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TEXTILE SERIES - REPORT NO. 73

DEVELOPMENT OF A SEWABILITY TEST FOR COTTON FABRICS

by
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OFFICE OF THE QUARTERMASTER GENERAL

Office of The Quartermaster General
Research and Development Division

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FOREWORD

The very great increase in the number and variety of resins and other chemical finishing agents which have come to be employed in the finishing of textile fabrics, coupled with the employment by practically all Government contractors for clothing of increasingly high speed sewing machines, has made the matter of sewability of fabrics one of major concern both to the cutting-up trades and to consumers.

To the military procurement agencies, concerned with the length of service life of clothing provided to troops, it is a matter of prime importance that fabrics shall not be damaged in sewing, and that the resulting product shall have the maximum strength of seams, consistent with other requirements.

It has become evident that some finishes applied to textile fabrics greatly reduce the mobility of the yarns to shift as the needle penetrates the fabric, thereby making it susceptible to serious cutting by the needle in the sewing operation.

To prevent the delivery of fabrics unsatisfactory in this respect, a study was made to obtain a quantitative test method which could be used for quality control purposes. Such a test method has been developed, as is described in this report, which is now being used in practically all specifications for light and medium weight cotton fabrics. The adoption of this test has greatly reduced this particular type of damage and has led to the production of end items that exhibit marked improvement in appearance as well as in serviceability in the field.

This test and procedure for eliminating poor sewability of fabrics were developed by Mr. E. B. Frederick, who is in charge of seams and stitches research at the Quartermaster Research and Development Laboratories and is the author of this report.

This work was done in the Textile Materials Engineering Laboratory of the Quartermaster Research and Development Laboratories, which is under the supervision of Mr. L. I. Weiner. A major portion of the test work was performed by Mrs. L. V. Johnson. The contributions of Mr. N. E. Roberts and Mr. G. Winston for editorial and statistical assistance in the preparation of this report are gratefully acknowledged.

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ABSTRACT

The development of the seam efficiency test to measure the sewability of a fabric is described. It is shown that this test, which involves the establishment of a ratio between the strength of the original fabric and the strength of the seamed fabric, is more realistic, reproducible, and sensitive than the previous test which rated a fabric for sewability on the basis of the number of fabric yarns cut per inch during the sewing operation.

I. INTRODUCTION

Some fabrics, which meet all the usual specification requirements, cannot be sewn into acceptable garments because of the susceptibility of their yarns to damage by the sewing needle. It appears that the problem is primarily a lack of mobility of the yarns; instead of moving when the needle penetrates the fabric structure, these yarns remain taut and hence are severed.

It has long been recognized that yarn severance detracts from the neatness of garments, since the cut yarns fray during wear, and their loose ends appear on the surface of the seam, as shown in Figure 1. Fabric damage by sewing takes on a more serious aspect, however, when it affects the strength of the seam. It is primarily from this standpoint that the Quartermaster Corps has found it necessary to adopt an efficient sewability test for its cotton fabric specifications.

Essentially, the sewability of a fabric, or the degree of its resistance to needle damage, can be determined in two ways. One measure of this property is the proportion of fabric yarns cut by the needle. Another is the loss in fabric strength occasioned by needle damage. The former principle is not new; until recently a test based on yarn severance appeared in certain military fabric specifications. The particular test used, however, did not approximate actual sewing conditions to the extent necessary for a realistic procedure. The shortcomings of the test became apparent when it failed to detect the poor sewability of a fabric that was so susceptible to needle damage that several manufacturers reported they could not make garments of acceptable quality from it.

It was proposed that this test be replaced by the seam efficiency test, which is based on strength determinations. This method consists of sewing a seam in the fabric, breaking the fabric at the line of stitching, and establishing a ratio between the original and the seamed fabric strengths. Experience has shown that if this seam efficiency ratio falls below 80 per cent, the fabric has been excessively damaged by the sewing operation.

In the evaluation of the seam efficiency test it was found convenient to make, in addition to the strength determinations, a count of the fabric yarns cut in sewing the seam. A much closer correlation was found between yarn severance as obtained in this way and seam efficiency, than between yarn severance as measured in the original test and the actual sewing performance of a fabric. This finding suggested that either procedure could be used to

FIG. 1

APPEARANCE OF SEAM

AS A RESULT OF EXCESSIVE YARN DAMAGE

determine sewability. Subsequent work on the two methods, however, as described in this report, showed that the seam efficiency test was more realistic, more reproducible, and more sensitive than the yarn severance test, and hence it has been adopted for the evaluation of military fabrics.

II. TEST METHODS

A. Seam Efficiency Test

The details of the seam efficiency test are given in the Appendix.* Briefly, the test consists of joining together two cuts of fabric, one 48 by 12 inches and the other 48 by 8 inches, along their length (warpwise) by means of a properly formed 401-LSc-2 seam. The stitch length (number of stitches per inch) and the size and finish of the thread are usually the same as those required by the specification for the end item in which the fabric is to be used. For heavier fabrics, where the specified thread may not be as strong as the fabric itself, a heavier thread is used. When the seam is sewn, ten pairs of filling breaks (i.e. perpendicular to seam) are made in the sample using a vertical Scott tester. The first of each pair is made in an unsewn portion of the fabric, thus determining the filling breaking strength of the fabric itself. Then using guide lines made on the fabric prior to testing, the fabric is placed in the tester so as to break the same filling yarns as before, but with the seam midway between the jaws, thus determining the seamed strength of the fabric. The average of the ten original fabric strengths is then used with the average of the ten seamed strengths to compute seam efficiency according to the formula

$$\text{Seam Efficiency} = \frac{\text{Seamed Fabric Strength}}{\text{Original Fabric Strength}} \times 100$$

B. Yarn Severance Test

A warpwise seam is made in the fabric, as for the seam efficiency test. The sewing thread is then removed from the seam

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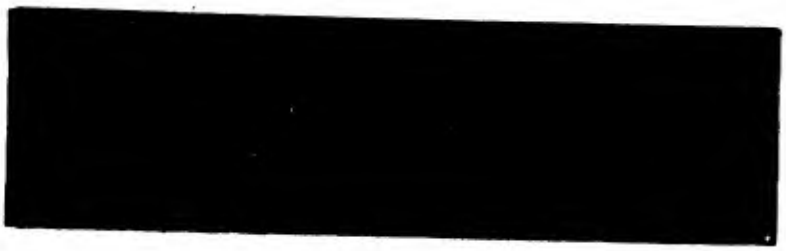
* Test Method 5110, "Sewability of Woven Cloth; Strength-of-Seam Method," from Federal Specification CCC-T-191b, "Textile Test Methods," which is reproduced in the Appendix, is the final test as now conducted. It includes some refinements on the method followed in obtaining the results reported in this paper.

and five one-inch sections of the bottom fabric are cut away to within 1/8 inch of the line of stitching. The warp yarns are then carefully removed to approximately 1/8 inch beyond the line of stitching. During this process the severed filling yarns in each one-inch length are counted, and their average is expressed as a percentage of the total number of picks per inch. In Figure 2 is shown a photographic comparison of two fabrics prepared for determination of yarn severance. The upper photograph shows a fabric with little yarn severance while the lower photograph shows one which has been severely damaged in sewing. Since the fabric yarns most susceptible to needle damage are those running perpendicular to the seam direction, only the filling yarns cut in making a warp seam are counted; warp yarn severance in such a case is usually negligible and almost always significantly less than filling yarn severance. Furthermore, from the standpoint of seamed fabric strength, the cut yarns which run parallel to the seam are of minor importance.

FIG. 2 . YARN SEVERANCE IN FABRICS OF GOOD AND POOR SEWABILITY



Good Sewability

Poor Sewability

III. CORRELATION OF THE TWO SEWABILITY TESTS

A. Procedure

For an analysis of the two sewability tests, seven different fabric constructions, as listed in Table I, were taken from stock at the Philadelphia Quartermaster Depot. Unfortunately, none of the constructions, except the herringbone twill, were available from a sufficient number of different sources of manufacture to permit a detailed study of each. However, since the materials included covered a rather wide range of the most commonly used military clothing fabrics, they permitted a general analysis of the relative effectiveness of the two sewability tests.

The fabrics were tested as described above, first for seam efficiency, and then for yarn severance, using the same seam for each test. The seam conditions used, also shown in Table I, were in some cases the same as those specified for end items made from the particular material. In other cases they were those required to produce seams stronger than the fabric so that the seam tests would show, not thread strength, but fabric strength at the line of stitching. Sufficient thread tension was used to ensure the proper formation and uniformity of the stitches and to afford a distribution of 40% needle and 60% lower thread in the seam.

B. Results and Discussion

The results obtained in the two types of sewability tests on the seven fabrics are summarized in Table II. This table shows that although all the fabrics (except 9.0 oz. oxford) well exceeded, on the average, the specified breaking strength, several of them showed a low seamed strength and consequently a low seam efficiency value. The table also shows that the seam efficiency test is applicable to fabrics over a rather wide range of fabric weights and strengths.*

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* In exceptional cases, fabrics may be found of such high strength that any thread with which it is practical to sew them will fail instead of the fabrics themselves in the seam strength test. If seam efficiency is computed in such cases (where the seam strength value represents thread strength rather than seamed fabric strength) it will indicate a poorer sewability than the fabric actually has. For fabrics as strong as these, a true seam efficiency value is not only impossible to obtain, but unnecessary. The only important consideration in such fabrics is that the neatness of their seams will not be marred by the appearance of loose ends of the fabric yarns cut during sewing. Hence, where realistic seam efficiency values cannot be obtained because of sewing thread failure, yarn severance is a satisfactory criterion for sewability.

Table I

Correlation Study Fabrics and Seam Conditions Used for Seam Efficiency Test

	Weight (oz./sq.yd.)	No. of Mfg. Sources	Thread Combination		Stitches per inch	Needle Size
			Needle	Looper		
1. Broadcloth	3.2	5	70/3	80/3	14	.036
2. Poplin	5.0	4	70/3	80/3	14	.036
3. Oxford	6.5	3	A	A	14	.044
4. Uniform Twill	8.2	2	24/3	60/3	14	.049
5. Herringbone Twill	8.5	10	24/3	60/3	14	.049
6. Oxford	9.0	3	24/3	60/3	14	.049
7. Sateen	9.0	4	24/3	60/3	14	.049

Table II

Average Values of

Sewing Characteristics of Army Fabrics

Characteristic	Broadcloth 3.2 oz. (5 contractors)	Oxford 6.5 oz. (3 contractors)	Poplin 5.0 oz. (4 contractors)	Oxford 9.0 oz. (3 contractors)	Herringbone Twill 8.5 oz. (10 contractors)	Uniform Twill 8.2 oz. (Type I) (3 contractors)	Sateen 9.0 oz. (3 contractors)
Original fabric strength, filling-wise (lb.)							
Specification Requirement	25	50	60	100	85	120	125
Average	29	62	81	92	109	121	153
Minimum - Maximum	25-33	52-69	69-90	86-101	81-157	114-136	147-155
Range (per cent of average)	28	28	26	16	70	18	5
Seamed fabric strength (lb.)							
Average	18	51	64	85	84	74	134
Minimum - Maximum	12-27	46-61	46-75	75-96	56-109	61-84	129-137
Range (per cent of average)	88	28	46	24	63	4	6
Seam efficiency (%)							
Average	60	83	78	92	78	63	88
Minimum - Maximum	41-80	75-87	66-89	88-95	56-97	54-72	88-88
Range (per cent of average)	66	15	29	8	53	29	0
Filling yarns cut per inch (%)							
Average	14	19	8	2	15	17	2
Minimum - Maximum	0-28	10-27	1-13	0-4	4-34	9-26	2-2

The significance of the average data in Table II can be better demonstrated if the values for the various contractors on a single fabric construction are shown. This is done, by way of example, in Table III for the broadcloth fabric which was represented by five contractors. Here it can be seen that four of the five fabrics were subject to yarn severance of from 5 to 28 per cent. It is significant that of the five submissions of broadcloth, the fabrics from Manufacturers D and K showed the highest values for yarn severance and next-to-the-lowest for seam efficiency; these were materials that could not be made into shirts in production sewing because of their poor resistance to needle damage.

In general, the data in Tables II and III indicate a correspondence between the seam efficiency of a fabric and the number of filling yarns severed by the needle. Some exceptions must be made to this observation, however. The type of fabric break obtained at the seam, as illustrated in Figure 3, explains some of these exceptions. A direct break, shown in the upper photograph, is the type normally experienced with fabrics of poor sewability. Such breaks were obtained with fabrics from Manufacturers D and K, and to a lesser extent, Q (Table III). Occasionally however, a low coefficient of friction among the yarns will cause them to slip, as shown in the middle photograph, resulting in seam failure at a very low load even though none of

Table III

Cloth, Cotton, Broadcloth, Khaki #1, 3.2 ounce

Characteristic	Manufacturer I	D	K	C	Q
Original fabric strength, filling-wise (lb.)	28	27	25	33	31
Seamed strength (lb.)	12	14	13	27	22
Seam Efficiency (%)	41	52	51	82	71
Filling yarns cut per inch (%)	0	22	28	5	13

FIG. 3. TYPES OF SEAM FAILURES.

BREAK

SLIPPAGE

SLIPPAGE AND BREAK

the yarns are broken. Such a case is exemplified by the fabric from Manufacturer I, which shows no filling yarn severance, but at the same time has the lowest seam efficiency (41 per cent) of all the five fabrics in Table III. Under optimum conditions there will be some slippage of the yarns before the break occurs, as shown in the lower photograph of Figure 3. This was the case with the fabric from Manufacturer C (Table III). These observations indicate that yarn severance is not the only factor determining seam durability, and that thus the seam efficiency test, whose results reflect the contribution of other fabric properties such as yarn slippage, is to be preferred as a sewability test.

The degree of correlation between seam efficiency and yarn severance is also limited by the fact that some fabric yarns are damaged, but wholly severed, by the needle. It is impossible, by any method depending upon observation alone such as the yarn severance test, to determine the contribution of these partially severed yarns to lowered fabric strength after sewing. Thus, in the yarn severance test only completely broken yarns are counted. The seam efficiency test on the other hand which is based on an actual determination of strength loss, provides a more complete picture of the damage done to the fabric by the sewing operation.

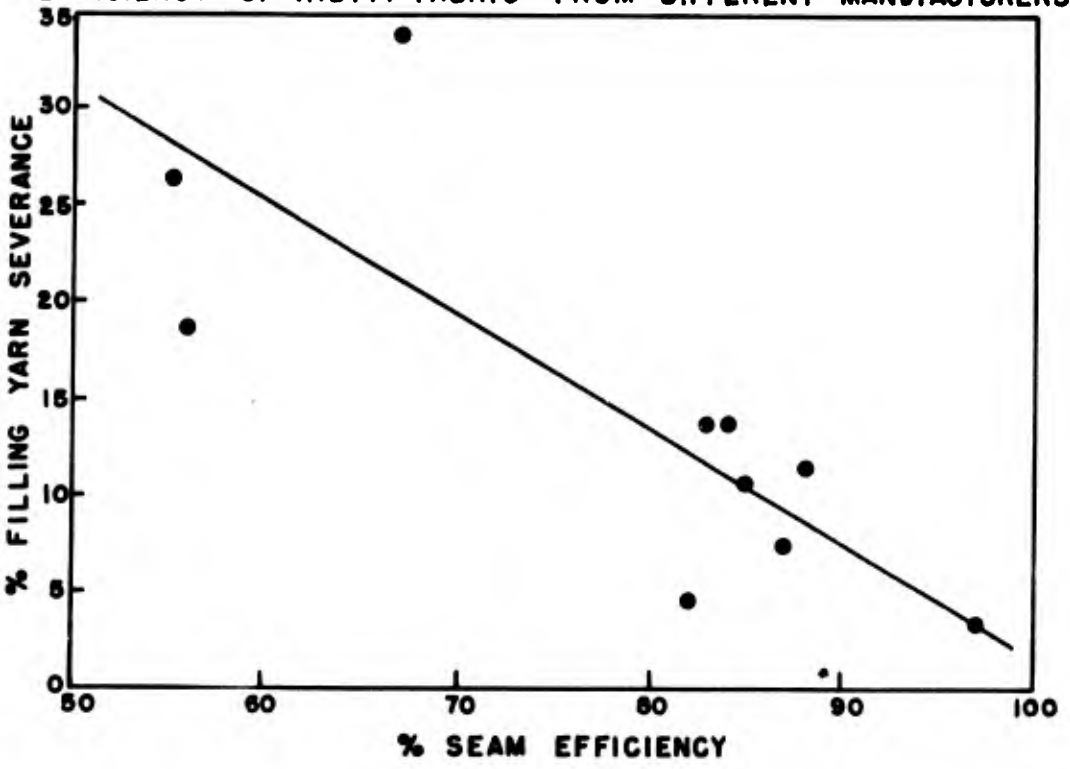
In spite of these known limitations, an attempt was made to correlate the two sewability tests, using as a basis the herringbone twill fabric which was the only one represented by a sufficient number of different manufacturers (ten) to permit a statistical relationship to be established. The average values for the fabrics from each of the ten manufacturers which ranged from 97 to 55 per cent for seam efficiency and from 4 to 34 per cent for filling yarn severance, are shown graphically in Figure 4. A rank correlation of these data resulted in a coefficient of $\rho = .71$. It is thus evident that a realistic method of determining yarn severance is to some degree a measure of fabric sewability, but that it cannot be relied upon to the same extent as a test like that for seam efficiency, which is based on an actual measurement of the damage done to the fabric in sewing by means of strength tests.

IV. COMPARATIVE REPRODUCIBILITY AND SENSITIVITY OF YARN SEVERANCE AND SEAM EFFICIENCY TESTS

In order to test the comparative reproducibility and sensitivity of the two methods, a further investigation was undertaken. By reproducibility is meant the consistency of

FIG. 4

RELATIONSHIP BETWEEN FILLING YARN SEVERANCE & SEAM EFFICIENCY OF H.B.T. FABRIC FROM DIFFERENT MANUFACTURERS



results for each procedure as evaluated by the coefficient of variation. By sehsitivity is meant the validity of each procedure or its ability to discriminate between the sewability of two or more fabrics of different sewing quality.

A. Procedure

For this study two herringbone twill fabrics of different sewing qualities were selected, from which 10 sections were cut. Seven specimens were taken from each section for tests of both seam efficiency and yarn severance. The seam efficiency test was the same as that described above and in more detail in the Appendix. For determination of yarn severance, unbroken sections of the same seam made for the seam efficiency te were cut from the fabric and the sewing thread was removed. The average number of filling

Table IV

Comparison of Seam Efficiency and Yarn Severance Methods for Evaluating Sewability

(10 sections of 7 specimens each per fabric)

	Seam Efficiency, %	Yarn Severance, %
Average values		
Fabric P	82.6	16.8
Fabric Q	77.2	19.1
Combined average	80.0	18.0
Reproducibility (incl. differences among sections)		
Coefficient of variation, V	13.3	57
Sensitivity		
Discrimination factor	9	1.1
Sensitivity for seam efficiency / Sensitivity for yarn severance	8.2	
Fabric P		
95% control limits (avg. of 5 specimens-1 section)		
Upper control limit - UCL	91.4	25.2
Lower control limit - LCL	73.8	8.4
Limits of error from over-all avg. (% avg.)		
$\frac{\bar{X} - \text{UCL or LCL}}{\bar{X}}$ (100)		
	10	50

yarns severed, determined by the method described above, was expressed as a percentage of the total number of filling yarns.

B. Results and Discussions

The results of these experiments are analyzed in Table IV. The average values in Table IV follow the general trend established by most of the earlier data, in that the fabric with the higher seam efficiency (Fabric P) also showed the less yarn severance. Statistical analysis of the individual values comprising these averages, however, showed that the reproducibility and sensitivity of the seam efficiency test is much better than that of the yarn severance test. The fact that the coefficient of variation of the latter is approximately four times that of the seam efficiency test indicates the much poorer consistency of yarn severance values. Not only is the seam-efficiency test the less variable of the two methods; it is also approximately eight times as sensitive, according to this experiment, in discriminating between fabrics of different sewing qualities. The discrimination factor, as shown in the table, is the ratio of the differences of fabric averages to the average variability of the values within each fabric, taking cognizance of the difference among sections.

To determine the 95% control limits as a measure of the relative validity of the two tests, five specimen averages were taken from a randomly selected section of Fabric P. Taking cognizance of the differences among average section values and the average variability of the seven specimens within a section, the limits of error were found to be 10% of the over-all average for the seam efficiency test and 50% for yarn severance. That is to say, 95% of the time a given seam efficiency value will be within 10% of the over-all average, whereas a yarn severance value can be off as much as 50% from the over-all average.

V. SUMMARY

The seam efficiency test, as described in this report, is a reliable method for determining the sewability of fabrics. Its effectiveness has been proved in laboratory experiments and it has stood the test of time as an acceptance procedure. It is more realistic than the yarn severance test, an alternate method of determining sewability, in that it involves reproducing an actual sewing operation. Studies of the comparative reproducibility and sensitivity of the two methods has shown the superiority of the seam efficiency test.

SEWABILITY OF WOVEN CLOTH; STRENGTH-OF-SEAM METHOD

1. Scope

1.1 This method is intended for determining the sewability of woven cotton fabrics by use use of a seam-strength test. It is especially applicable to clothing-type fabrics ranging in weight up to about 8.5 ounces per square yard. A requisite of this method is that the seam construction (required for the end item) must be sufficiently strong to cause cloth failure along the line of needle penetration when tested in accordance with 4. For fabrics heavier than indicated above or otherwise not suitable for testing by this method, see method 5400.

2. Test Specimen

2.1 The specimen shall be a panel of cloth 4 inches by approximately 20 inches with the long dimension parallel to the filling direction of the cloth which is a part of a unit formed by joining two pieces of cloth together by means of an LSc–2 seam (fig. 5110 A), prepared as follows:

2.2 *Preparation of unit.*—A piece of the cloth, approximately 20 by 48 inches with the long dimension parallel to the warp, shall be cut in the warp direction into two strips of 12 by 48 inches and 8 by 48 inches. The two strips shall then be joined together along their length (warpwise) by means of a properly formed 401 (see fig. 5110 B) LSc–2 seam, ¼ inch gage (distance between needles). Care shall be taken that when the two strips are placed together for sewing they shall occupy, as nearly as the sewing operation will permit, the same relative position as in the uncut 20-by 48-inch piece.

2.3 The size and finish of top and lower threads and the size of the needle shall be as specified in the material specification. The needle shall be of the smallest size which will permit free running of the specified size of thread through the eye with no chafing to weaken the thread. Typical examples of seaming conditions for three different types of cloth are:

	Needle size [1]	Thread size		
		Point	Top	Bottom
Cloth, cotton, broadcloth, 3.2 ounces per square yard	0.032	Round	60/3	70/3
Cloth, cotton, W. R. twill, water rep. 5-ounce	.040	do	40/3	60/3
Cloth, cotton, unif. twill, 8.2-ounce, type I	.049	do	24/3	60/3

[1] Size of needle is given in inches across the blade at the eye.

2.4 Unless otherwise specified in the material specification, 12 stitches per inch shall be used. The tension on the sewing thread shall be sufficient to form a firm stitch. The distribution of thread in the seam shall be 40 percent, by length, needle and 60 percent lower thread (bobbin). The sewing shall be done at the full speed of the machine.

2.5 The seam shall be inspected for proper folding and no test shall be made on any section improperly formed. Lines parallel to the filling yarn and perpendicular to the seam shall be drawn across the seamed piece (unit) at approximately 4-inch intervals starting 6 inches from the edge where the sewing of the seam was started. The specimen may be tested without removal from the unit or the unit may be cut into 4-inch panels, 2.1, by leaving 1½ inches on each side of the 4-inch center test portion.

3. Apparatus; Method Cited

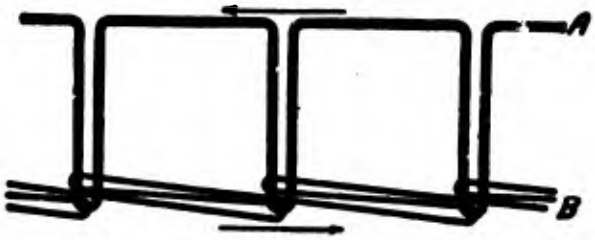
3.1 *Apparatus.*

3.1.1 High speed (approximately 4,300 revolutions per minute ±100) double needle, ¼-inch gage (between needles) sewing machine of the 401 type stitch, fitted with a folder capable of forming the LSc–2 type seam.

3.1.2 Breaking strength apparatus as described in method 5100.

3.1.3 Threads and needles as specified in the material specification.

Seam type LSc-2
FIGURE 5110 A



Stitch type 401
FIGURE 5110 B

3.2 *Method cited.*

Method 5100, Strength and elongation, breaking, of woven cloth; grab method.

4. Procedure

4.1 *Testing.*—The procedure involves two breaking strength determinations which shall be made in pairs on the same 1-inch set of filling yarns using the vertical lines in the unit or edges of the specimen as guides.

4.1.1 *Filling-wise fabric strength.*—The free portion of the 12-inch strip of the unit or specimen shall be placed in the clamps of the machine, lining up the guide marks with the vertical edge of the front jaws in the top and bottom clamps. The specimen shall then be securely fastened by tightening the jaws, the specimen ruptured, and the result read from the chart, scale, or dial.

4.1.2 *Filling-wise seam strength.*—The jaws of the machine shall then be loosened and the unit or specimen moved upward along the same filling threads until the seam is midway between the clamps perpendicular to the direction of the application of the load. Care should be taken in the placing of the specimen seam in the testing position so as to exclude from the test that portion of cloth that had been held in the jaws of the machine in the determination of the filling-wise strength of the cloth. The guide marks or edges of the specimen are again aligned with the same vertical edge of the jaws in both clamps as in the previous determination. The specimen is then securely fastened, the break made, and the result read from the chart, scale, or dial. Only those tests where the failure of the seam occurs at the line of needle penetration (including slippage) shall be considered.

4.2 *Calculation of results.*

4.2.1 The cloth sewability shall be calculated as follows:

$$\text{Seam efficiency, percent} = \frac{\text{seam strength in pounds}}{\text{cloth strength in pounds, filling}} \times 100$$

5. Report

5.1 Unless otherwise specified in the material specification, 10 specimens shall be tested from each Unit-of-Product.

5.2 The seam efficiency of the Unit-of-Product shall be the average of the results obtained from the specimens tested and shall be reported to the nearest 1.0 percent.