose	15.0	37.0	52.0	7.0	20.0	40.0	60.0	20.0
sticky	3.0	7.0	89.0	0	0	0	100.0	0
dry	15.0	26.0	67.0	7.0	10.0	10.0	80.0	20.0
cold	11.0	7.0	81.0	3.0	0	0	100.0	0
firm	60.0	63.0	15.0	33.0	50.0	60.0	30.0	40.0
tight	30.0	30.0	63.0	18.0	10.0	10.0	80.0	0
elastic	74.0	30.0	26.0	30.0	80.0	50.0	0	40.0
moist	0	3.0	96.0	0	0	0	100.0	0
limp	11.0	18.0	78.0	11.0	30.0	10.0	50.0	10.0
stiff	0	26.0	75.0	0	0	30.0	70.0	0

Table B-4
CONSUMER ACCEPTANCE OF SIMILAR HOSIERY FOUND ON FUTURE MARKETS

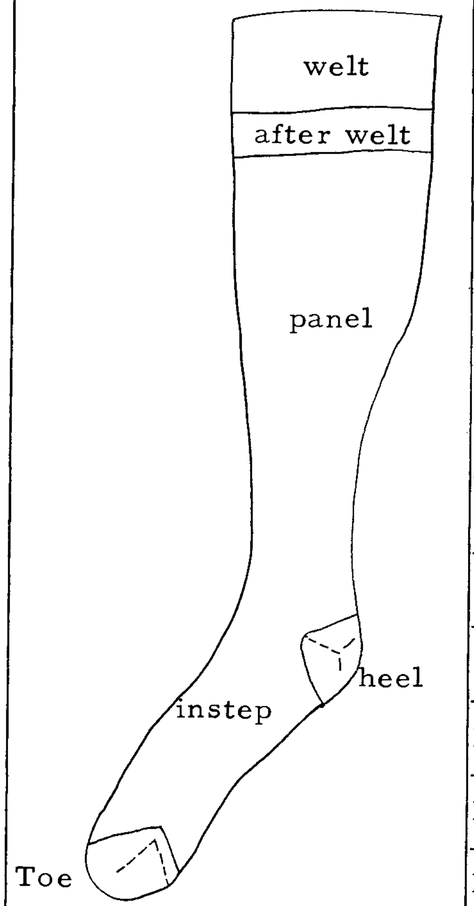
	YES		NO	
Fiber	Total	Percent	Total	Percent
Group I N-27				
A	23	89.0	3	27.0
B	13	48.0	14	52.0
Group II N-10				
A	9	90.0	1	10.0
B	7	70.0	3	30.0

APPENDIX C

Results of Tests of Significance

Table C-1

DAILY WEAR DATA SHEET



NUMBER ________

FIBER ________

DATES WORN (There are spaces for 5 days.)

________ ________
________ ________
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MARK THE DIAGRAM AT THE LEFT TO SHOW WHERE RUN ORIGINATED AND WHERE IT ENDS. Use X to mark the start and an arrow to show direction.

←—— X ——→

Check kind of fault	✓	Tell cause of fault if known
Hole in toe plus run		
Hole in heel plus run		
Run in panel or instep		
Run in welt or after welt		
Run in welt that continues into panel		

Table C-2
SIGNIFICANT MEAN DIFFERENCES OF WEAR AND LABORATORY TESTS OF GROUP I USING F VALUES

Kind of Test	Source of Variation	D.F.	M.S.	F ratio
Total Days Worn	Subjects	29	55.14	2.17*
	A X B	1	299.3	11.76**
	Error	29	25.44	--
Maximum 15 Days Worn	Subjects	29	31.85	3.25**
	A X B	1	129.1	13.18**
	Error	29	9.791	--
Snags - 5 Day Check	Subjects	29	76.00	2.39*
	A X B	1	960.0	30.23**
	Error	29	31.76	--
Total Hosiery Faults	A X B	1	45.61	22.47**
	Subjects	29	2.980	--
	Area	7	52.16	42.40**
	(AXB)X Subjects	29	2.030	--
	(AB) X Area	7	4.090	4.01*
	Area X Subjects	203	1.230	--
	Error	203	1.020	--
Snags per Day	Subjects	29	21.25	1.42
	A X B	1	388.2	25.92**
	Error	29	14.98	--
Total Runs	Subjects	29	16.79	0.79
	A X B	1	0.0166	0.01
	Error	29	2.120	--
Abrasions	Subjects	29	3.260	2.22*
	A X B	1	2.400	1.63
	Error	29	1.470	--
Bursting Strength - Knees	A X B	1	0.6901	0.09
	N X W	1	1.732	0.23
	(AB)(NW)	3	2.093	0.29
	Error	92	7.475	--
Bursting Strength - Toes	A X B	1	533.3	4.35*
	N X W	1	355.0	2.90
	(AB)(NW)	3	188.1	1.54
	Error	44	122.5	--
Stretch Test	A X B	1	0.8626	172.9**
	Among Samples	22	0.0050	--

* Significant to the 0.05 percent level
** Significant to the 0.01 percent level

Table C-3

GROUP I COVARIANCE OF FAULTS WITH DAYS WORN

Source of Variation	ESTIMATE OF ERROR			
	SS	DF	MS	F ratio
Abrasion Faults				
Error	39.63	28	1.42	--
Subjects plus Error	133.86			
Adjusted Subjects	94.23	29	3.25	2.29*
Treatment plus Error	44.61			
Adjusted Treatments	4.98	1	4.98	3.51
Regulation of Error	2.97	1	2.97	2.09
Total Runs				
Error	55.95	28	1.99	--
Subjects plus Error	109.44			
Adjusted Subjects	53.49	29	1.84	0.92
Treatment plus Error	56.03			
Adjusted Treatments	0.08	1	0.08	0.04
Regulation of Error	0.53	1	0.53	0.27

* Significant to the 0.05 percent level

Table C-4
SIGNIFICANT MEAN DIFFERENCES OF WEAR AND LABORATORY TESTS
OF GROUP II USING F VALUES

Kind of Test	Source of Variation	D. F.	M. S.	F ratio
Total Days Worn	Subjects	9	47.47	3.74*
	A X B	1	12.80	1.01
	Error	9	12.69	
Maximum 15 Days Worn	Subjects	9	41.42	3.26**
	A X B	1	12.80	1.01
	Error	9	12.69	--
Snags - 5 Day Check	Subjects	9	319.9	1.35
	A X B	1	1960.0	8.29*
	Error	9	236.3	--
Total Hosiery Faults	A X B	1	110.0	30.39**
	Subjects	9	18.48	--
	Area	7	77.88	12.21**
	(AXB)X Subjects	9	3.620	--
	(AB) X Area	7	24.12	121.68**
	Area X Subjects	63	6.380	--
	Error	63	0.190	--
Snags per Day	Subjects	9	143.7	3.97*
	A X B	1	747.6	20.65**
	Error	9	36.21	--
Total Runs	Subjects	9	1.867	3.50*
	A X B	1	0.200	0.38
	Error	9	0.533	--
Abrasions	Subjects	9	2.361	2.82
	A X B	1	1.250	1.27
	Error	9	0.8056	--
Bursting Strength - Knees	A X B	1	239.2	31.40**
	N X W	1	7.508	0.98
	(AB)(NW)	3	83.01	18.91**
	Error	28	7.622	--
Bursting Strength - Toes	A X B	1	517.6	3.37
	N X W	1	529.0	3.44
	(AB) (NW)	3	400.9	2.61
	Error	12	153.6	--
Stretch Test	A X B	1	0.3403	171.9**
	Among Samples	6	0.0020	--

* Significant to the 0.05 percent level
** Significant to the 0.01 percent level

Table C-5
GROUP II COVARIANCE OF FAULTS WITH DAYS WORN

Source of Variation	ESTIMATE OF ERROR			
	SS	DF	MS	F ratio
Abrasion Faults				
Error	6.69	8	0.84	--
Subjects plus Error	28.46			
Adjusted Subjects	21.77	9	2.42	2.88*
Treatment plus Error	7.37			
Adjusted Treatments	0.68	1	0.68	0.81
Regulation of Error	0.56	1	0.56	0.67
Total Runs				
Error	2.24	8	0.28	--
Subjects plus Error	13.99			
Adjusted Subjects	11.75	9	1.31	4.68*
Treatment plus Error	3.11			
Adjusted Treatments	0.87	1	0.87	3.11
Regulation of Error	2.56	1	2.56	9.50*

* Significant to the 0.05 percent level