THE UNIVERSITY OF MANITOBA

THE EFFECT OF CERTAIN SOAPS AND SYNTHETIC DETERGENTS ON NYLON AND ON RAYON HOSIERY

BEING A THESIS SUBMITTED TO THE COMMITTEE
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- - J. F.

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CHAPTER I

INTRODUCTION

In a recent report, Goodings (20) of the Ontario Research Foundation stated, "The place of research in connection with the textile industry in Canada is a very important matter and one which, it is suggested, has not so far received the detailed study which it deserves." In 1939, Canadian mills produced 3,200,000 dozen pairs of full-fashioned hosiery, (20), the net value of hosiery and knitted goods industry for that year being 40,485,197 dollars (10). Thus it would seem, in an industry of this size, there is adequate scope for research which would benefit the industry and the consumer alike.

The fact that consumers desired information concerning the hose they bought was indicated by a survey conducted by Sears (44) at the University of Missouri. Upon questioning 592 college girls, it was discovered that they would welcome more information about the wearing quality, fiber, and color fastness of the hose they purchased. Labels collected in connection with the study rarely gave more than brand name and size. In a very few cases, construction of the hose, fibre content, washing directions and color were included.

Although little has been accomplished regarding labelling of hosiery in Canada, a beginning has been made.

Under the Dominion Trade and Industrial Commission Act, which became effective in February, 1941, it became unlawful to label hosiery with false or misleading description (32). According to the provisions of this order, should hosiery be labelled as to fibre content, it is compulsory to name all fibres present to the extent of five per cent and in order of predominance (7). The Wartime Prices and Trade Board issued several orders regulating the types of full-fashioned hosiery to be manufactured and the size of yarn to be used with each gauge. Prices have been set for each type (1). The consumer is further protected by the fact that hosiery manufacturers must submit samples of their stockings to the Administrator of Knitted Goods to be checked for the purpose of maintaining quality and construction standards (4).

During the past decade the hosiery industry has seen many changes. Nylon hosiery first appeared in 1941 and were an immediate success. Shortly after, silk, the traditional fibre for women's full-fashioned hose, disappeared from the market, due to the freezing of Japanese assets. To replace silk, hosiery manufacturers turned to nylon and rayon yarns. However, all nylon shipments for non-military purposes ceased in February, 1942 (8), leaving rayon as the sole fibre in the popular hosiery field. In February, 1946, nylon hosiery reappeared on the retail market throughout Canada with hosiery manufacturers expecting an output of 1,800,000 dozen pairs of nylon hose compared with 800,000 dozen pairs of rayon hose and cotton hose combined (6). It would appear that nylon hose are well in the lead in the hosiery field, supplemented by rayon for less costly hose. There has been some controversy as to whether silk will ever regain its former place in women's full-fashioned hosiery. One author (5) states there will be no silk hosiery while another (9) believes that, although the bulk of hosiery production in the future will be nylon, sufficient consumer demand would bring silk hosiery back on the market if only as a luxury. Nylon and rayon hose have been chosen for study because it would appear they are now and will be for some time to come, the leaders in the hosiery field.

Kiene (12) stated that the post-war period will see an increase in the use for clothing of synthetic fabrics such as rayon and nylon. It was only reasonable to assume that these new fibres would require different laundry methods than those employed in the washing of natural fibres such as silk, cotton, and wool. Therefore, in this study an attempt was made to discover the best possible washing procedures to recommend for the home-washing of nylon and rayon hose. The purpose was not to compare the serviceability of nylon and rayon hose but to find out how the strength of each was affected by various laundry methods. In a study of this size, it was not possible to vary all the conditions that enter into laundering. Such factors as temperature, concentration of detergent, time of washing, and volume of bath were held constant. The detergents, number of rinses, type of water, and number of washings were varied. Four different detergents, which appear on the Canadian retail market and which were especially recommended for hosiery, were chosen for study. Two of the detergents were mild neutral soaps, one a sulphated alcohol, and the fourth, a mixture of soap and sulphated alcohol. Two different types of water were employed, hard water and distilled or soft water. Two different rinsing procedures were used; hose given one rinse were compared with hose given three rinses. Hose treated in the a bove manner were tested for bursting strength after one, fifteen, and thirty washings.

Wear plus laundering are two factors that influence the serviceability of a garment. Because hose require frequent washings, it was assumed that the serviceability of the hose might be definitely affected by the method applied in the laundry procedure. To determine this effect, apart from that produced by wear, bursting strength methods were applied. This method was supported by Hays, Petersen, and Taylor (25) of the United States Bureau of Home Economics, who found that in lieu of consumer wearing studies, bursting strength was one of the best methods of predicting serviceability.

The statistical analysis of the data consisted of the application of the analysis of variance technique to ascertain any real differences in the results of the methods applied.

It is hoped that the following questions may be answered by this study:

1. Do the four detergents used in laundering cause significant differences in the resulting strength of nylon and of rayon hose?

2. Is there any indication that distilled water is superior to hard water in its effect on the strength of the hose studied?

3. Does the greatest change in strength occur after one, fifteen, or thirty washings?

4. Is the use of three rinses more beneficial than one rinse in the strength preservation of the hosiery?

5. Are there any significant interactions between the various factors involved?

CHAPTER II

REVIEW OF THE LITERATURE

Burlingame is quoted in a recent study (13) as having said, "The restoration to a condition of cleanliness of wearing apparel and fabrics which have been worn and used is one of the most persistently recurring and one of the oldest of tasks which always has, and probably always will, confront civilized mankind." Richardson (41) defined laundering as "the process in which dirt, grease, and other forms of soil are removed from fabrics by agitating them in water containing water softener, soap, or other detergents." Because hose are subjected to many forms of soil, such as dirt, perspiration, and grease, they require frequent washings. A survey of washing instructions by various authors (24) (42) (47) indicated that stockings should be washed after each wearing. Laundering is also necessary in maintaining the pleasing appearance of hosiery.

Aust (13) stated that the type of detergent, the type of water, and the number of washings were among the more important variables as far as their effect on the fabrics was concerned. A summary of studies concerning the effect of these factors in the washing of various fabrics will be given.

The Effect of Different Detergents on Fabric Strength:

Many studies have been carried out to compare different detergents, both natural and synthetic. Although no investigations have previously been conducted on nylon or rayon hosiery, Richardson (41) compared the washing of silk hosiery with soap and with sodium lauryl sulphate. Results, indicating the effect on the strength of the hosiery, are listed in Table 1.

TABLE 1. EFFECTS OF WEAR AND LAUNDERING, WITH EITHER SOAP OR A NON-SOAP DETERGENT, ON SILK HOSE. THE HOSE WERE LAUNDERED AFTER EACH DAY OF WEAR, UNTIL WORN OUT

Brand	Av. No. Times Laundered	Av. Bursting Strength		
		New Unlaundered lb./sq. in.	Worn Laundered With Soap lb./sq.in.	Worn Laundered With Non-soap lb./sq. in.
A	23	70	59	63
B	25	66	55	63
C	33	77	65	67
D	33	79	65	67
E	42	105	84	87
F	42	101	85	86
G	53	105	78	81

Richardson concluded, that although the strength of the hose laundered with soap appeared less than that of the hose laundered with sodium lauryl sulphate, statistical analyses of the data indicated no significant differences. Additional studies were reported by this investigator on cotton, rayon, linen, and wool, using the same detergents as in the washing of the hose. In all cases there was no significant difference in the strength of the fabric, whether the soap or the synthetic detergent was used.

Aust (13) compared the washing of silk lingerie material with soap and with a synthetic detergent of the sulphated fatty alcohol type. Using breaking strength as a criterion, she concluded that the synthetic detergent might be considered preferable to the soap.

Castonguay, Leekley and Edgar (14) used soap, silicated soap, and sulphated alcohol in their comparison. The fabrics laundered were cotton, regenerated rayon, acetate rayon, silk, wild silk, and wool. These investigators found that the wet strength of all the fabrics was lowered by washing but only the silk washed with sulphated alcohol and the wild silk lost more than half their wet strength during fifty washings. A greater percental loss in wet strength by cotton compared with the rayons reflected the loss of sizing from the cotton, the high wet strength of the original cotton, and the low wet strength of the original rayons. However, loss of wet strength by the rayons, which was ascribed to impairment of micellar orientation during alternate swelling and drying, was surprisingly low. Whereas silk lost 86 per cent of its wet strength during fifty washings with sulphated alcohol, only a 30 per cent loss was observed in an earlier study when an aromatic sulphonate was used under the same conditions. Wool lost 11 per cent during fifty washings with sulphated alcohol as compared to approximately 20 per cent with either soap.

A similar study was carried out by Ester, et al.(18) comparing an aryl sulphonate and soap in hard water. The fabrics used were cotton, linen, acetate rayon, regenerated rayon, silk, and wool. Again the wet strength of all the fabrics was lowered by washing. Only the linen lost more than half its wet strength during fifty washings. The greater percental loss suffered by linen and cotton compared with acetate rayon was attributed to the initial high wet strengths of the linen and cotton, and to the low wet strength of the rayon. The acetate rayon, cotton, and regenerated rayon lost 8, 15, and 25 per cent. respectively, in wet strength during fifty washings, whether washed in water alone or with aryl sulphonate, or with soap. The high wet strength of silk washed in water with or without soap was in decided contrast to the 86 per cent loss of wet strength by a silk washed with sulphated alcohol (14). High values for wet strength of wool washed in water with soap contrasted with wool washed in water with or without aryl sulphonate. It was concluded from these two studies that the different detergents used produced varying effects on the strength of the fabrics, depending on the fabric used. Silk showed much higher wet strength values after washing with soap or an aromatic sulphonate than when washed with a sulphated alcohol. Wool gave higher wet strengths with soap and with a sulphated alcohol than when an aryl sulphonate was used. There appeared to be little difference in the wet strength of the cotton and rayon, whether they were washed with soap or with the synthetic detergents.

Van Antwerpen (49) conducted a study showing the effect on the breaking strength of wool after fifty washings with a sulphonated ether, a sulphated alcohol, a sulphonated ester, and ordinary soap. The breaking strength of wool treated with the sulphated ether increased, but decreased when the wool was treated with the other detergents, the soap showing the greatest loss. These results were not interpreted as indicating that sulphonated ether increases the tensile strength of the fibres, but as showing that the pieces of cloth washed with the ether compound, retained the normal gain in tensile strength usually present in a washed piece of goods. This increase in strength, due to the alignment of fibres and the attendant distribution of strain, was lost in the samples washed with soap, sulphonated esters and sulphated alcohols. He attributed the loss to continued sorption of detergent and precipitates of hard water soap, resulting in over-lubrication and slippage of fibres.

Mendrzyk, Sommer, and Viertel (34) compared the effect of washing woolen uniform cloth with soap and with a fatty alcohol sulphonate. They discovered that the wearability of the cloth was not significantly affected by the type of detergent used. However, in the washing of linen and cotton, Honegger and Schnyder (28) discovered that wear resistance was reduced more by soap than by the fatty alcohol sulphonate.

Ohl (38) washed wool and rayon with soap and with oxygen-bearing detergents. As far as the effect on the strength and elasticity of the fibres was concerned, he found no significant difference between the two types of detergent. Ladteu and Moldauskii (31) compared the effect of soap made from natural oils with that of "substitute soaps", such as resinates and soaps made from liquid synthetic acids, in the washing of white cotton. These investigators concluded that oil soaps were more destructive to the cloth in washing than were the substitute soaps. Schnyder (43) reported that soap baths consisting of fatty acid soaps and of synthetic soaps caused little change in breaking strength. The fibre on which the wash test was conducted was not specified.

From the various washing tests examined, it would appear that investigators are not in full agreement as to the comparative effect on fabric strength of the different detergents. Five studies showed no significant differences between the effects of different detergents on strength; two studies showed greater losses with the use of synthetic detergents; and three studies showed greater losses with the use of soap as the detergent. This disagreement may be due to fabric variation and also to a dissimilarity in washing methods. In consideration of these facts, it is apparent that there is need of further investigation in this field and of standardization in testing methods.

The addition of bleaches and building agents to soaps may affect the strength of the fabric being laundered. Hays and Rogers (26) washed dish towels composed of rayon, cotton, and linen. They found that the towels were deteriorated more when a bleach, sour, and high temperature were used than when no bleach or sour and a lower temperature were used.

Smit (46) washed cotton and linen in a soap solution with varying amounts of soda added. The strength of the cotton was only slightly affected at all concentrations. Linen, however, lost from eighteen to thirty-two per cent of its strength; the higher concentrations of soda giving the greater losses in strength. Simola (45) conducted a similar study. He reported a substantial loss in strength for both cotton and linen. The loss for cotton after fifty washings in a soap-soda solution was 22 per cent while the loss for linen after the same number of washings was 52 per cent. When soda alone was used, these values were 12 and 2 per cent for cotton and linen respectively.

The Effect of Soft and Hard Water on Fabric Strength:

The type of water used, generally classified as hard or soft, seems to have a decided effect on laundered fabrics. The deposition of calcium soaps on textiles, when hard water was used, was claimed by Kohler (30) to be definitely deleterious. Opitz (40) found calcium soap deposits harmful in the washing of cotton, flax, and viscose rayon. Cohen and Mack (15) experimented with unweighted silk, soaking the material under different conditions. They discovered that the use of hard water increased the tendering action caused by the soaking. Similarly, Aust (13), in a laundry study of pure dye silk crepes, found that hard water caused greater losses in both dry and wet strength. Ohl (39) stated that soft water was a prerequisite for good washing action while Schenke (42) advised that soft water be used in the washing of rayon hosiery.

Further evidence which supports the theory that soft water is preferable to hard in the washing of cotton and linen is supplied by the following investigators. Honegger and Schnyder (28) found that, while soft water processes seemed to improve wear resistance, a combination of hard water and a fatty alcohol sulphonate reduced the resistance to wear and still greater reduction resulted with hard water and soap. Simola (45) washed linen and cotton goods in water of varying degrees of hardness. Resultant weakenings in strength of from 5 to 15 per cent in distilled water, 8 to 19 per cent in water of four degrees hardness, and 24 to 29 per cent in water of 25.4 degrees hardness were observed.

However, in the washing of rayon, Ester, et al.(18) noted similar wet strength results for hard and distilled water. As the degree of hardness was not given in this experiment, it may not be assumed that these results would be obtained with water of all degrees of hardness.

Oldenroth (36), moreover, claimed that the high incrustations produced on laundered goods by hard water soaps, increased the resistance to tearing.

Investigators generally agreed that washing in hard water was deleterious to the strength of fabrics, strength losses increasing with the number of degrees of hardness. Only one investigator found no significant difference in the use of soft and hard water while another theorized that hard water soaps might increase fabric strength.

The Effect of the Number of Washings on Fabric Strength:

When number of washings was the factor considered, most investigators appeared to agree that the strength of fabrics was lowered by successive washings. This loss may not always be attributed to washing action alone. In some investigations, the garments were subjected to wear tests as well as laundering tests. In a study of twelve silk fabrics, Griffith (22) found that decreases in strength resulting from fifteen launderings varied from 15 to 17 per cent. In a further study, however, the same author (23) discovered that weighted silks showed increased strength after fifteen launderings. Aust (13) found definite losses in the strength of pure dye silks after twenty-five launderings. The six fabrics used lost from 36 to 45 per cent of their warpwise strength and from 29 to 40 per cent of their filling-wise strength. From a wear and washability test conducted on silk hosiery, Richardson (41) obtained losses of 10 and 16 per cent for hose washed twenty-three times, and 23 and 26 per cent for hose washed fifty-three times. Castonguay, Leekley, and Edgar (14) reported losses exceeding 50 per cent in a silk and a wild silk, following fifty washings.

The strength of wool does not appear to be as impaired by successive washings as might be expected. Elmquist and Hays (17) reported a decrease in strength of woolen blankets after repeated launderings. Wool fabrics, tested after eight launderings by Cranor, McFadden, and Fryer (16) showed only slight decreases in breaking strength. Castonguay, *et al.* (14) gave losses ranging from 11 to 20 per cent in a wool fabric after fifty washings. Richardson (41) reported a study on wool shirts which showed only slight decreases in strength while wool hose lost from 25 to 31 pounds per square inch in bursting strength during twenty washings. Van Antwerpen (47) made an interesting discovery in the washing of wool in various detergents. While the wools washed with a sulphated alcohol, with a sulphonated ester, and with a soap showed decreases in breaking strength after fifty washings, the wool washed with a sulphonated ether showed a marked increase in strength.

McFadden (35) stated that, in general, twenty-six rayon slip fabrics lost strength after fifteen launderings. Richardson (41) found a slight decrease in strength of one viscose rayon after thirty-two washings while another viscose rayon appeared to gain in strength during one hundred washings. Cuprammonium rayon, tested by the same investigator, showed increases of from four to six pounds per square inch in bursting strength, following twenty-five washings. Castonguay, et al.(14) reported the loss in wet strength of rayons was surprisingly low after fifty washings.

Lovell, Roberts, and Brodie (33) reported losses in strength of cotton, fabric after one hundred washings. The fabric lost from 6 to 14 per cent in warpwise tensile strength and from 3 to 23 per cent in filling-wise tensile strength. Richardson (41) found that cotton lost from 35 to 40 per cent of its original strength in thirty-four washings. Castonguay et al. (14) attributed the large loss in strength by cotton to the loss of water-soluble sizing, often found in this material. This theory is supported by the fact that cotton goods frequently show greater loss in strength after the first washing than in later washings. Simola (45) found that cotton was weakened 15 per cent in twenty-five washings, and 22 per cent in fifty washings. Hays, Rogers, and Boyer (27) carried out a service study on women's full-fashioned cotton hose. They reported that the amount of deterioration, as measured by bursting strength, was greater during the first twelve periods of wear and laundering than during the second half, the twelfth to twenty-fourth period.

In summarizing, fifteen investigators found varying losses in strength after a number of washings. However, one investigator reported an increase in strength of weighted silk following fifteen launderings; another reported increased strength of wool washed with a sulphonated ether, while increases in strength of cuprammonium and viscose rayon were reported following twenty-five washings and one hundred washings, respectively.

The Effect of the Number of Rinses on Fabric Strength:

No investigations were found in the literature comparing the effect of the number of rinses on the strength of fabrics. Honegger and Schnyder (29), however, observed a definite loss of strength due to rinsing while performing laundry tests. Washing instructions frequently call for thorough rinsings (11) (31) (42), but do not indicate any particular advantage to the strength of the fabric in so doing.

In regard to such factors as temperature, washing time, concentration of detergent, and volume of baths in the washing of hosiery, a survey of the literature revealed conflicting procedures. In the washing of cotton hose, Hays, Petersen, and Jelinek (24) used an 8.75 per cent neutral soap solution. The laundry method included one 6-minute suds at 30°C. (86°F.) with 300 milliliters soap, one 10-minute suds at 70°C. (158°F.) with 150 milliliters soap, four 5 - to 6 - minute rinses at 60°C. (140°F.), and a final 5 - minute rinse in cold water. A slight variation of this procedure was used by Hays, Rogers, and Boyer (27) in a further study on cotton hose. The volume of the bath for the 10-minute suds at 70°C. was raised to 225 milliliters of soap solution. Furry and Hansen (19) washed cotton stockings in a 0.5 per cent neutral soap solution at 38°C. (100°F.). The volume of the bath and the washing and rinsing times were not stated in this study.

For the washing of silk hosiery, Richardson (41) used a 0.3 per cent solution of soap and a 0.2 per cent solution of a non-soap detergent. The hose were washed for one minute and rinsed twice for one minute each at 104°F. Schenke (42) advised that a temperature not exceeding 100°F. should be employed in the washing of rayon hosiery.

On comparing these reports it would appear that there is a lack of consistency in the laboratory technique applied in the washing of hosiery. Standardization of laundry methods would permit greater ease of comparison between studies on hosiery and thus increase the value of individual investigations.

CHAPTER III

METHOD OF PROCEDURE

<u>Physical Characteristics</u>:

Twenty-four pairs each of nylon hosiery of the same brand and rayon hosiery of the same brand were selected for study. The hose were analyzed for fibre content, count of wales and courses, filament count, yarn denier, twist, and resistance to abrasion.

The welt, leg, and foot reinforcement of the nylon and rayon hose were examined microscopically for fibre identification. To support the microscopic findings, the fibres were further identified, using a commercial fibre identification stain. The colour was first removed from the samples with a bleach. The materials were then wetted with the identification stain, allowed to stand for two minutes, then washed thoroughly in cool water. The colour thus formed on the materials indicated the kind of fibre used. To increase the accuracy of the test, the samples were compared with other samples of known fibre content, similarly treated.

By using the Suter thread counter, the gauge or number of wales per inch and one-half was determined. Likewise the number of courses per inch was determined, no two determinations being made on the same set of wales or courses.

The number of filaments in the yarn was counted with the aid of a microscope. A short length of yarn was untwisted and each filament pulled out separately with a pick needle.

The denier of the yarn was determined by using the Suter Universal Yarn Numbering Balance. Three samples, ninety centimeters in length, were used and their mean determined. In measuring the length of the sample, care was taken to straighten out kinks in the yarn without stretching it. The sample was then twisted into a knot and hung by one thread on the hook in the weighing chamber. The beam clamp was released and the index lever rotated until the beam was in balance, the denier then being indicated by the index pointer. This test was carried out under standard conditions of a relative humidity of 65 $\pm$ 2 per cent and a temperature of $70^{\circ} \pm 5^{\circ}$F. (2).

The United States Testing Company's twist tester was used to determine the direction of twist and the number of turns per inch of the leg yarn and seaming thread of both the nylon and rayon hose. A mean of ten samples was taken.

Using a Taber Abraser with CS-10 Fine Calibrase Wheel and five hundred gram wheel pressure, the resistance to abrasion of the leg of the hose was taken. The appearance of a small hole was used as the end-point of the experiment. A mean of three samples was determined.

The number of fashion marks at the top of the leg, the calf, the heel, and the toe of the nylon and the rayon hose was noted.

<u>Sampling</u>:

Of the twenty-four pairs of hosiery used, twelve pairs were washed in distilled water while the remaining twelve pairs were washed in water of ninety equivalent parts of calcium carbonate per million hardness. The hose were grouped in lots of eight stockings, the first group to be given one washing; the second, fifteen washings; and the third, thirty washings. In each group of eight, four of the stockings, each treated with a different detergent, were given one rinse while the other four were given three rinses. The detergents used included two neutral soaps, one in flake, the other in bead form, a sulphated alcohol, and a soap and sulphated alcohol mixture. A graphical breakdown of sample treatments is to be found in Appendix Table I.

<u>Washing Procedure</u>:

Before washing, the seaming thread was removed and the hose numbered for identification purposes. A four-jar

Wash-Fastness Tester manufactured by the United States Testing Company was used for laundering the hose. Into each pint jar was placed three hundred milliliters of the four different kinds of detergent solution. The solution consisted of one gram of detergent in three hundred milliliters of water (o.33% solution). The hose were placed in the pint jars, one to a jar, which were then rotated in the Wash-Fastness Tester for five minutes at 100°F. The hose were then removed from the pint jars, squeezed gently to remove excess soap and rinsed separately in one liter of water at 100°F. for two minutes, agitating gently by hand. Half of the hose were given one 2-minute rinse while the other half were given three 2-minute rinses. After rinsing, the hose were squeezed gently to remove excess moisture and hung on a smooth rod to dry. Twenty-four hours were allowed between washings for the stockings requiring repeated washings.

Bursting Strength:

The bursting strength of each of the treated hose was determined under standard conditions of 70° $\pm$ 5°F. and a relative humidity of 65 $\pm$ 2 per cent, the hose being conditioned for at least twelve hours before bursting. A Scott Tester with the Ball-burst attachment was used; ten bursts taken throughout the leg of the hose and their mean calculated. The bursting strength was recorded as the force in pounds required for a one inch steel ball to burst a one and three-quarters inch circle of fabric. Bursting strengths were also taken of an unwashed hose of each type to be used as a control.

Statistical Treatment:

The analysis of variance was applied to the bursting strength results obtained in this study to accurately determine any significant differences between the various treatments. The significance of variation among the treatments was measured by means of the "F" Test, which is the quotient obtained by dividing the treatment by the error mean square.

No effort was made to compare the strength of the nylon and the rayon hose, each being analyzed separately. The data for an experiment representing 480 determinations, ten bursts on each stocking, was analyzed into the variance for differences among the means of the forty-eight stockings and differences among the bursts within stockings. In deciding on a valid error for this experiment it was realized that the repetition of bursts on the same stocking did not constitute real replication in the sense of providing an error for comparing treatments applied to whole stockings. In the analysis of variance, Table 3, the within stocking variance is much smaller than the pooled variance for triple and quadruple interactions which is evidence that the former would not be a valid error. For these reasons, the variance for the pooled interactions was used. The main effects and simple interactions were then determined and analyzed for significance.

Formulae used in Statistical evaluation of data (21):

Total Sum of Squares . . . . $\overset{N}{\underset{I}{S}}(x^2) - \frac{[S(x)]^2}{N}$

Sum of Squares among Totals for a Series of Treatments . . . . . . $\frac{\overset{k}{\underset{1}{S}}(T_i{}^2)}{n} - \frac{[S(x)]^2}{N}$

For the calculation of the interaction sums of squares the reader is referred to the method recommended by Goulden(21).

Key to symbols in the preceding formulae:

S - summation sign
x - value of single variate
n - number of variates in treatment totals
k - number of treatments totals
N - total number of variates = nk
T_i - treatment total

CHAPTER IV

DATA AND DISCUSSION

Physical Characteristics:

A summary of the physical analyses of the nylon and the rayon hose is given in Table 2. The nylon hose were knit of 100 per cent nylon. The leg yarn contained one strand of nylon, while the seaming thread was made up of three strands. Of the rayon hose, the leg and welt were composed of cuprammonium rayon while the foot reinforcement and seaming thread were cotton. The leg yarn was two-strand rayon and the seaming thread three-ply cotton.

The hose were not labelled as to gauge but experimentally the gauge of the nylon hose was found to be sixty-two, and that of the cuprammonium, forty-nine. These figures appear to be comparatively high, which may be accounted for by the fact that although hose are generally knit on a fourteen inch needle bar they are only approximately twelve inches around the top of the stocking when finished.

In the yarn of the nylon hose, the number of filaments was ten for the leg yarn, and thirteen for the seaming thread yarn. The rayon hose leg yarn was composed of sixty filaments. The denier of the nylon hose was thirty-five, while that of the two-fold rayon hose was seventy-five.

TABLE 2. PHYSICAL ANALYSES OF NYLON AND OF RAYON HOSIERY

	Nylon	Rayon
1. Fiber Identification		
Welt	nylon	cuprammonium
Leg	nylon	cuprammonium
Foot	nylon	cotton
Seaming Thread	nylon	cotton
2. Gauge	62	49
3. Course Count	51	40
4. Filament Count		
Leg	10	60
Seaming Thread	13	--
5. Denier	35	75
6. Twist		
Leg	34.51 t.p.i.[1] 1-strand Z-twist	13.43 t.p.i. 2-strand Z-twist
Seaming Thread	11.43 t.p.i. 3-strand Z-twist	15.11 t.p.i. 3-strand S-twist
7. Resistance to Abrasion	147 cycles	43 cycles
8. Number of Fashion Marks		
Top of Leg	16	4
Calf	48	31
Heel	34	19
Toe	46	30

1- twists per inch

In measuring the twist of the nylon hose, the leg yarn was found to have 34.51 twists per inch and the three-fold seaming thread, 11.43 twists per inch. Of the rayon hose, the two-fold leg yarn had 13.43 twists per inch and the three-fold seaming thread, 15.11 twists per inch. In both the nylon and the rayon hose, the leg yarns were Z-twist and the seaming thread yarns were S-twist.

Following the test for resistance to abrasion, nylon hose were found to withstand 147 wear cycles and the rayon hose, forty-three wear cycles.

The number of fashion marks at the top of the leg, calf, heel, and toe of the nylon hose was sixteen, forty-eight, thirty-four, and forty-six, respectively. For the rayon hose, the number of fashion marks at the top of the leg, calf, heel, and toe was four, thirty-one, nineteen, and thirty, respectively.

Bursting Strength:

Bursting strength data for the nylon and the rayon hose, following the various washing procedures, are given in Appendix Tables 11 and 111, respectively. These tables indicate individual bursts within each stocking and also stocking totals. Mean bursting strengths of individual nylon and rayon stockings are listed in Appendix Tables IV and VI, while mean bursting strengths for the main effects and simple interactions of the treatments on the nylon and the rayon hose are summated in Appendix Tables V and VII, respectively. These data were used in calculating the analyses of variance of the nylon and of the rayon hose, which are to be found in Tables 3 and 4, respectively.

Since it was decided that the high order interactions were to be used as an error and since the triple and quadruple interactions were not significantly different, an error sum of squares was formed by combining the sums of squares of both the triple and quadruple interactions. This was used to test the significance of the main effects and the simple interactions. In both the nylon and the rayon hose, this error variance was approximately five times as large as that provided by the variance within stockings. Thus, it would appear that the true error lay, not within the individual stockings, but among the treated stockings.

In the case of the nylon hose, significant differences in bursting strength were found between detergents, between the number of washings, and between the number of rinses. The interaction of the type of water with the number of washings was also significant.

In considering the rayon hose, there appeared to be significant differences in the strength of the hose between the number of washings. The following interactions were significant: water with detergents, water with washings, and water with rinses.

Owing to the occurrence with some stockings of bursts at a rather low value which might appear to be out of line with the other values for the same stocking a test of the heterogeneity of variance between stockings was made for the data of Appendix Table III. The value of X^2 obtained, Snedecor (48) was 42.865 and for 47 degrees of freedom this proved to be somewhat less than expectation. The conclusion is that the variation was homogeneous.

TABLE 3. ANALYSIS OF VARIANCE OF NYLON HOSE

Variables	Sum of Squares	D.F.[1]	Variance	F
Within stockings . . .	5544.50	432	12.83	
Among stockings . . .	5619.93	47	119.57	
Detergents	629.88	3	209.96	3.61#
Water	198.92	1	198.92	3.42
Washings	1923.31	2	961.65	16.52##
Rinses	331.67	1	331.67	5.70#
Detergents x Water.	161.89	3	53.96	0.93
Detergents x Washings.	115.34	6	19.22	0.33
Detergents x Rinses..	189.66	3	63.22	1.09
Water x Washings	670.47	2	335.24	5.76##
Water x Rinses	26.13	1	26.13	0.45
Washings x Rinses ...	34.15	2	17.08	0.29
Error	1338.50	23	58.20	
Total	11164.43	479		

Significant at five per cent level

Significant at one per cent level

1 Degrees of Freedom

TABLE 4. ANALYSIS OF VARIANCE OF RAYON HOSIERY

Variables	Sum of Squares	D.F.[1]	Variance	F
Within stockings	3314.98	432	7.67	
Among stockings	2773.51	47	59.01	
Detergents	74.08	3	24.69	0.71
Water	58.45	1	58.45	1.67
Washings.	337.54	2	168.77	4.84#
Rinses	12.19	1	12.19	0.35
Detergents x Water. .	551.61	3	183.87	5.27##
Detergents x Washings	54.62	6	9.10	0.26
Detergents x Rinses .	143.24	3	47.75	1.37
Water x Washings	448.02	2	224.00	6.42##
Water x Rinses	158.13	1	158.13	4.53#
Washings x Rinses. ..	132.91	2	66.46	1.90
Error	802.72	23	34.90	
Total	6088.48	479		

1 Degrees of Freedom

Significant at five per cent level

Significant at one per cent level

Detergents:

The mean bursting strengths of the nylon and rayon hose washed in soap flake, bead soap, a soap and sulphated alcohol mixture, and a sulphated alcohol are to be found in Table 5.

TABLE 5. BURSTING STRENGTH IN POUNDS OF NYLON AND RAYON HOSE BEFORE AND AFTER LAUNDERING WITH FOUR DETERGENTS

	Control	Soap Flake	Bead Soap	Soap and Sulphated Alcohol	Sulphated Alcohol
NYLON	33.35	28.55	29.90	31.45	31.15
RAYON	20.95	26.58	26.48	26.83	27.48

In the case of the nylon hose, there were significant differences between the detergents. The two detergents containing the sulphated alcohol appeared to be similar in their action on the hose, and to be less destructive than the soaps, as illustrated in Figure 1. Of the two soaps, the soap flake was more destructive than the bead form.

These results are in agreement with Aust (13), who discovered that silk fabrics showed greater losses in strength when washed in soap than when washed with a synthetic detergent of the sulphated fatty alcohol type. In the washing of wool, Castonguay, Leekley, and Edgar (14) and Van Antwerpen (48) agreed that greater percentile losses occurred when soap rather than a sulphated alcohol was used as the detergent. The fact that nylon is a proteic substance, and therefore somewhat similar chemically to silk and wool, may account for its comparable reaction to these detergents.

With the rayon hose, however, although figures for the bursting strength of the hose washed with the synthetic detergents were slightly higher than those washed with soap, the differences were not significant. Ester et al. (18) also found similar results in the strength of rayon, whether washed with soap or with a sulphated alcohol.

In regard to the superiority of one type of detergent over another it must be remembered that the foremost purpose of a detergent is its dirt removal properties, which have not been considered in this study. While greater strength retention may be indicated by one type of detergent, the fact that it is inferior in the removal of dirt may preclude its general use.

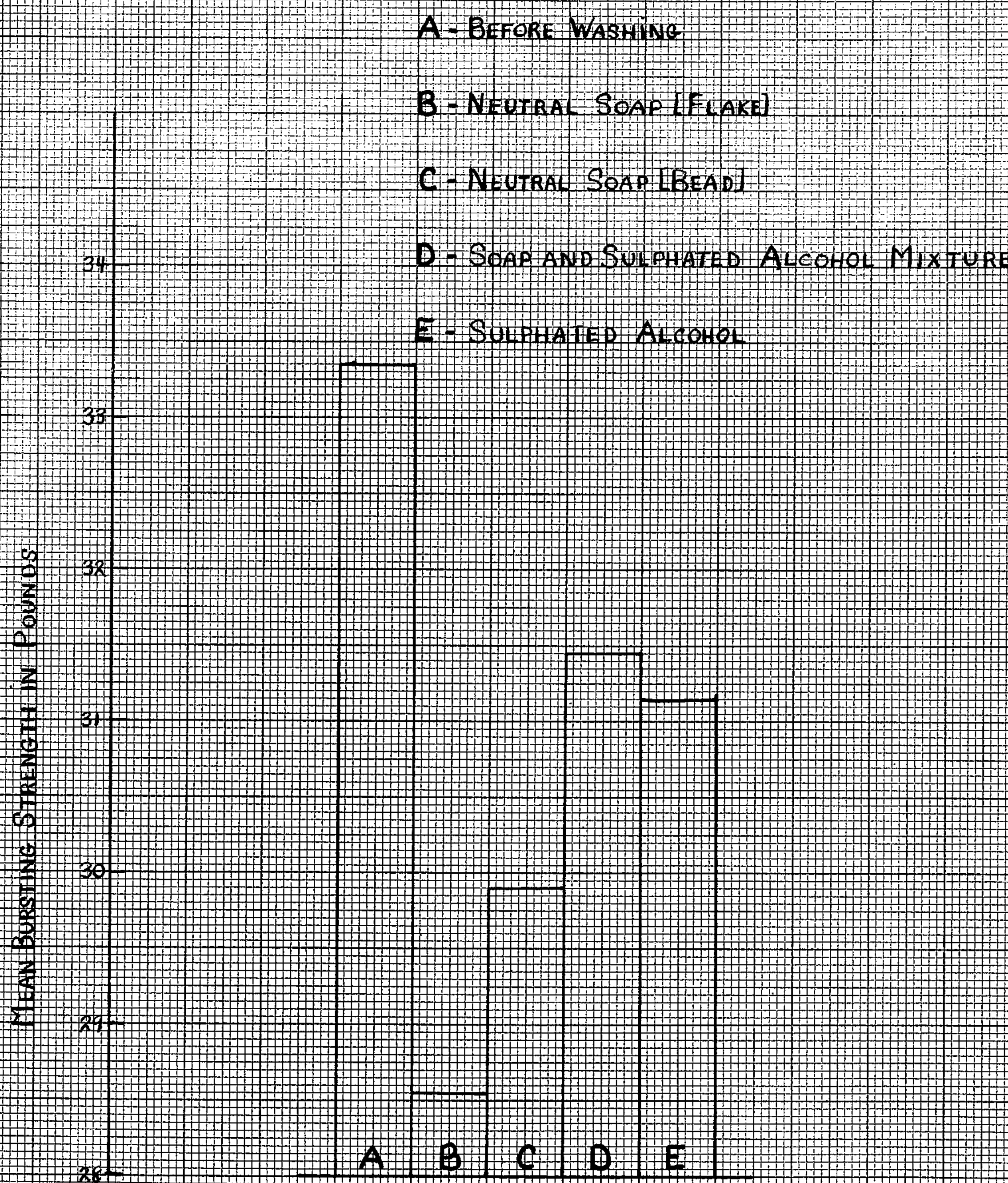

FIGURE I. BURSTING STRENGTH OF NYLON HOSE BEFORE AND AFTER LAUNDERING WITH FOUR DETERGENTS

Type of Water:

The mean bursting strengths of the hose washed in hard and distilled water are listed in Table 6.

TABLE 6. BURSTING STRENGTH IN POUNDS OF NYLON AND RAYON HOSE BEFORE AND AFTER LAUNDERING IN DISTILLED AND HARD WATER

	Control	Distilled Water	Hard Water
NYLON	33.35	30.91	29.62
RAYON	20.95	27.18	26.49

Although there appeared to be a tendency for the hose washed in soft water to remain slightly stronger than those washed in hard water, the difference was not significant. This result is surprising, due to the fact that most investigators (15) (30) (40) agree that hard water has a deteriorating effect on fabrics. However, Ester <u>et al</u>. (18) claimed that distilled and hard water gave similar results in the wet breaking strength of rayon. It is difficult to compare studies in which hardness of water is a factor, as the degree of hardness is often varied. In this study, the water was of ninety parts per million hardness, which is considered only moderately hard. If the water had been of a higher degree of hardness, it may be assumed that greater differences in strength between the soft and hard waters would have occurred. For example, Aust (13) used water of 272 parts per million hardness in washing silk fabrics and reported that the hard water caused greater losses than distilled water in both wet and dry strengths of the fabrics. Another instance indicating that varying degrees of hardness produced different strength values in washed fabrics was shown by Simola (45). He found that water with a hardness of 432 parts per million caused from 24 to 29 per cent loss in strength of linen and cotton while distilled water gave a weakening of from only 5 to 15 per cent.

Number of Washings:

Mean values for the bursting strength of nylon and rayon hose before and after one, fifteen, and thirty washings are listed in Table 7.

TABLE 7. BURSTING STRENGTH IN POUNDS OF NYLON AND RAYON HOSE WITH NUMBER OF WASHINGS

	Control	1 Washing	15 Washings	30 Washings
NYLON	33.35	27.57	30.87	32.36
RAYON	20.95	25.87	26.72	27.92

In the case of the nylon hose, there were highly significant differences for the strength of the hose between the number of washings, as illustrated in Figure 2. The hose appeared to lose considerable strength after one washing. However, strength gains were noted on further washings. Following thirty washings, the hose had practically regained their original bursting strength. The drop in strength after one washing might be attributed to the removal of water-soluble finishes present on the unwashed hose. The rise in strength values after fifteen and thirty washings is more difficult to explain. However, Van Antwerpen (49) attributes the increase in strength to the alignment of fibres, and an attendant distribution of strain.

The rayon hose also showed significant differences in strength with number of washings. These differences are illustrated graphically in Figure 3. The rayon hose contrasted with the nylon hose in that a decided increase in strength occurred after one washing, followed by more gradual increases up to thirty washings. Similar findings were reported by Richardson (41) who discovered increases from four to six pounds in the bursting strength of a cuprammonium rayon after twenty-five washings. Again, the increase in strength might be based on the previous theory offered by Van Antwerpen.

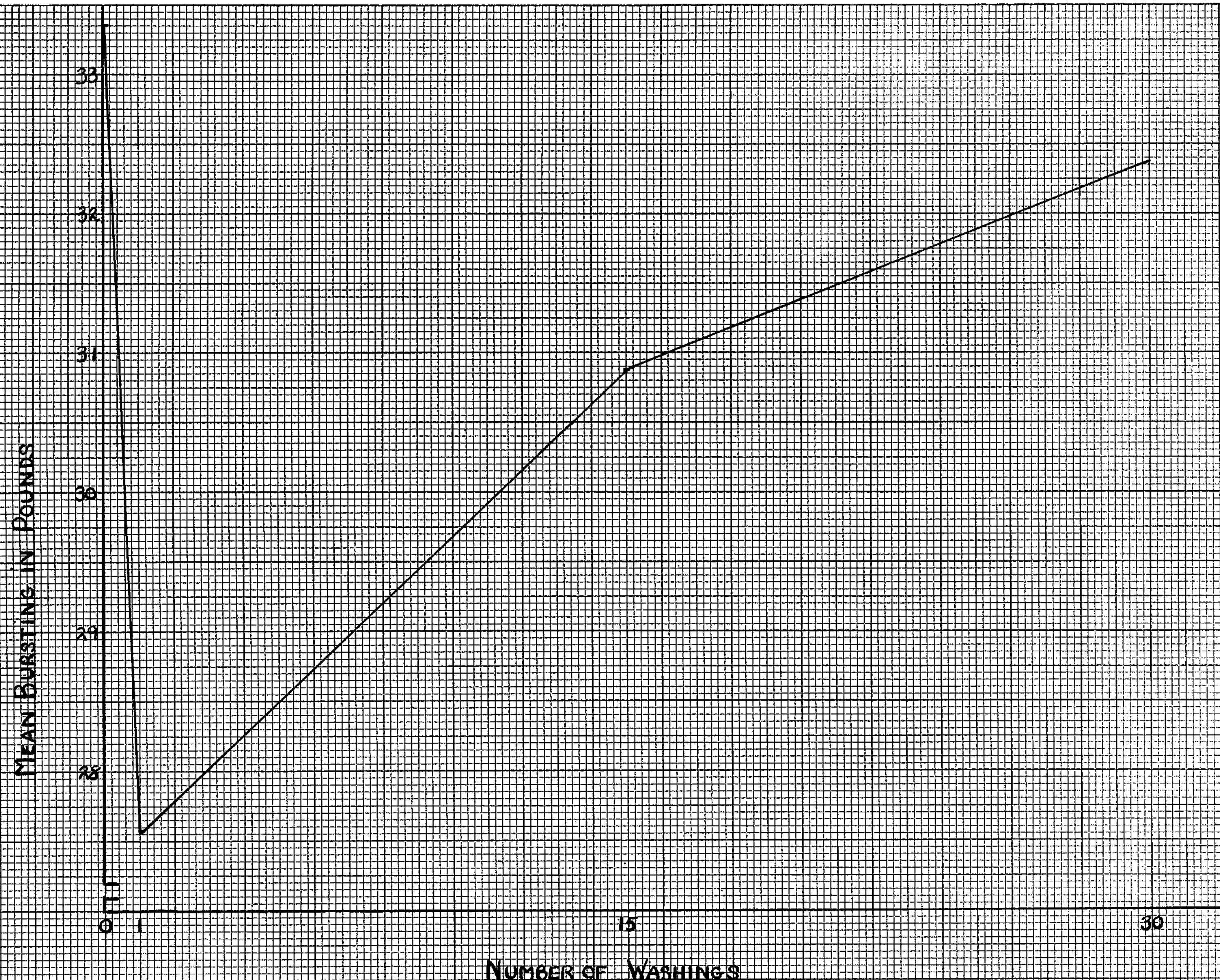

FIGURE 2. CHANGE IN BURSTING STRENGTH OF NYLON HOSE WITH NUMBER OF WASHINGS

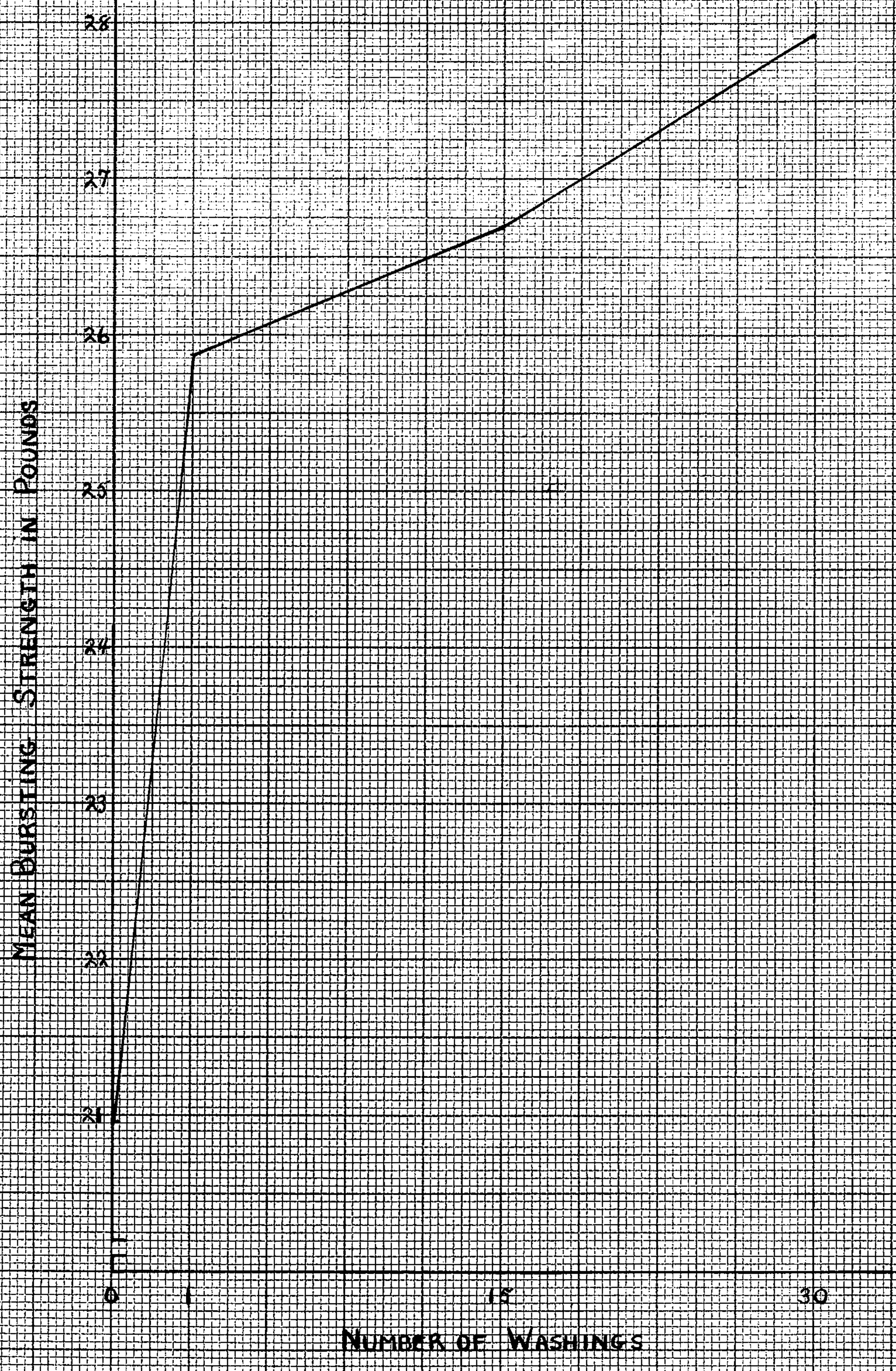

Figure 3. Change in Bursting Strength of Rayon Hose with Number of Washings

Number of Rinses:

Table 8 indicates the change in bursting strength of the nylon and rayon hose treated with one rinse and with three rinses.

TABLE 8. BURSTING STRENGTH IN POUNDS OF NYLON AND RAYON HOSE WITH NUMBER OF RINSES

	Control	One Rinse	Three Rinses
NYLON	33.35	31.09	29.43
RAYON	20.95	26.68	26.99

The nylon hose showed that the use of one rinse gave significantly higher bursting strength results than the use of three rinses, as shown in Figure 4. Because nylon hose are so sheer, they require careful handling. The decrease in strength after three rinsings may be attributed to the increased manipulation of the stockings during the rinsing process.

The case of the rayon hose, where no significant differences occurred in the strength or the hose with number of rinses, is more difficult to explain. However, the rayon yarn (75 denier) was considerably coarser than the nylon yarn (35) denier). This fact may account for its ability to withstand the increased number of rinses. It was concluded that the invariable instructions for thorough rinsing may not be necessary.

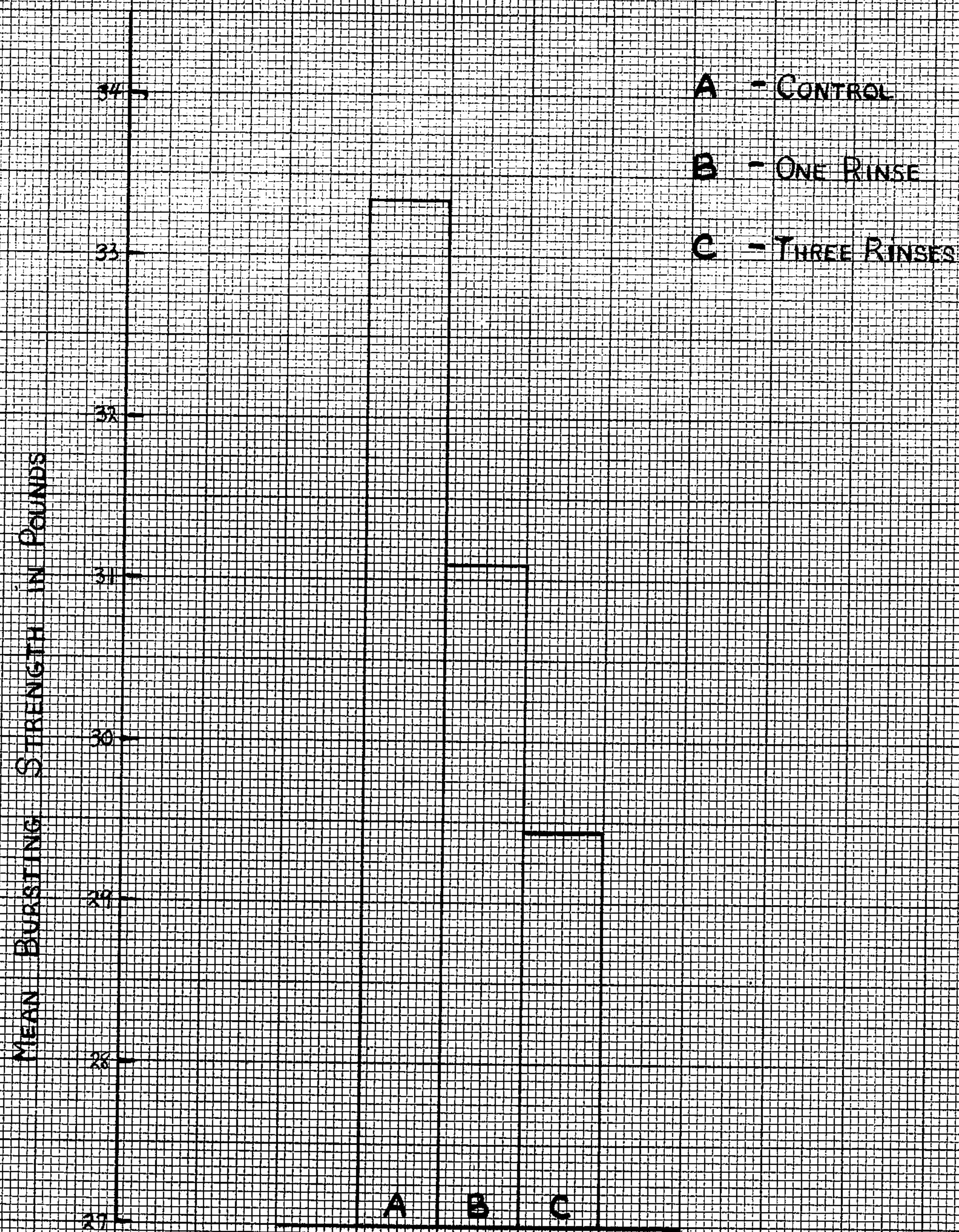

FIGURE 4. CHANGE IN BURSTING STRENGTH OF NYLON HOSE WITH NUMBER OF RINSES

Significant Interactions between the Various Washing Treatments:

In the washing of the rayon hose, the interaction between the type of water and the different types of detergents was highly significant. The bursting strength values of this interaction are listed in Table 9.

TABLE 9. BURSTING STRENGTH IN POUNDS OF RAYON HOSE SHOWING THE INTERACTION BETWEEN DETERGENTS AND TYPE OF WATER

	Control	Soap Flake	Bead Soap	Soap and Sulphated Alcohol	Sulphated Alcohol
Distilled Water	20.95	27.89	27.97	26.28	26.59
Hard Water	20.95	25.24	24.97	27.38	28.36

On observing Figure 5, it appears that soap gives higher bursting strength results than the synthetic detergent in distilled water. However, when hard water was used, the synthetic detergents were superior to the soaps in their effect on the strength of the fabric .

When fabrics are washed with soap in hard water, precipitates of hard water soaps are formed on the fabric. Van Antwerpen (49) attributes the loss in strength of such fabrics to the continued sorption of the detergent and precipitates of hard water soaps, which cause over-lubrication and slippage of fibres. The sulphated alcohol,however,does not precipitate hard water soaps and this fact may account for the greater strength retention of the rayon hose washed in this detergent.

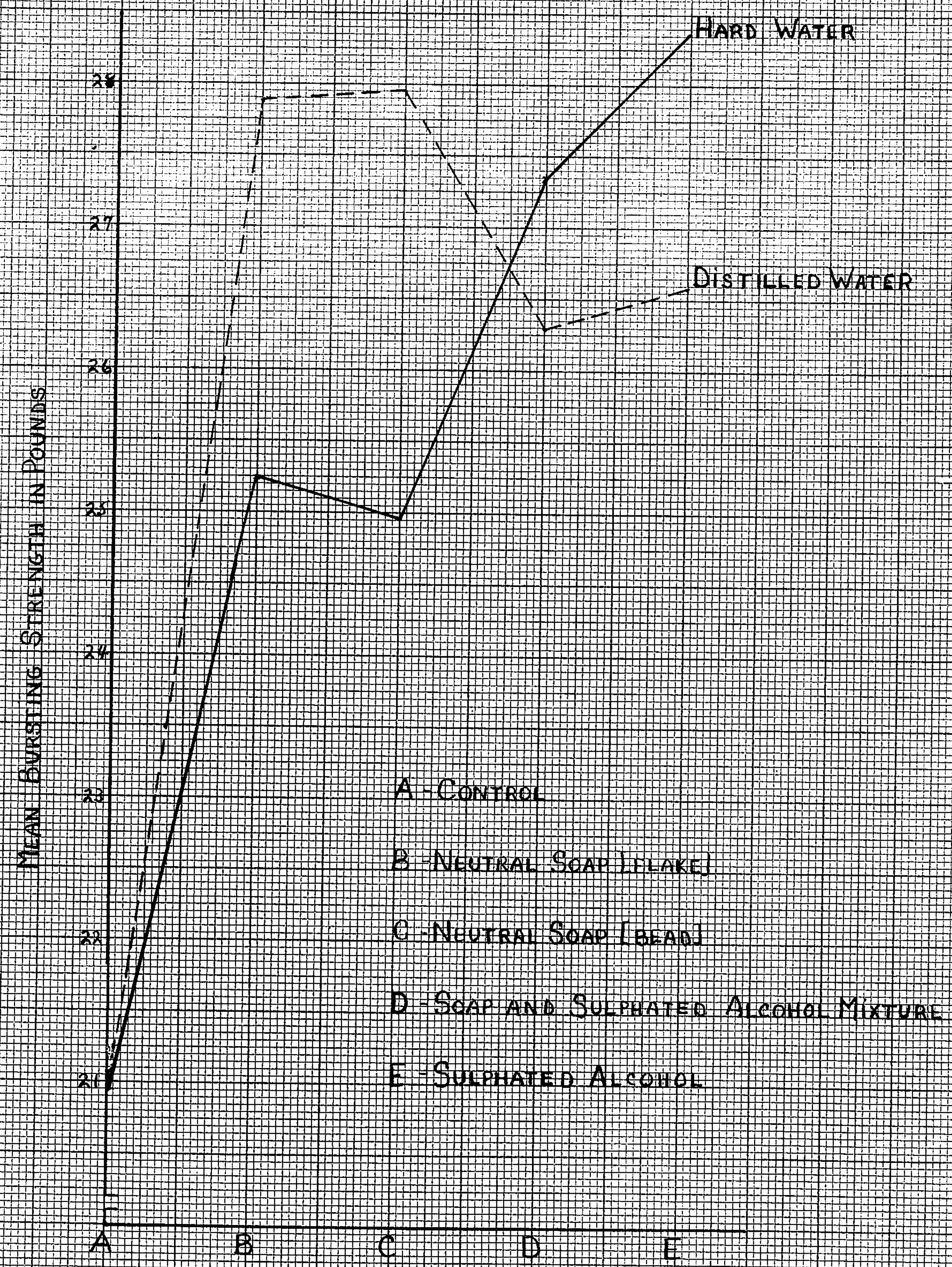

FIGURE 5. BURSTING STRENGTH OF RAYON HOSE BEFORE AND AFTER WASHING IN DISTILLED AND HARD WATER WITH FOUR DETERGENTS

The interaction of the type of water with the number of washings had a highly significant effect on the bursting strength of both the nylon and rayon hosiery. The mean values of the bursting strengths of the nylon and rayon hose, illustrating this interaction, are listed in Table 10.

TABLE 10. BURSTING STRENGTHS IN POUNDS OF NYLON AND RAYON HOSE SHOWING INTERACTION BETWEEN TYPE OF WATER AND NUMBER OF WASHINGS

	Control	1 Washing	15 Washings	30 Washings
NYLON				
Distilled Water	33.35	29.85	30.41	32.46
Hard Water	33.35	25.28	31.32	32.26
RAYON				
Distilled Water	20.95	27.36	25.84	28.34
Hard Water	20.95	24.38	27.59	27.49

In the case of the nylon hose (Figure 6), the bursting strength loss was considerably greater after one washing in hard water than after one washing in distilled water. However, following thirty washings, the bursting strength results for the hose washed in hard and distilled water were almost identical. This fact might be interpreted as indicating that there would be no particular advantage in using softened water in the washing of nylon hosiery. It must be remembered however, that hosiery are subjected to considerable strain in wearing and runs often occur during the initial periods of wear and laundering. If the strength can be maintained at a higher level during these periods with the use of soft water, it is reasonable to assume that the hose would give longer service.

In contrast to the nylon hose, the rayon hose (figure 7), gained in strength after one washing, the distilled water showing a much higher gain than the hard water. Like the nylon hose, the strength results following thirty washings were closely similar for the two types of water. The same reasoning suggested for washing the nylon hose in soft water might also apply here. No logical explanation could be found for the fact that after fifteen washings the hose washed in hard water appeared to be stronger than the hose washed in distilled water in both cases.

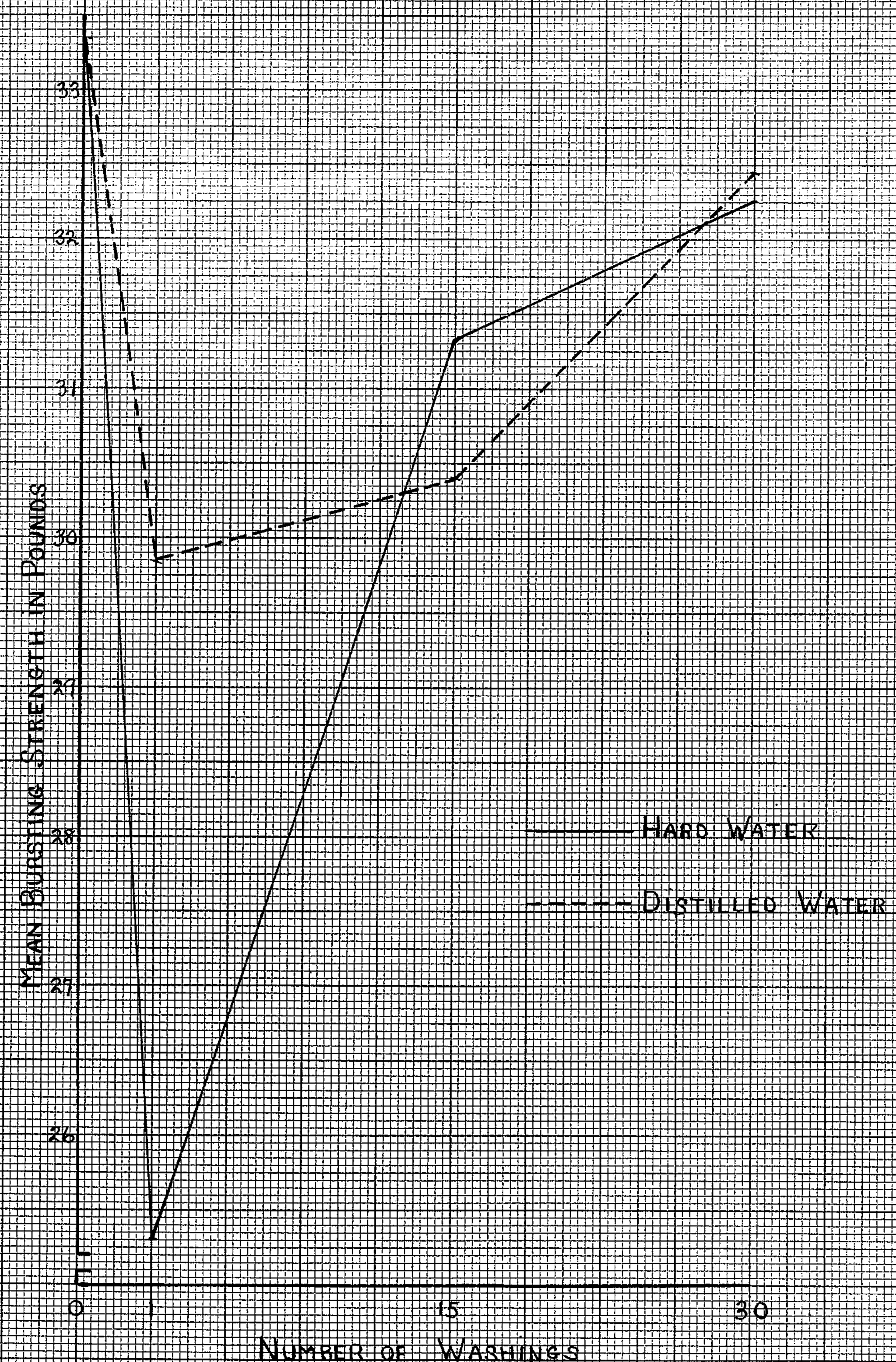

FIGURE 6. BURSTING STRENGTH OF NYLON HOSE BEFORE AND AFTER LAUNDERING IN DISTILLED AND HARD WATER

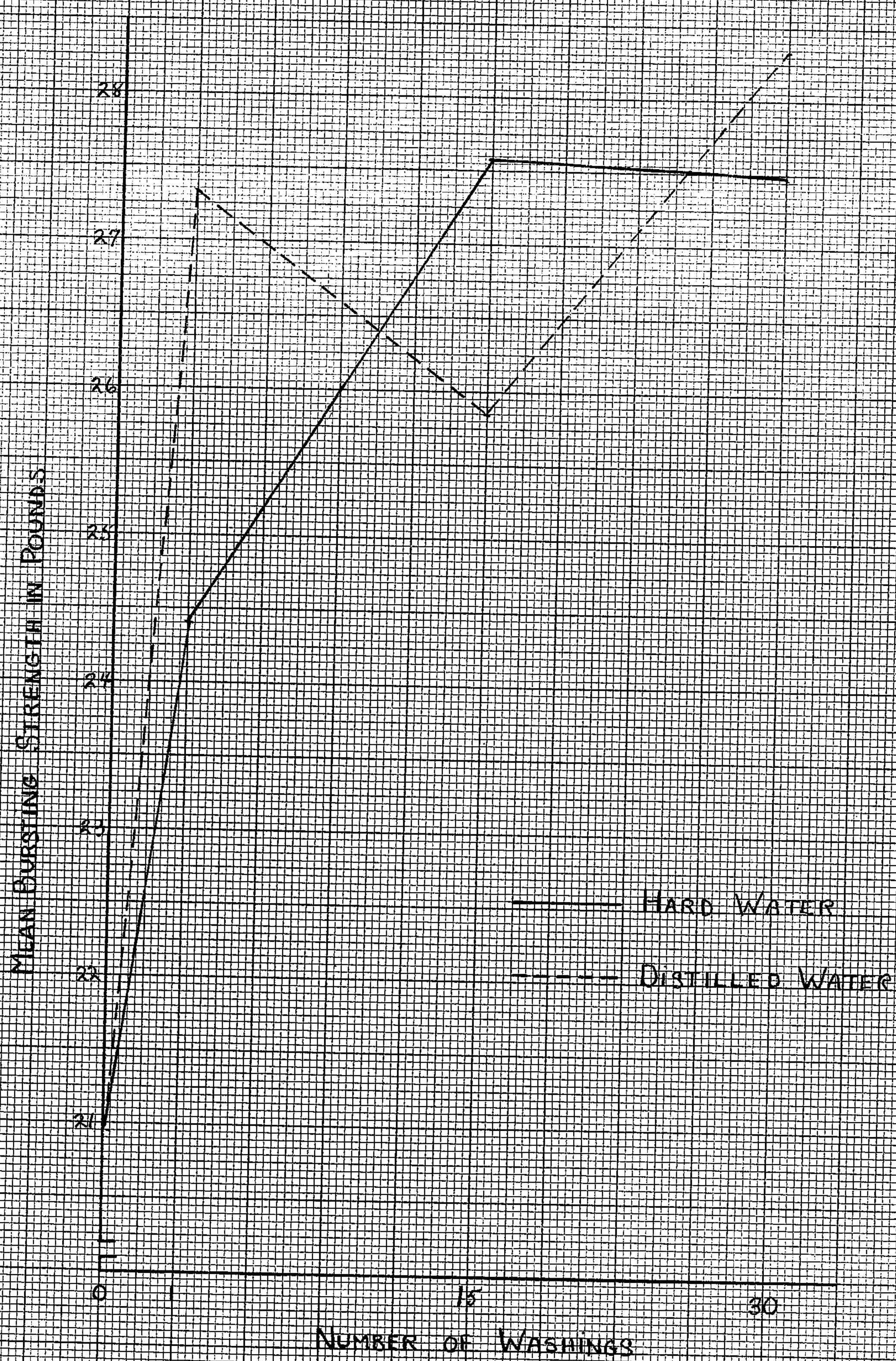

FIGURE 7. BURSTING STRENGTH OF RAYON HOSE BEFORE AND AFTER LAUNDERING IN DISTILLED AND HARD WATER

The bursting strength of rayon hose washed in distilled and hard water with one and three rinses is shown in Table 11. The results are illustrated graphically in Figure 8.

TABLE 11. BURSTING STRENGTH IN POUNDS OF RAYON HOSE SHOWING INTERACTION BETWEEN TYPE OF WATER AND NUMBER OF RINSES

	Control	One Rinse	Three Rinses
Distilled Water	20.95	26.45	27.92
Hard Water	20.95	26.90	26.07

Following one rinse, there appears to be little difference in the results obtained from the hard or the soft water. However, after three rinses the soft water gives an increase in strength while the hard water decreases the strength of the hose. Again, this may be due to the sorption of detergent and hard water soaps as previously suggested by Van Antwerpen (49).

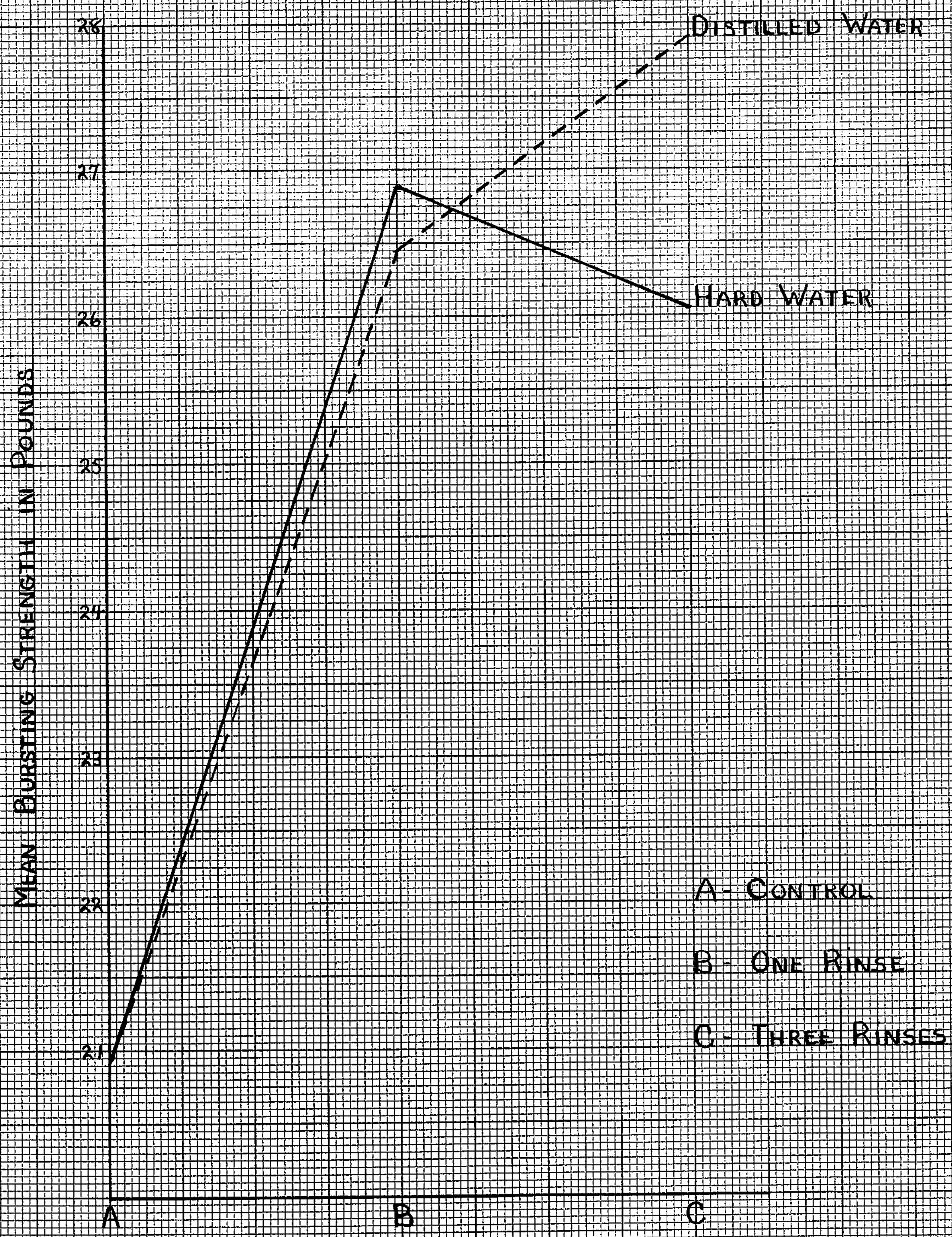

Figure 8. Bursting Strength of Rayon Hose Before and After Washing in Distilled and Hard Water with Number of Rinses

CHAPTER V

SUMMARY

Nylon and rayon hose were tested for change in bursting strength after one, fifteen, and thirty washings. Comparisons were made between four different detergents, a soap flake, a bead soap, a soap and sulphated alcohol, and a sulphated alcohol. Other comparisons were made between hard and soft water and between the use of one and three rinses.

Findings have been summarized as follows:

1. The detergents containing the sulphated alcohol appeared to be less destructive to the strength of nylon hose than the soaps. In the case of the rayon hose, there was no significant difference between the four detergents.

2. The data showed no significant differences between the use of hard or soft water in the washing of both the nylon and rayon hose. However, when the number of washings was considered, the hose washed with soft water were considerably stronger after one washing than those washed with hard water; whereas after thirty washings there was little difference between the two types of water.

3. The nylon hose showed decided loss in strength after one washing but increased in strength until, after

thirty washings, the hose had practically regained their original bursting strength. The rayon hose, however, gained in strength after one washing, followed by regular increases up to thirty washings.

4. In the rinsing of the nylon hose, the use of one rinse gave significantly higher bursting strength values than the use of three rinses. The rayon hose, however, showed no significant differences in the type of rinse employed. When the type of water was considered in the rinsing of the rayon hose, it was found that soft water was preferable to hard water if three rinses were used.

5. There was a highly significant interaction between the type of water and the type of detergent used in the washing of rayon hosiery. The synthetic detergents were superior to the soaps in strength retention when hard water was used. However, in the case of soft water, the soaps gave slightly higher strength values than the synthetic detergents.

Although interesting trends have been indicated by this study, further investigations are necessary to substantiate this report. A similar study, showing the effect on the wet strength of nylon and rayon hosiery after various washing treatments might help to answer some of the questions arising out of this study for which no satisfactory explanation could be found.

APPENDIX

TABLE I BREAKDOWN OF SAMPLE TREATMENTS INDICATED GRAPHICALLY

Twenty-four pairs of rayon and twenty-four pairs of naylon hose were used in the present study, The treatment received by each stocking is indicated below.

- 48 hose (24 pairs)
  - 24 hose washed in distilled water
    - 8 hose washed once
      - 4 hose treated as follows
        - 1 hose washed in detergent A & rinsed once
        - 1 hose washed in detergent B & rinsed once
        - 1 hose washed in detergent C & rinsed once
        - 1 hose washed in detergent D & rinsed once
      - 4 hose treated as follows
        - 1 hose washed in detergent A & rinsed 3 times
        - 1 hose washed in detergent B & rinsed 3 times
        - 1 hose washed in detergent C & rinsed 3 times
        - 1 hose washed in detergent D & rinsed 3 times
    - 8 hose washed 15 times
      - 4 hose treated as indicated above
      - 4 hose treated as indicated above
    - 8 hose washed 30 times
      - 4 hose treated as indicated above
      - 4 hose treated as indicated above
  - 24 hose washed in 90 p.p.hard water
    - 8 hose washed once
      - 4 hose treated as indicated above
      - 4 hose treated as indicated above
    - 8 hose washed 15 times
      - 4 hose treated as indicated above
      - 4 hose treated as indicated above
    - 8 hose washed 30 times
      - 4 hose treated as indicated above
      - 4 hose treated as indicated above

TABLE 11 BURSTING STRENGTH IN POUNDS OF NYLON HOSE AFTER VARIOUS WASHING TREATMENTS GIVING INDIVIDUAL BURSTS AND STOCKING TOTALS

	Distilled Water						Hard Water					
	1 washing		15 washings		30 washings		1 washing		15 washings		30 washings	
	1 rinse	3 rinses	1 rinse	3 rinses	1 rinse	3 rinses	1 rinse	3 rinses	1 rinse	3 rinses	1 rinse	3 rinses
Soap (flake)	29.0	25.0	28.0	30.5	33.0	30.5	17.0	19.0	20.5	26.5	25.5	26.5
	25.5	35.0	27.5	27.0	34.0	31.5	24.0	24.0	29.0	30.0	29.0	32.5
	28.0	36.0	35.5	29.5	33.0	30.5	30.0	26.5	25.5	31.5	26.5	20.5
	22.0	31.0	37.0	33.0	35.5	30.5	27.5	18.0	19.5	29.0	30.0	29.0
	24.5	32.5	27.5	35.5	35.0	25.5	29.0	24.0	17.0	27.5	37.5	34.0
	35.0	28.5	32.5	27.0	33.0	28.0	23.0	21.5	18.0	23.0	34.0	32.5
	22.0	25.0	31.0	23.5	36.5	29.5	24.0	30.0	24.0	32.5	28.0	26.5
	20.5	26.0	37.0	26.0	29.0	27.0	24.0	20.5	22.0	32.5	36.0	30.0
	23.0	32.5	30.5	27.0	33.0	29.0	24.0	29.0	20.5	30.0	36.0	32.5
	19.5	32.5	34.5	35.5	36.5	31.5	29.0	23.5	30.0	31.5	34.0	37.5
	249.0	304.0	321.0	294.5	338.5	293.5	251.5	236.0	226.0	294.0	316.5	301.5
Soap (bead)	22.5	26.5	26.0	35.5	30.5	31.5	26.5	18.0	35.0	29.0	30.5	24.0
	35.0	26.5	28.5	31.0	36.5	30.5	23.0	25.5	35.0	32.5	30.5	34.0
	36.0	33.5	26.0	26.0	33.0	32.0	23.0	25.5	36.0	30.0	37.5	31.5
	33.5	24.0	27.5	32.0	35.5	25.5	24.0	21.5	35.0	28.0	40.0	35.0
	39.0	26.5	26.0	26.0	39.0	29.0	19.0	21.5	36.0	36.0	30.5	36.5
	30.0	30.5	30.0	35.5	36.5	29.0	18.0	23.0	38.5	30.0	40.0	35.0
	32.5	20.5	27.5	24.5	35.0	33.0	24.0	24.0	25.5	32.5	30.0	28.0
	25.0	33.5	28.5	32.0	29.0	31.5	31.5	24.0	34.5	34.0	24.5	26.5
	32.5	31.0	34.5	35.5	31.5	28.0	25.5	24.0	34.0	29.0	30.0	29.0
	36.0	25.0	33.5	34.5	35.0	25.5	24.0	24.0	34.0	25.5	30.0	29.0
	322.0	277.5	288.0	312.5	341.5	295.5	238.5	231.0	343.5	306.5	323.5	308.5
Soap and Sulphated Alcohol	31.0	29.0	33.0	33.0	29.0	27.0	28.0	28.0	38.5	28.0	34.0	30.0
	24.0	34.0	32.0	28.5	34.0	37.5	26.5	23.5	32.5	29.0	37.5	35.0
	34.0	31.5	33.0	29.5	30.5	32.5	29.0	32.0	36.0	36.0	37.5	29.0
	31.0	25.5	33.5	27.0	37.5	33.0	24.0	21.5	36.0	27.5	32.5	34.0
	27.5	22.0	28.5	29.5	34.0	31.5	32.5	32.5	40.0	38.5	30.5	30.5
	34.0	27.0	29.0	33.0	26.5	37.5	24.0	28.0	42.5	26.5	35.0	34.0
	34.5	26.5	32.5	27.0	34.0	37.5	25.5	26.5	32.0	30.0	38.5	37.5
	28.0	29.0	33.5	24.5	35.5	34.0	24.0	20.5	38.5	29.0	30.5	35.0
	34.5	30.5	28.5	37.0	32.5	35.0	29.0	26.5	40.0	36.0	34.0	29.0
	30.0	35.0	32.0	29.5	31.5	33.0	27.5	29.0	41.0	29.0	35.0	34.0
	308.5	290.0	315.5	298.5	325.0	338.5	270.0	268.0	377.0	309.5	345.0	328.0
Sulphated Alcohol	26.5	32.0	31.0	27.0	35.0	34.0	27.5	21.5	34.0	26.5	35.0	29.0
	33.0	27.5	30.0	28.5	37.5	29.0	26.5	21.5	37.5	25.5	35.0	29.0
	36.5	31.5	33.5	29.5	35.0	31.5	26.5	26.0	39.0	30.0	36.5	29.0
	36.5	35.0	31.0	28.5	25.5	29.0	33.5	20.5	31.5	23.0	31.5	31.5
	30.5	32.5	29.0	28.5	28.0	34.0	25.5	23.0	30.0	29.0	37.5	29.0
	37.5	26.5	31.0	30.5	39.5	35.5	21.5	29.0	40.0	37.5	40.0	29.0
	25.5	29.0	26.0	30.5	33.0	36.5	33.5	21.5	36.0	28.0	35.0	32.5
	26.5	30.0	31.0	30.5	31.0	34.0	32.5	21.5	29.5	34.0	36.5	30.0
	39.0	33.5	33.5	28.5	33.0	31.5	19.0	29.0	31.5	32.5	30.5	28.0
	34.5	33.5	35.5	29.5	36.5	35.0	36.5	31.5	40.0	34.0	41.5	31.5
	326.0	311.0	311.5	291.5	334.0	330.0	282.5	245.0	349.0	300.0	359.0	298.5

TABLE III BURSTING STRENGTH IN POUNDS OF RAYON HOSE AFTER VARIOUS WASHING TREATMENTS GIVING INDIVIDUAL BURSTS AND STOCKING TOTALS

	Distilled Water						Hard Water					
	1 washing		15 washings		30 washings		1 washing		15 washings		30 washings	
	1 rinse	3 rinses	1 rinse	3 rinses	1 rinse	3 rinses	1 rinse	3 rinses	1 rinse	3 rinses	1 rinse	3 rinses
Soap (flake)	21.5	33.5	23.5	30.5	31.5	28.0	18.0	26.5	26.5	23.0	27.5	28.0
	27.5	30.5	21.5	28.5	32.5	26.0	20.5	24.5	29.0	26.5	27.5	28.0
	25.5	35.0	20.5	23.5	27.5	28.5	24.0	25.5	29.0	29.0	26.5	23.0
	30.0	32.5	22.0	28.0	30.0	28.5	15.5	26.5	30.0	30.0	20.0	21.5
	20.5	33.5	22.0	26.0	31.5	27.0	18.0	26.5	26.5	21.5	27.5	28.0
	26.5	33.5	23.5	32.0	29.0	27.0	18.0	26.5	31.5	24.0	30.0	26.5
	26.5	26.5	23.5	32.0	31.5	27.0	18.0	23.5	29.0	23.0	30.0	31.5
	25.5	29.0	26.5	23.5	31.5	26.0	19.0	19.0	30.0	25.5	28.5	26.5
	29.0	30.0	28.5	30.5	29.0	30.5	23.0	23.0	26.5	28.0	25.0	25.5
	27.5	30.0	23.0	27.0	31.5	29.5	23.0	23.0	25.5	24.0	28.5	25.5
	260.0	314.0	234.5	281.5	305.5	278.0	197.0	244.5	283.5	254.5	271.0	264.0
Soap (bead)	28.5	34.5	27.0	29.5	28.5	30.5	27.5	20.5	26.5	29.0	27.0	25.0
	26.0	31.0	21.5	26.0	33.0	29.5	24.0	18.0	23.0	30.0	29.0	21.0
	26.0	30.0	21.0	28.5	23.5	30.5	23.5	14.5	23.0	29.0	23.0	23.5
	24.0	27.5	23.0	28.5	32.0	29.5	25.5	24.0	25.5	26.5	20.5	25.0
	26.0	29.5	20.0	28.5	27.5	29.5	21.5	27.5	23.0	24.0	22.0	28.5
	27.0	27.5	26.0	29.5	27.5	30.5	23.0	19.0	24.0	30.0	27.0	19.0
	26.0	28.5	26.0	30.5	29.5	28.5	26.5	23.0	28.0	23.0	27.0	26.5
	27.0	28.5	20.0	30.5	25.5	30.5	23.0	28.0	20.5	25.5	24.5	25.5
	26.0	34.5	26.0	27.0	32.5	28.5	28.0	26.5	31.5	21.5	29.0	29.0
	26.0	31.0	25.0	32.5	32.5	27.0	27.5	24.0	29.0	21.5	29.0	28.0
	262.5	302.5	235.5	291.0	292.0	294.5	250.0	225.0	254.0	260.0	258.0	251.0
Soap and Sulphated Alcohol	26.0	32.0	22.5	27.5	30.0	30.5	28.0	26.5	32.5	27.0	29.0	32.5
	26.0	22.5	26.0	25.0	30.0	30.0	26.5	23.0	30.0	29.0	30.5	30.5
	23.5	21.5	23.5	25.0	29.0	28.5	25.5	17.0	21.5	20.5	29.0	28.5
	26.0	19.0	21.0	27.5	26.5	28.5	23.0	28.0	31.5	27.5	28.0	28.5
	26.5	25.0	23.5	23.5	24.0	32.0	26.5	29.0	29.0	28.5	30.5	27.5
	16.5	28.5	23.5	25.0	29.0	27.5	26.5	19.0	28.0	29.0	30.5	30.0
	30.0	26.5	20.0	31.0	25.5	27.5	28.0	29.0	30.0	26.5	29.0	27.5
	30.0	33.5	20.0	30.5	27.5	25.0	23.0	20.5	30.5	24.0	28.0	28.5
	26.5	25.5	23.5	27.5	27.5	24.0	23.0	25.5	36.0	24.0	25.5	28.5
	26.5	29.0	26.0	27.0	31.5	23.5	29.0	28.0	30.5	28.5	24.5	27.5
	257.5	263.0	229.5	269.5	280.5	277.0	259.0	245.5	299.5	264.5	284.5	289.5
Sulphated Alcohol	31.5	26.0	29.5	27.5	28.0	29.5	24.0	29.0	31.5	29.5	31.0	24.0
	21.5	29.5	31.0	26.0	29.0	23.5	24.0	29.0	34.0	27.0	31.0	27.5
	29.0	22.5	23.5	25.0	28.0	25.0	26.5	28.0	30.0	29.5	28.5	27.5
	22.0	27.5	26.0	26.0	28.0	26.0	25.5	25.5	34.0	29.5	33.0	28.5
	21.5	31.0	27.5	25.0	27.0	30.5	23.0	29.0	31.5	29.0	30.5	29.5
	27.5	29.5	27.5	28.0	25.5	28.0	25.5	29.0	30.0	26.0	28.0	22.0
	31.0	26.0	31.0	19.5	24.5	28.5	19.5	30.0	34.0	26.0	29.0	31.0
	29.5	26.0	22.5	27.0	25.5	24.5	25.5	27.5	32.5	27.0	31.5	28.0
	30.0	22.5	30.0	21.5	28.0	27.0	25.5	30.5	34.0	22.5	31.5	29.0
	25.5	20.0	28.5	23.5	27.0	27.0	26.5	26.5	31.5	22.0	29.0	31.0
	269.0	260.5	277.0	249.0	270.5	269.5	245.5	284.0	323.0	268.0	303.0	278.0

TABLE IV. BURSTING STRENGTH IN POUNDS OF NYLON HOSE AFTER VARIOUS WASHING TREATMENTS GIVING STOCKING MEANS

	DW				HW			
	D1	D2	D3	D4	D1	D2	D3	D4
C	33.35							
W1R1	24.90	32.20	30.85	32.60	25.15	23.85	27.00	28.25
R2	30.40	27.75	29.00	31.10	23.60	23.10	26.80	24.50
W2 R1	32.10	28.80	31.55	31.15	22.60	34.35	37.70	34.90
R2	29.45	31.25	29.85	29.15	29.40	30.65	30.95	30.00
W3 R1	33.85	34.15	32.50	33.40	31.65	32.35	34.50	35.90
R2	29.35	29.55	33.85	33.00	30.15	30.85	32.80	29.85

TABLE V. BURSTING STRENGTH IN POUNDS OF NYLON HOSE, SHOWING MEAN VALUES OF MAIN EFFECTS AND SIMPLE INTERACTIONS OF THE TREATMENTS.

	R1	R2	DW	HW	W1	W2	W3	
D1	28.37	28.73	30.01	27.09	26.01	28.39	31.25	28.55
D2	30.95	28.86	30.62	29.19	26.73	31.26	31.72	29.90
D3	32.35	30.54	31.27	31.63	28.41	32.51	33.41	31.45
D4	32.70	29.60	31.73	30.57	29.11	31.30	33.04	31.15
					27.57	30.87	32.36	
W1	28.10	27.03	29.85	25.28				
W2	31.64	30.09	30.41	31.32				
W3	33.54	31.18	32.46	32.26				
			30.91	29.62				
DW	31.50	30.31						
HW	30.68	28.55						
	31.09	29.43						

Key to Tables IV and V:

C - control

R1 - one rinse
R2 - three rinses

DW - distilled water
HW - hard water

D1 - soap flake
D2 - bead soap
D3 - soap & sulphated alcohol mix.
D4 - sulphated alcohol

W1 - one washing
W2 - fifteen washings
W3 - thirty washings

TABLE VI. BURSTING STRENGTH IN POUNDS OF RAYON HOSE AFTER VARIOUS WASHING TREATMENTS GIVING STOCKING MEANS

		DW				HW			
		D1	D2	D3	D4	D1	D2	D3	D4
C		20.95							
W1	R1	26.00	26.25	25.75	26.90	19.70	25.00	25.90	24.55
	R2	31.40	30.25	26.30	26.05	24.45	22.50	24.55	28.40
W2	R1	23.45	23.55	22.95	27.70	28.35	25.40	29.95	32.30
	R2	28.15	29.10	26.95	24.90	25.45	26.00	26.45	26.80
W3	R1	30.55	29.20	28.05	27.05	27.10	25.80	28.45	30.30
	R2	27.80	29.45	27.70	26.95	26.40	25.10	28.95	27.80

TABLE VII. BURSTING STRENGTH IN POUNDS OF RAYON HOSE, SHOWING MEAN VALUES OF MAIN EFFECTS AND SIMPLE INTERACTIONS OF THE TREATMENTS

	R1	R2	DW	HW	W1	W2	W3	
D1	25.86	27.28	27.89	25.24	25.39	26.35	27.96	26.58
D2	25.87	27.07	27.97	24.97	26.00	26.01	27.39	26.48
D3	26.84	26.82	26.28	27.38	25.63	26.58	28.29	26.83
D4	28.13	26.82	26.59	28.36	26.48	27.93	28.03	27.48
					25.87	26.72	27.92	
W1	25.01	26.74	27.36	24.38				
W2	26.71	26.73	25.84	27.59				
W3	28.31	27.52	28.34	27.49				
			27.18	26.49				
DW	26.45	27.92						
HW	26.90	26.07						
	26.68	26.99						

Key to symbols used in Tables VI and VII:

C - control

R1 - one rinse
R2 - three rinses

DW - distilled water
HW - hard water

D1 - soap flake
D2 - bead soap
D3 - soap & sulphated alcohol mixture
D4 - sulphated alcohol

W1 - one washing
W2 - fifteen washings
W3 - thirty washings

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