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FACTORS AFFECTING THE PERFORMANCE OF HOSIERY ON THE HOSIERY-TESTING MACHINE

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ABSTRACT

The results which have been obtained on the hosiery-testing machine since the publication of Research Paper RP679 are discussed. It is shown that laundering, dyeing, aging, finishing, and construction all have a great effect on the distensibility, elasticity, and endurability of the stockings on repeated distention. The information given furnishes a necessary background for the use of the machine for hosiery testing and demonstrates its suitability for researches in knitting, degumming, dyeing, finishing, aging, laundering, redyeing, and refinishing of hosiery.

CONTENTS

I. INTRODUCTION

The need for a comprehensive study of the various factors which may affect the performance of hosiery on the hosiery-testing machine of the National Bureau of Standards was indicated in Research Paper RP679.[1] Although it has not been possible to study hosiery manufactured under strictly controlled conditions and sampled at the successive stages in the process, a large number of women's full-fashioned stockings have been tested. These tests provide information on the effects of laundering, dyeing, aging, finishing, and construction on the performance of the stockings on the machine.

The purpose of this paper is to summarize the results of these tests and thus furnish a necessary background for those who would use the machine for hosiery testing.

[1] Herbert F. Schiefer and William D. Appel, *Hosiery-testing machine.* BS J. Research, 12, 543–49 (1934) RP679.

II. TEST PROCEDURE

A standardized laundering treatment was made the first step in the test procedure because it is customary to launder stockings frequently, and because stockings may give very different results when tested on the machine before and after laundering. This was shown in the previous paper and is confirmed further along in this one.

The stocking to be laundered was placed in a pint jar containing 200 ml of soap solution at 100° F. The soap solution contained 0.5 percent of "neutral" soap[2] dissolved in distilled water. The jar was agitated for 30 minutes in a Launder-Ometer.[3] The stocking was removed from the jar and rinsed in 4 changes of water at 100° F. The excess water was removed by centrifuging and the stocking dried on a hosiery form in a current of air at room temperature.

The hosiery-testing machine and the test procedure given in Research Paper RP679 [1] were used.

The curves plotted by the hosiery-testing machine show the load necessary to distend the upper part of the leg of the stocking to any extent between a minimum and maximum circumference, 13.3 and 21.3 inches in these tests, for a series of loading and unloading cycles. They give a complete record of the ability of the stocking to distend, its recovery after distending to the maximum circumference, and the change in these characteristics on repeated distention.

It is neither convenient nor necessary to use the entire series of curves or in fact the entire curve for any 1 cycle in expressing the essential results of a test. For example, an examination of the curves shows that the circumference, at a load of 30 pounds, taken from the loading curve in the first cycle of test is a criterion of the ease with which the stocking can be distended. In this paper this characteristic is called the "distensibility" of the stocking and the circumference in inches at a load of 30 pounds in the first cycle of the test is taken as the measure of distensibility. The maximum load on the stocking in the first cycle of test is also reported, since it may be of interest.

Similarly, the algebraic difference between the circumference of the stocking at a load of 30 pounds in the first cycle and the circumference at a load of 10 pounds in the two-hundredth cycle is taken as the measure of the tendency of the stocking to recover its original circumference after repeated loading, here called the "elasticity" of the stocking.

The number of cycles of the test required to produce a failure, that is, a hole in the stocking, is taken as the measure of "endurability" of the stocking.

By looking at the load-elongation curves of the first and two-hundredth cycles one can tell immediately whether or not a stocking has high or low distensibility and elasticity. Excellent examples are shown by the curves in B of figure 9, in which the solid curves represent a stocking having high distensibility and elasticity and the broken curves represent one having low distensibility and elasticity. In the former the curve for the first cycle rises rapidly as the load is increased and the curve for the two-hundredth cycle remains relatively close to the curve for the first cycle. Because of its high distensibility

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[1] See footnote 1, p. 1.

[2] Federal Specification P-S-566.

[3] In the Launder-Ometer the jar is attached to a horizontal shaft with the base of the jar toward the shaft 2 inches from the center of rotation. The shaft is rotated at a speed of 40 to 45 rpm. The temperature is maintained constant by a water bath in which the jar is rotated.

this stocking can accommodate itself readily to the shape of the leg of the wearer without creating large stresses in the fabric, and because of its high elasticity it continues to fit the leg with use. In the latter the curve for the first cycle rises slowly as the load is increased and the curve for the two-hundredth cycle is separated considerably from the curve for the first cycle. Because of its low distensibility this stocking causes binding on the leg of the wearer and creates large stresses in the fabric, and because of its low elasticity it ceases to fit the leg with use. The endurabilities of the stockings are obtained from the counter on the machine and not from the load-elongation diagram.

The individual calibrations of the hosiery-testing machine over a period of 6 months check each other very closely. The uncertainty in the load at 10 pounds is less than 0.5 pound and at 100 pounds less than 2 pounds. The uncertainty in the circumference is less than 0.1 inch. Variations in the load-elongation diagrams between stockings, which are considerably greater than these values, must be attributed to actual differences between the stockings.

III. EFFECT OF LAUNDERING

It is obvious that the method of laundering, the materials used, and the manner of drying after laundering would have an appreciable effect on the behavior of the stockings on the machine and probably in actual use. Stockings laundered by the ordinary home method without boarding were found to behave differently from stockings laundered in accordance with the procedure used in this study. A stocking which was boarded and dried at elevated temperature had a harsher feel and a lower endurability than a similar stocking which was boarded and dried at room temperature. An extensive study of the effects of these factors was not made in this investigation. It is a fruitful field for future studies. In this paper the effect produced by laundering stockings in accordance with the procedure described in section II, is discussed.

The following discussion is based upon tests made on 89 pairs of stockings obtained from 13 hosiery mills. The stockings were knit according to definite construction specifications from 3-, 4-, 5-, and 7-thread silk yarn on 42- and 45-gage full-fashion knitting machines. Approximately one-half of them were knit with 6 more courses per inch than those of the other half. The specifications did not require that the stockings from the different mills should be degummed, dyed, and finished by the same procedure.

One stocking of each pair was tested as received from the mills. The other stocking of each pair was laundered and then tested. In 45 pairs the endurability of the unlaundered and laundered stockings was greater than 1,000 cycles, while in 15 pairs the endurability of the unlaundered and laundered stockings was less than 1,000 cycles. In 21 pairs the endurability of the unlaundered stockings was less than 1,000 cycles and of the laundered stockings it was greater than 1,000 cycles, while in the remaining 8 pairs the opposite was found.

That the same laundering treatment does not have the same effect on all stockings is clearly indicated by these results and by typical curves of 4 pairs shown in figure 1. The 4 pairs were obtained from 4 different hosiery mills, but were knit according to the same construction specification, namely from 4-thread silk yarn on 42-gage knitting machines with 42 courses per inch.

The laundering treatment did not have an appreciable effect on the behavior of the stockings represented by the curves in A and B of figure 1. The curves in A are for a pair in which the endurability of both stockings was greater than 1,000 cycles. The curves in B are for a pair in which it was less than 200 cycles for both stockings

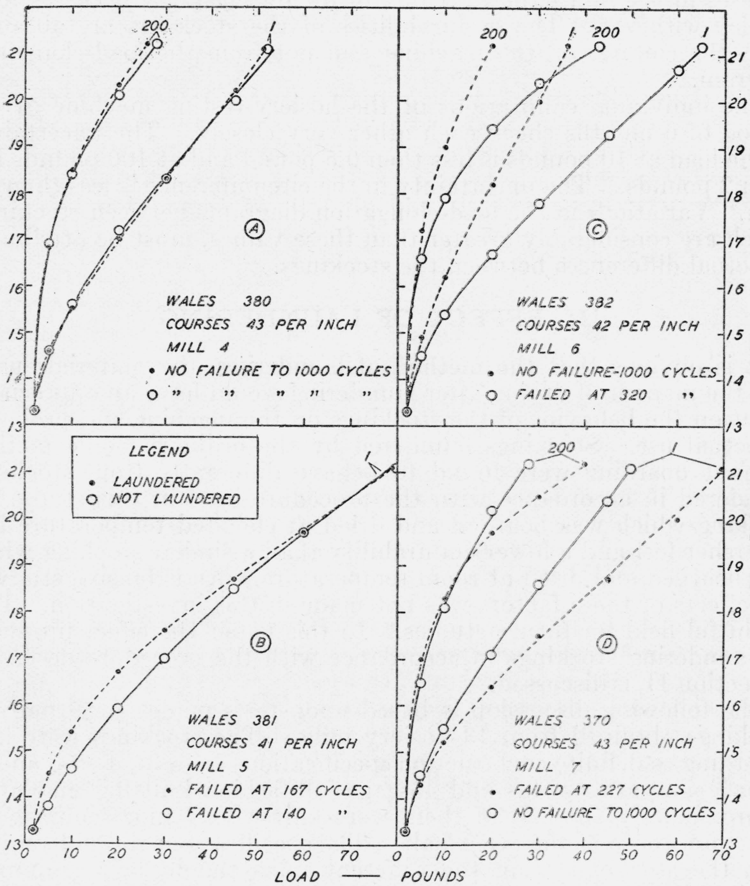

FIGURE 1.—*The effect of laundering on the performance of 4 pairs of stockings.*

These stockings were knit on 42-gage knitting machines from 4-thread silk yarn. The total number of wales exclusive of the seam, the courses per inch, and the number of cycles of test are indicated in the chart. The numbers on the curves indicate the loading cycle.

The laundering treatment did have a great effect on the behavior of the stockings represented by the curves C and D of figure 1. The effect shown in C, however, is the opposite from that shown in D. In C the endurability of the unlaundered stocking was 320 cycles and for the laundered stocking it was greater than 1,000 cycles. In D the endurability of the unlaundered stocking was greater than 1,000 cycles and for the laundered stocking it was 227 cycles.

The effect of laundering probably depends chiefly upon the treatments of the stockings after they are knit, since these stockings were all knit according to the same construction specification. This conclusion is confirmed later in this paper.

The difference in the curves for stockings which have an endurability greater than and less than 1,000 cycles is very striking and should also be noted in the subsequent figures. In general a stocking with an endurability less than 1,000 cycles has less distensibility and elasticity than a stocking with an endurability greater than 1,000 cycles.

IV. EFFECT OF DYEING AND AGING

Two series of stockings, one degummed and the other degummed and dyed, were obtained for this study. The stockings were all knit on 1 knitting machine using the same construction and the same lot of silk. There were 48 stockings, 24 of which were knit simultaneously on the machine. All of the stockings were degummed simultaneously and one-half of the degummed stockings were then dyed simultaneously. The stockings for each series were stated to be as nearly alike as practicable in ordinary manufacturing.

Part of the degummed and of the dyed stockings were tested on the hosiery-testing machine 3 days after they had been received at the Bureau. The remaining stockings were tested approximately 20 days after they had been received. During this period the stockings were continuously exposed to the conditions prevailing in the room of constant temperature and relative humidity. Some of the stockings which were tested at the latter period were laundered before testing.

The results for the individual tests on the unlaundered stockings are given in figure 2. They show that differences between stockings stated to be manufactured as nearly alike as is practicable in the industry can be measured on the hosiery-testing machine. The difference between individual stockings with respect to the maximum load of the first cycle may be as large as 20 percent and with respect to the distensibility may be as large as 5 percent. These differences are at least 10 times as great as the uncertainty in the calibration of the machine. They may be due to a number of causes, such as variations in the silk yarn, which are known to be appreciable, variations between sections of the knitting machine, variations in the tensions on the yarn, and variations in uniformity of degumming, dyeing, and finishing, and variations in boarding. Since the differences in the above results may be caused by several of these variations, these data do not lend themselves to a determination of the factors which caused the observed differences. For such a study a more extensive series of stockings should be knit by deliberately varying 1 factor at a time. This study may be well worth while undertaking since a sensitive test is now available. For the present paper the discussion is confined to the effect of those factors which can be shown to have caused large variations.

The effect of dyeing on the stockings is indicated by the difference between the average curves, A and C for stockings tested 3 days after being received, or B and D for stockings tested approximately 20 days after being received. The effect of aging on the degummed stockings is shown by the difference between the average curves A and B, and on the dyed stockings by the difference between the average curves C and D. The average distensibility, elasticity, endurability, and maximum load of the first cycle are given in table 1.

These data bring out 3 interesting facts, namely: (1) That the hosiery-testing machine is sufficiently sensitive to measure differences which occur in hosiery manufactured to be as nearly alike as practicable; (2) that dyeing decreased the distensibility, elasticity, and endurability of degummed stockings; (3) that aging decreased the distensibility, elasticity, and endurability of both the degummed and the dyed stockings.

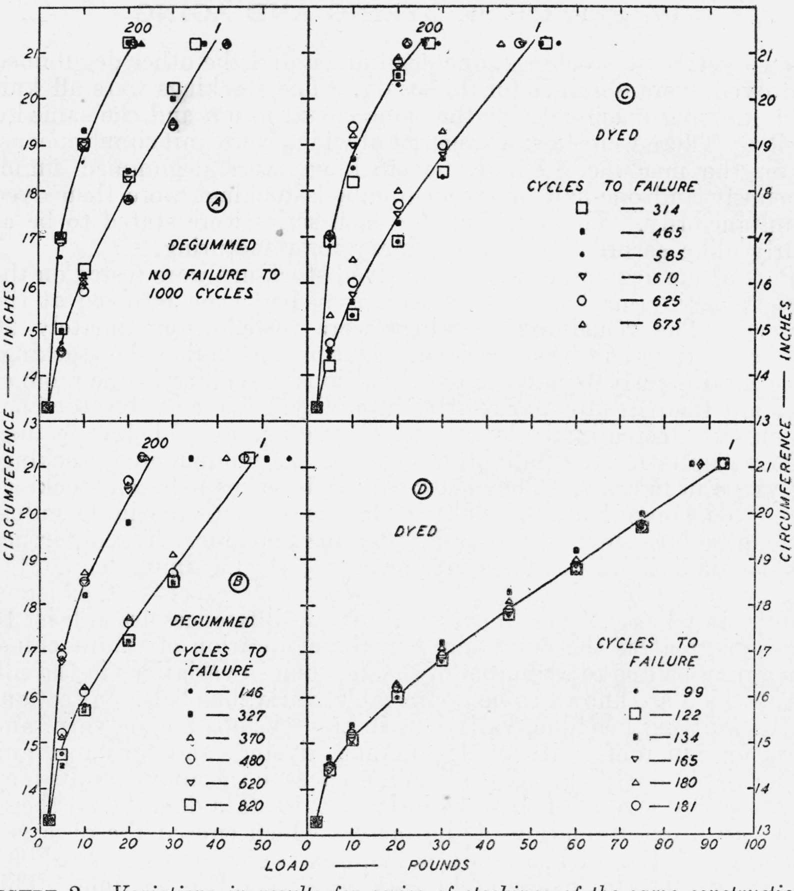

FIGURE 2.—*Variations in results for series of stockings of the same constructions taken from the same lots.*

All of the stockings represented in this figure were made at the same time by 1 manufacturer and were degummed in the same bath. Six stockings in each of the groups listed below were tested and the results for individual stockings are indicated by the symbols. Data for the first loading cycle are given and for the two-hundredth loading cycle when failure occurred after 200 cycles of test. The numbers on the curves indicate the loading cycle. A. Degummed stockings, tested 3 days after being received. B. Degummed stockings, tested approximately 20 days after being received. C. Degummed and dyed stockings, tested 3 days after being received. D. Degummed and dyed stockings, tested approximately 20 days after being received.

Tests on 2 similar series of stockings which were obtained from a second mill confirmed the results given above.

The effects of dyeing, aging, and laundering on all of the stockings from these 2 mills are shown very clearly in figure 3 and in table 1, where the average results are given for the various conditions. It is apparent that conclusions 2 and 3 are confirmed by these results for the stockings from the 2 mills. These data, however, bring out other interesting facts which will be discussed more fully.

TABLE 1.—*Results showing the effect of dyeing, aging, and laundering on the performance of stockings from mills 1 and 2*

Mill number	Condition of stocking	Time elapsed between receipt and testing	Number of stockings tested	Endurability; cycles to failure [1]	Maximum load in first cycle	Distensibility; circumference at 30 pounds in first cycle	Elasticity; circumference at 30 pounds in first cycle minus circumference at 10 pounds in two-hundredth cycle
		Days			*Pounds*	*Inches*	*Inch*
1	Degummed	3	6	1,000+	40	19.7	0.7
1	do	20	6	460	48	18.7	.2
1	Degummed and laundered	20	11	777	52	18.2	−.2
1	Dyed	3	6	546	50	18.8	0
1	do	20	6	147	90	16.9	
1	Dyed and laundered	20	10	470	58	18.0	−.6
2	Degummed	3	1	1,000+	56	18.6	.6
2	do	20	6	560	65	17.8	.1
2	Degummed and laundered	20	8	1,000+	50	18.6	.3
2	Dyed	3	4	133	74	17.6	[2] −1.4
2	do	20	6	88	79	17.2	
2	Dyed and laundered	20	10	1,000+	48	18.8	.7

[1] Tests were not continued beyond 1,000 cycles.
[2] Value is for the one hundred and thirty-third cycle.

The great difference in the results for the unlaundered stockings when tested 3 and approximately 20 days after being received from the mills was somewhat surprising. This difference is real, however, and must be attributed to some chemical or physical change in the silk.

Analysis of the silk for ammonia nitrogen and determinations of the pH of aqueous extracts of the silk appeared to indicate that the silk was not affected chemically.

The lapse of time, 17 days, between the tests may have permitted the yarns, which are plastic immediately after degumming, to become set, that is more rigid, and therefore less free to bend and to move one on another. This physical change could cause the difference which has been observed. This explanation appears logical inasmuch as the same effect was observed for the stockings of different constructions obtained from 2 different sources. It seems plausible also because laundering appears to have eliminated, at least partially, the difference observed.

If set of the yarn accounts for the difference observed in the above tests, then it is probable that a difference could have been observed in the yarn after unravelling it from the stockings. Unfortunately this marked effect of aging was not anticipated. It was impossible, therefore, to make tests on the yarns. It is probable that the yarn from an aged stocking would have shown different elastic properties under low loads than the yarn from an unaged stocking.

It is probable that the effect of aging would vary with a number of factors such as the amount of gum left on the silk, the amount and the kind of finishing materials put on the yarn, the dyeing process, the atmospheric conditions during aging, and the duration of the aging period. An extensive and systematic study of the effects of these factors should be made. The effect of aging can be partially eliminated by laundering and probably can be minimized by a proper finishing treatment after dyeing and proper conditions of storing.

It is to be further noted that the records of the dyed unlaundered stockings from mill 2 show the reversal effect discussed in Research Paper RP679. That is, the maximum load decreases for a few cycles and then increases and finally becomes greater than for the first cycle

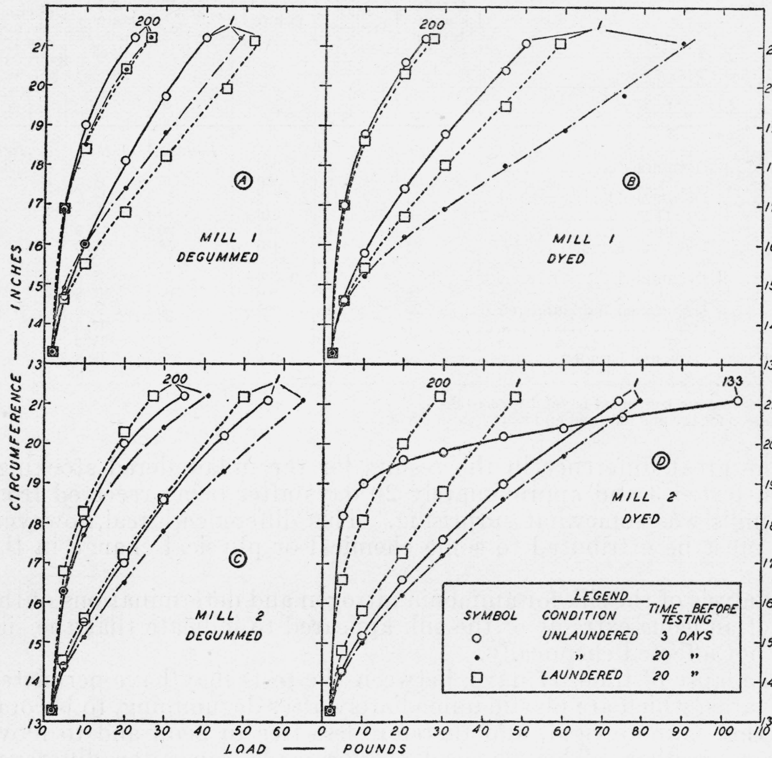

FIGURE 3.—*Effect of dyeing, aging, and laundering on the performance of stockings*

The numbers on the curves indicate the loading cycle.

The first and one hundred thirty-third cycles drawn in D of figure 3, show this reversal effect. Typical test records of stockings which do and which do not show the reversal are shown in figure 4. The endurability of stocking A, which shows the reversal, was 115 cycles. Stocking B did not exhibit the reversal and had an endurability greater than 1,000 cycles. Photographs of parts of these stockings after test are shown in figure 5. The stocking at the top showed the reversal while the stocking at the bottom did not.

When stockings which exhibited the reversal effect were tested, there was a very perceptible "grinding" noise produced by the movement and stretching of the silk yarn. The yarn became very fuzzy,

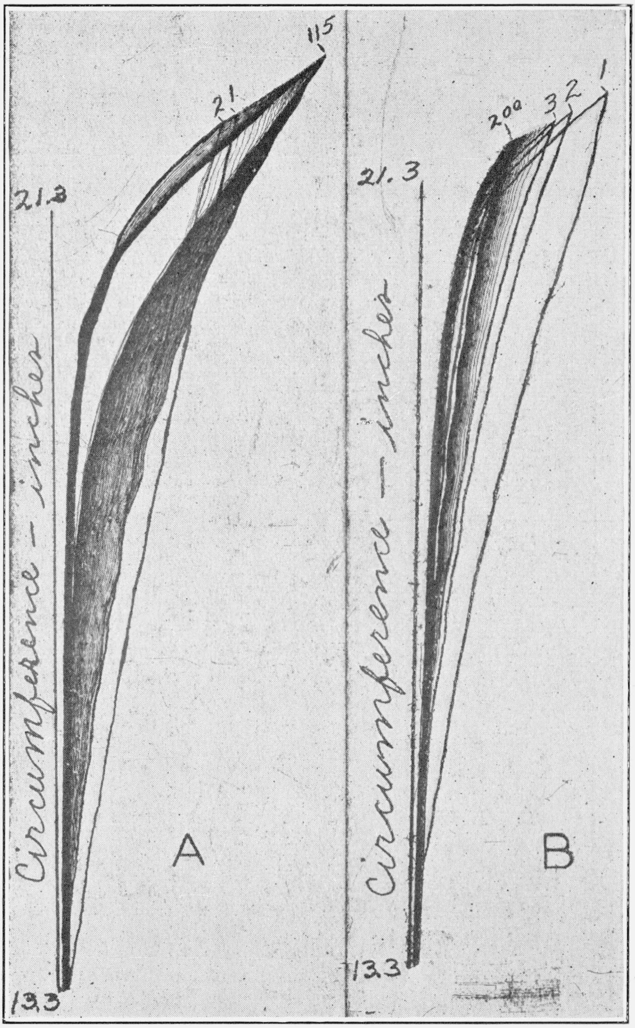

FIGURE 4.—*Typical test records of stockings which do and which do not show the reversal effect.*

Stocking A, which shows the reversal, failed at 115 cycles; while stocking B did not fail in 1,000 cycles. The curves shown in this figure are not plotted on a rectangular system of coordinates.

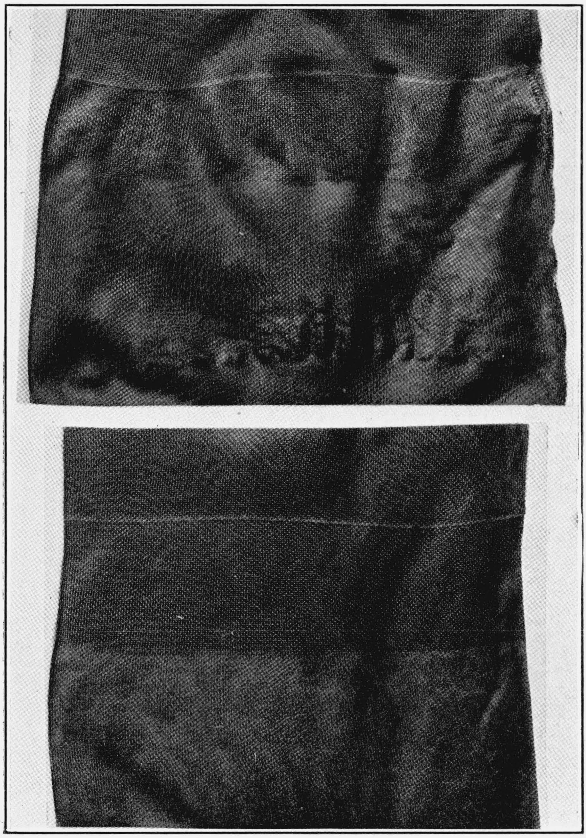

FIGURE 5.—*Appearance of stockings after test.*

The stocking shown at the top is one which exhibited the reversa leffect and failed at 115 cycles. The stocking at the bottom is one which did not show the reversal and which did not develop failures in 1,000 cycles.

the fabric became puckered, and the elasticity of the stockings decreased, i. e., they became badly deformed or baggy. It is probable that the friction between the silk filaments of the yarns increased during the test and accounted mainly for the increase in the maximum load observed for each succeeding cycle to failure.

These stockings which exhibited the reversal effect when tested before laundering behaved quite differently when tested after laundering. There was no reversal of the curves and there was no perceptible noise during the tests. The endurability was greater than 1,000 cycles, the silk yarn did not become fuzzy, the fabric did not become puckered, and the elasticity of the stockings did not decrease, i. e., they did not become badly deformed or baggy. It may be concluded, therefore, that the reversal effect observed in these stockings is produced by the particular finish given to them. This conclusion has recently been confirmed by tests on other stockings.

The results discussed in this section show the effect of dyeing, aging, and laundering on the behavior of these particular series of stockings. The effect of laundering on these stockings was to increase the distensibility, elasticity, and endurability, and probably confirms the claim which many women have made, namely, that they get better service from some of their stockings if they launder them before wearing. The utility of some finishes on stockings is questionable, particularly so when the effect is removed in the first laundering.

V. EFFECT OF FINISHING

In order to demonstrate whether or not the effect of different finishes could be determined with the hosiery-testing machine 3 groups of stockings were obtained from mill 3. There were 5 pairs in each group, each pair having been given a different finish. The stockings of a group were all of the same construction. The 3 groups differed, however, in construction, including variations in the gage, in the number of courses per inch, and in the number of threads in the silk yarn. One stocking of each pair was tested as received, while the other stocking was laundered before being tested.

TABLE 2.—*Results showing the effect of 5 finishes on similar stockings*

Finish number	Condition of stocking	Number of stockings tested	Endurability; cycles to failure [1]	Maximum load in first cycle	Distensibility; circumference at 30 pounds in first cycle	Elasticity; circumference at 30 pounds in first cycle minus circumference at 10 pounds in two-hundredth cycle
				Pounds	*Inches*	*Inch*
1	Unlaundered	3	120	85	17.3	--------
2	do	3	286	74	17.1	−0.6
3	do	3	672	61	17.8	.3
4	do	3	728	77	17.5	.2
5	do	3	1,000+	57	18.3	.3
1	Laundered	3	960	71	17.3	−.8
2	do	3	1,000+	49	18.6	.2
3	do	3	1,000+	47	18.8	.2
4	do	3	1,000+	62	17.8	−.3
5	do	3	1,000+	54	18.4	−.1

[1] Tests were not continued beyond 1,000 cycles.

The tests showed a marked difference between the finishes. The effect of differences between the constructions was small, probably because the several factors which were varied in the construction had compensating effects. The results are given in table 2 in which the values represent the averages for each finish on the 3 constructions. The effects of each finish and of laundering are clearly indicated. The finish has a greater effect on the unlaundered stockings than on the laundered stockings. The curves for the laundered and unlaundered stockings of finishes 1 and 5 are shown in figure 6. They represent the extreme effects of the 5 finishes.

A number of compounds are being sold to the consumer for treating stockings in the home to make them more durable. Aluminum

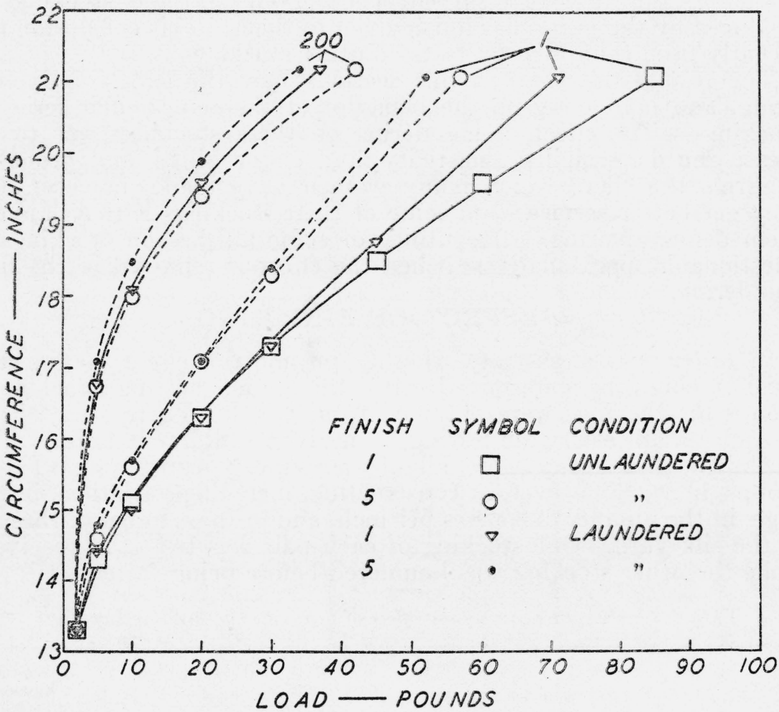

FIGURE 6.—*The effect of finishes 1 and 5 on similar stockings.*

The numbers on the curves indicate the loading cycle.

sulfate has been used for this purpose. It forms an insoluble aluminum soap on the yarn. In order to determine the effect of a known finishing treatment, 8 pairs of stockings were treated with aluminum sulfate and soap as follows. The stockings were laundered according to the method previously described. One stocking of each pair was then immersed for 30 minutes in a solution of aluminum sulfate at 100° F. This solution was prepared by dissolving 2 teaspoonfuls of aluminum sulfate in ½ pint of water. This amount of solution was sufficient for treating 2 stockings. After this treatment the stockings were dried at room temperature without boarding. They were then washed very gently for 5 minutes in a beaker containing

0.5 percent of soap solution at 100° F. The soap solution and procedure for rinsing and drying prescribed for laundering were used.

The results are shown in figure 7. In A, B, C, and D of figure 7 the effect of this treatment is shown on stockings knit from 2-, 3-, 4-, and 7-thread silk yarn, respectively, in which the endurabilities of the untreated stockings were less than 1,000 cycles and the elasticities were low. The treated stockings of these 4 pairs had endurabilities greater than 1,000 cycles and the elasticities were high. In each pair there were great differences between the curves of the treated and of the untreated stockings.

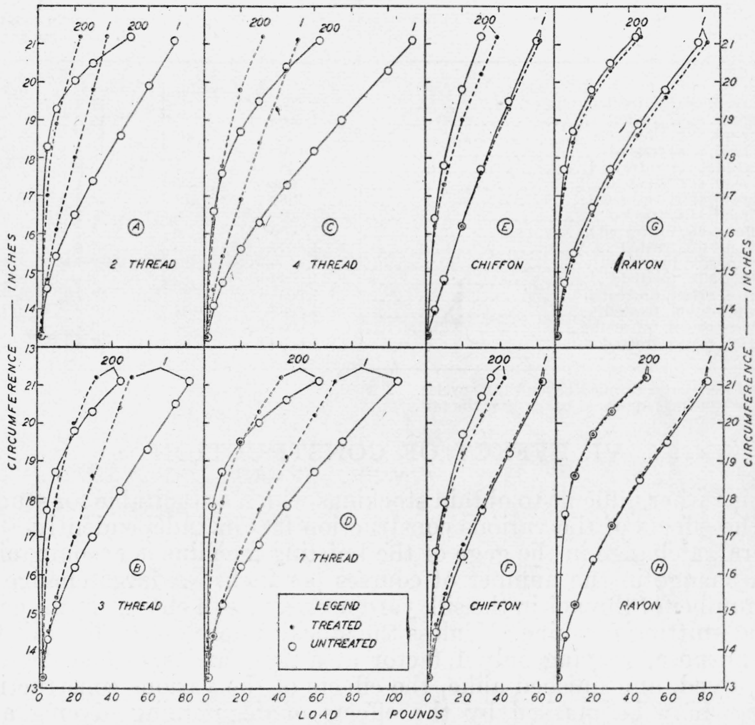

FIGURE 7.—*The effect of finishing stockings of different constructions with aluminum sulfate and soap.*

The numbers on the curves indicate the loading cycle.

In E and F of figure 7 the effect of this treatment is shown on 3-thread chiffon silk stockings in which the untreated stockings had endurabilities greater than 1,000 cycles. The endurabilities of the treated stockings of these 2 constructions were also greater than 1,000 cycles. The treatment appears to have increased the elasticity of these stockings slightly. (See table 3.)

In G and H of figure 7 the effect of this treatment is shown on 2 pairs of service-weight rayon stockings in which the untreated stockings had endurabilities greater than 1,000 cycles and also had low elasticities, i. e., they became baggy in the test. The treatment had no effect on the rayon stockings.

The results of this treatment on the 8 pairs of stockings are summarized in table 3. The treatment had a great effect on some of the stockings and none on others.

TABLE 3.—*Results showing the effect of treating stockings with aluminum sulfate and soap.*

Designation of stocking	Endurability; cycles to failure[1]	Maximum load in first cycle	Distensibility; circumference at 30 pounds in first cycle	Elasticity; circumference at 30 pounds in first cycle minus circumference at 10 pounds in two-hundredth cycle
		Pounds	*Inches*	*Inch*
A, 2-thread, silk, untreated	205	75	17.4	[2]−1.9
A, 2-thread, silk, treated	1,000+	37	19.8	.9
B, 3-thread, silk, untreated	240	80	17.0	[2]−1.7
B, 3-thread, silk, treated	1,000+	51	18.6	.7
C, 4-thread, silk, untreated	346	113	16.3	[2]−1.3
C, 4-thread, silk, treated	1,000+	50	18.4	.6
D, 7-thread, silk, untreated	248	105	16.8	[2]−1.9
D, 7-thread, silk, treated	1,000+	68	17.7	.2
E, chiffon, silk, untreated	1,000+	60	17.7	−.1
E, chiffon, silk, treated	1,000+	62	17.6	.3
F, chiffon, silk, untreated	1,000+	63	17.7	−.2
F, chiffon, silk, treated	1,000+	62	17.8	.1
G, service, rayon, untreated	1,000+	77	17.7	[2]−1.0
G, service, rayon, treated	1,000+	83	17.5	[2]−.9
H, service, rayon, untreated	1,000+	80	17.3	[2]−1.3
H, service, rayon, treated	1,000+	82	17.3	[2]−1.3

[1] Tests were not continued beyond 1,000 cycles.
[2] These stockings appeared baggy after the test.

VI. EFFECT OF CONSTRUCTION

It is rather difficult to obtain stockings which are suitable for studying the effects of the various construction factors independently. In general, a change in the gage of the knitting machine is accompanied by a change in the number of courses per inch. A large change in the number of threads in the silk yarn necessitates a change in the gage of the knitting machine. Unless the stockings are especially knit for this purpose, varying only 1 factor at a time, and are then degummed, dyed, and finished alike, the effects of the various construction factors may be masked by the effects of degumming, dyeing and finishing.

However, the effects of these factors may be minimized and the general trend of the effects of the various construction factors found by a selection of results from those for the large series of stockings referred to in section III. These stockings were made to specified constructions by 13 manufacturers. Although the methods of degumming, dyeing, and finishing were not specified, the effects of variations in them probably would be relatively small when the endurability of the stockings is greater than 1,000 cycles. The following discussion is based upon the average results for stockings which did not fail in 1,000 cycles of test.

The curves in A of figure 8 indicate the effect which may be expected by varying the number of threads in the silk yarn. The stockings were knit on 42-gage knitting machines using 4- and 7-thread silk yarn. The 7-thread stockings were knit with an average of 41 courses per inch and the 4-thread stockings with an average of 43 courses per inch. The curves are based upon the average values obtained on stockings from 8 mills. As expected, the stockings knit from the 7-thread silk yarn require a greater load to distend to a given circumference than is required for the stockings knit from the 4-thread silk yarn. The effect due to the slight difference in the number of courses per inch, as will be shown below, would be to diminish the effect due to the difference in the number of threads. Thus the difference indicated may be considered as showing the true trend due to a difference in the thread.

The curves in B of figure 8 indicate the effect which may be expected by varying the number of courses per inch. The effect is shown for stockings knit from 4-thread silk yarn on 42- and on 45-

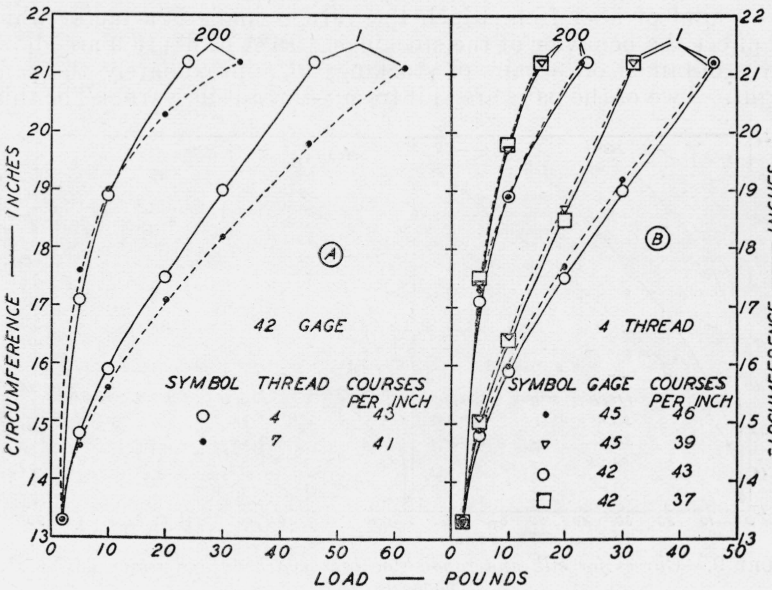

FIGURE 8.—*The effect of hosiery constructions on performance.*

The numbers on the curves indicate the loading cycle.

gage knitting machines. The curves show that a greater load is required to distend the stockings to a given circumference when the number of courses per inch is increased. This tendency is indicated by the stockings of both gages and is in agreement with that expected upon theoretical consideration. Take for example the 42-gage stockings with 37 and 43 courses per inch. The length of the silk yarn in 1 course in the stocking of 43 courses per inch is shorter than the length in 1 course in the stocking of 37 courses per inch. Obviously the stocking in which the length of yarn in 1 course is shorter and in which there are more courses per inch would require a greater load to distend to a given circumference.

The curves shown in B of figure 8 also indicate that the effect produced by increasing the gage from 42 to 45 is either small or is nullified by the difference in courses per inch. In view of the considerable effect noted above when the number of courses per inch is changed, it appears that in the present case the effect due to a change in the gage is nullified by the difference in courses per inch. This is in agreement with what would be expected from theoretical consideration. In a 45-gage stocking there are approximately 7 percent more stitches or loops in 1 course or circumference than in a 42-gage stocking. If both stockings have the same number of courses per inch, then because of the greater number of loops in 1 course in the 45-gage stocking, the length of the silk yarn in 1 course, is approximately 7 percent greater than in a 42-gage stocking. On this basis a smaller load should be required to distend the 45-gage stocking to a given circumference.

VII. EFFECT OF KIND OF FIBER

The kind of fiber from which the yarn is made is a factor which will affect the behavior of the stockings. In A of figure 9 are shown curves obtained on 3 pairs of stockings of approximately the same weight. Two of the pairs are knit from 8-thread silk yarn. The third

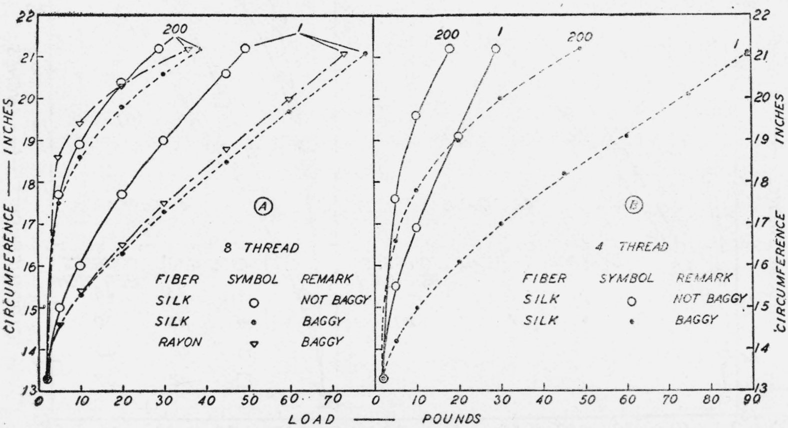

FIGURE 9.—*Curves for silk and rayon stockings which do and which do not show bagginess.*

The numbers on the curves indicate the loading cycle.

pair is knit from rayon yarn of about the same weight. The stockings were tested after laundering and all had endurabilities greater than 1,000 cycles. There is, however, a vast difference in the appearance of the tested stockings and their curves. The stockings made from rayon yarn are badly deformed or baggy. This is also true for 1 pair of the silk stockings, but not for the other. The similarity of the curves for the pair of silk stockings, which exhibited undesirable bagginess, and the curves for the rayon stockings and the great dissimilarity between the curves for the 2 pairs of silk stockings are very striking.

The curves obtained on 4 other pairs of rayon stockings as well as those obtained for the rayon stockings which are discussed in section V exhibited the same features as the curves shown for the rayon stockings in A of figure 9. This tendency of rayon stockings to become deformed or baggy with use is frequently considered to be an objectionable feature by the consumers. As is shown by these results and the experience of consumers, this objectionable feature may also be encountered in some silk stockings.

The curves shown in A of figure 9 are for 2 pairs of 4-thread silk stockings obtained from 2 mills. The 1 pair showed no tendency to become baggy while the other pair showed a great tendency. Both pairs had endurabilities greater than 1,000 cycles.

TABLE 4.—*Results showing the relation of kind of fiber to extensibility and elasticity of stockings*

Thread	Fiber	Endurability; cycles to failure [1]	Maximum load of first cycle	Distensibility; circumference at 30 pounds in first cycle	Elasticity; circumference at 30 pounds in first cycle minus circumference at 10 pounds in two-hundredth cycle	Remarks
			Pounds	*Inches*	*Inch*	
8	Silk	1,000+	49	19.0	0.1	Not baggy.
8	do	1,000+	78	17.3	−1.3	Baggy.
8 [2]	Rayon	1,000+	73	17.5	−1.9	Do.
4	Silk	1,000+	29	21.2	1.6	Not baggy.
4	do	1,000+	89	17.0	−.8	Baggy.

[1] Tests were not continued beyond 1,000 cycles.
[2] The weight of the rayon yarn is equivalent to an 8-thread silk yarn.

These results, summarized in table 4, show that elasticity is definitely related to the tendency of stockings to become baggy. In general for stockings which show little tendency to become baggy, the elasticity is between 0 and 1 inch, whereas for stockings which show a great tendency it is between −1 and −2 inches.

VIII. SUMMARY

The principal results of this work are summarized in the following statements:

Laundering stockings before testing them on the machine may have a marked effect or no effect on the results of the test and the effect may be beneficial or detrimental. It appears that the effect of laundering depends largely upon the kind of finishing treatment the stockings have received.

The distensibility, elasticity, and endurability of degummed stockings were decreased by dyeing. Aging decreased the distensibility, elasticity, and endurability of both degummed and dyed stockings. This decrease was partially eliminated by laundering. Chemical tests indicate that the aging effect was not caused by a deterioration of the silk by exposure to light. It is probably attributable to a set of the yarns, which are plastic immediately after degumming, but become more rigid and therefore less free to bend and move one on another.

The "reversal effect" observed in the load-elongation diagrams of some stockings appears to be due to the kind of finish on the stockings. Laundering tends to eliminate this effect.

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Marked differences in results were found to be produced by different commercial finishes on similar stockings. A finishing treatment of aluminum sulfate and soap was found to increase the distensibility, elasticity, and endurability of silk stockings which without the finish had endurabilities less than 350 cycles.

An increase in size of yarn or number of courses per inch in a stocking, or decrease in gage of the knitting machine on which a stocking is made, is accompanied by an increase in the load required to distend the stocking a given amount provided other factors remain constant.

The rayon stockings tested and some silk stockings become baggy on repeated distention. The tendency of stockings to become baggy is definitely related to the elasticity. In general a stocking with an endurability less than 1,000 cycles has less distensibility and elasticity than a stocking with an endurability greater than 1,000 cycles.

The hosiery-testing machine is suitable for measuring the differences in distensibility, elasticity, and endurability likely to occur in hosiery manufactured to be as nearly alike as practicable. The machine is suitable for researches on the effects of knitting, degumming, dyeing finishing, aging, laundering, redyeing, and refinishing of hosiery.

WASHINGTON, November 14, 1934.