AN INVESTIGATION OF THE EFFECT OF MACHINE AND YARN PARAMETERS ON THE STRENGTH OF TUFTED JUTE FABRIC

A THESIS

Presented to

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by

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In Partial Fulfillment

of the Requirements for the Degree

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AN INVESTIGATION OF THE EFFECT OF MACHINE AND YARN

PARAMETERS ON THE STRENGTH OF TUFTED JUTE FABRIC

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DEDICATION

To my loving and understanding wife, Susan.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (Continued)

SUMMARY

A study was made to determine the effect of the number of stitches per inch tufted and the size of the yarn tufted on the strength of jute carpet backing during 5/64 inch gauge tufting. It was concluded that increasing the number of stitches per inch decreased the breaking strength and breaking elongation of the fabric. The size of the yarn had no effect on the strength of the fabric. Large variations in the test results made data analysis difficult.

CHAPTER I

INTRODUCTION

Statement of the Problem

Woven jute fabric has been used traditionally as the primary backing fabric for the tufted carpet industry. Its extended use was based mainly on its low cost, thus making possible the economic production of a strong, durable fabric which possessed both body and flexibility.

Difficulties arose in the use of woven jute backing as the tufting industry began decreasing the needle spacing in order to increase the number of tufts per square inch. As the needles were placed closer together, needle deflection and subsequent machine stops due to needle breaks became more prevalent. A second phenomenon, which has made the jute unsuitable for the fine gauge tufting, was the appreciable decrease in strength of the filling yarns due to excessive damage.

This decrease in strength has prompted this research with the aim of determining the factors causing the strength loss.

Brief History Leading to the Problem

Woven carpets dominated the contract carpet markets--schools, offices, hospitals, and other nonresidential areas--until close gauge tufting machines were developed. The close gauges provide for a high stitch density which is important for the following reasons:

1. resists tracking and packing down

2. improves texture retention and appearance

3. wears longer

4. soils less readily and is easier to clean.

As the tufted contract carpet market expanded, so did the need for a suitable primary backing. The jute backings which were first tried and found unsuitable have been replaced by synthetic backings, both woven and nonwoven. Therefore, prompted by the loss of a market for woven jute backings, the American Jute and Carpet Backing Council has sponsored the research on which this thesis is founded.

Purpose of the Research

The purpose of this research was to investigate the effect of certain yarn and machine parameters on the strength of the tufted jute carpet backing during 5/64 inch gauge tufting. The denier of the carpet yarn used and the number of stitches per inch tufted into the backing fabrcic were varied in order to determine how these changes affected the amount of filling damage.

Review of the Literature

Since the tufted carpet industry has had such a fantastic rate of growth in the past five years, there has been a need for a suitable primary carpet backing. Many tufters first chose woven jute. In order to evaluate the reasons for its popularity, Burr et al. (1) postulated three criteria for evaluation of cost, performance, and bulk.

Cost considerations were fairly obvious. Woven jute was available at cheaper prices than those of comparable carpet backings.

When performance was considered, double jute backed carpet showed coordinated strength and rupture values, high flexural rigidity, and was less subject to grinning. (Grinning occurred when the carpet was bent over a sharp edge, and the primary backing was exposed.)

Bulk came naturally to woven jute backings. This bulk resulted not only in thicker and heavier carpets, but also provided greater pile support.

Jute did, however, exhibit several chemical and mechanical shortcomings. The following are several common chemical deficiencies (2):

1. low resistance to mildew and rot

2. reduced dimensional stability when wetted

3. adverse effect on color and light-fastness as a result of lignins.

Mechanical deficiencies which have been encountered follow (3):

1. needle deflection

2. low shear modulus leading to bowing and width variations within rolls

3. needle damage to filling yarns.

It was postulated that needle deflection was due in large part to fabric distortion within the fabric plane and could be rectified by cross-machine tension during tufting (1).

Shealy and Lauterback (3) discussed the needle damage to filling yarns as the number of tufts per square inch increased. With increasing stitch density, the number of interstices for tuft insertion decreased, resulting in the needles penetrating and splitting the yarn bundles in the backing fabric. The splitting caused fiber damage and subsequent strength reduction.

D. Seggie (4) compared jute carpet backing with several synthetic backing fabrics. Jute was heavier and thicker than synthetic backings. Warpwise strength of jute was greater than synthetics, but the synthetics were comparable to or stronger than jute in the filling direction. Dimensional stability and shrinkage after wetting of jute compared favorably with synthetics.

CHAPTER II

MATERIALS AND EQUIPMENT

Materials

A jute fabric which weighed approximately nine ounces per square yard was used as the primary backing for all experiments performed. The construction of the fabric was a plain weave with approximately 15 warp yarns per inch and approximately 13 filling yarns per inch.

The average breaking strengths and elongations, as determined by grab tests, for the fabrics A and B used in the experiments are given in Table 1. The data sheets for the fabrics are in the Appendix.

Table 1. Backing Fabric Properties

Fabric	Warpwise		Fillingwise	
	Breaking Strength (lbs)	Breaking % Elongation	Breaking Strength (lbs)	Breaking % Elongation
A	113	7.2	101	6.1
B	124	9.1	90	5.8

Fabrics A and B were both designated as nine ounce, 15 x 13, plain weave fabrics, but variations resulted due to the inherent variability of jute fabrics. This variability had its origin in the jute fiber. Below are given some of the basic properties of the jute fiber (5):

Specific gravity 1.48

Moisture regain . . . . 13.8 per cent

Tenacity . . . . 3.0-5.8 g/den

Modulus . . . . 200 ± g/den

Wet strength, per cent of dry 90-95

Rupture elongation . . . . 1.7-2.0 per cent

Length . . . . 0.2-30 in.

Tex (weight in grams per 1000 meters) 1.9-2.2

As the fibers were converted into a yarn, variations persisted and were further multiplied due to diameter variations in the jute fibers, thus resulting in nonuniform yarn size, breaking strength and breaking elongation. The nonuniformity of the jute yarns thus resulted in fabrics which varied in breaking strength and elongation.

Specifications for the nylon carpet yarns tufted in the experiments are given in Table 2.

Table 2. Carpet Yarn Specifications

Denier	Number of Filaments	Twist	Type
1300	68	0	Semidull, crimped, textured, trilobal
2600	136	0	Semidull, crimped, textured, trilobal
3700	204	0	Semidull, crimped, textured, trilobal

The yarns used were similar in all respects except for size which was one of the parameters in the investigation.

Equipment

Before describing the actual tufting machine used, a description of the tufting process will be given. In a loop pile machine such as the one used for this research, the needle carries the yarn through the backing fabric to a point just below the looper. (See Figure 1.) The looper, which works in a timed relationship with the needle, crosses the needle at a point just above the needle eye and close enough to the needle to catch the loop which has been carried through the backing fabric by the needle. The looper holds the loop as the needle retracts, and rocks back as the fabric advances one stitch length, thus releasing the loop. The cycle is then repeated as the needle again penetrates the fabric.

The tufted samples were obtained on a multi-pass tufting machine model number TM 8-18, which is shown in Figure 2 along with the table and creel. The original 3/16 inch gauge needle bar and looper bar were converted to 5/64 inch gauge (12.8 needles per inch) and set for a 1/8 inch pile height. The needle bar (fitted with Torrington Number 27 needles) and looper shaft are shown in Figures 3 and 4, respectively. Note that in order to obtain 5/64 inch spacing, two offset rows of needles spaced at 5/32 inch were used. The distance between the two rows of needles was 7/16 inch.

The machine is driven by a two horsepower motor and operates at approximately 720 stitches per minute. The jute fabric is fed through the machine by means of a feed roll pictured in Figure 4 which is driven off the main drive shaft through a gear reduction. (See Figure 5.)

Yarn is fed to the needles by means of two rubber-covered feed

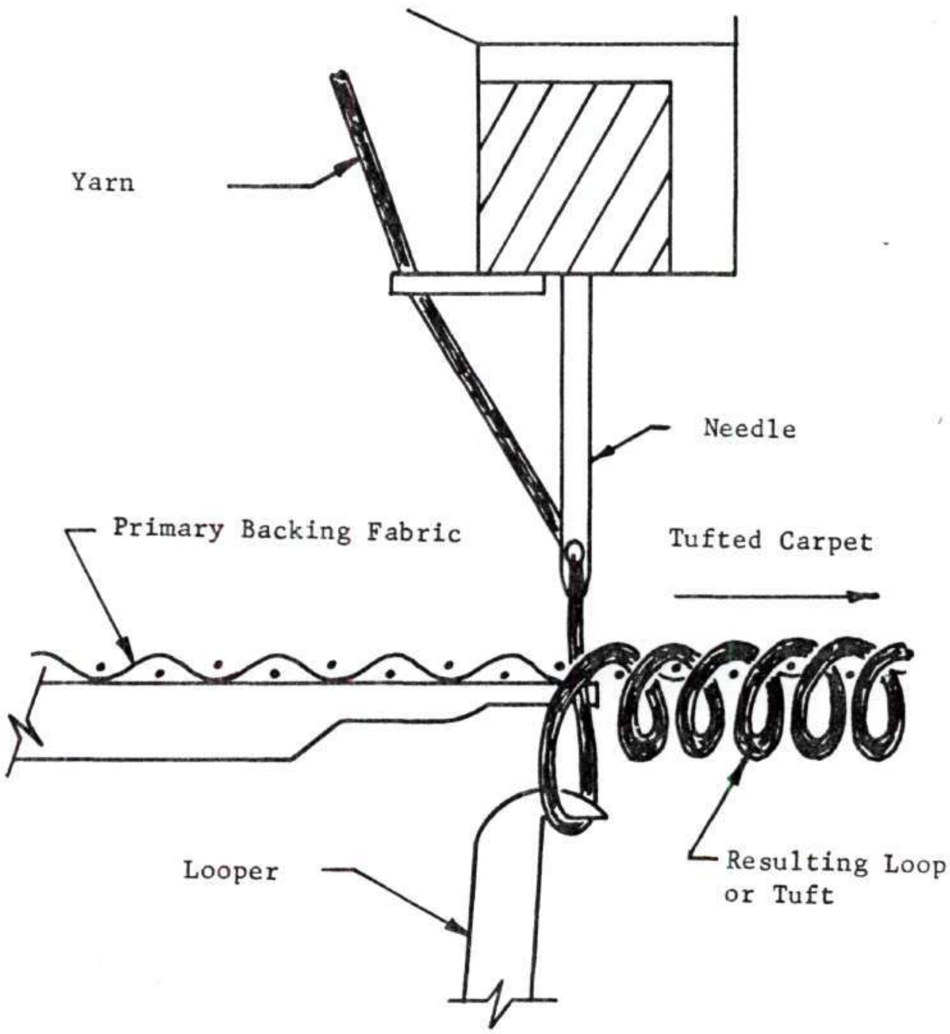

Figure 1. Elements of Carpet Tufting Process.

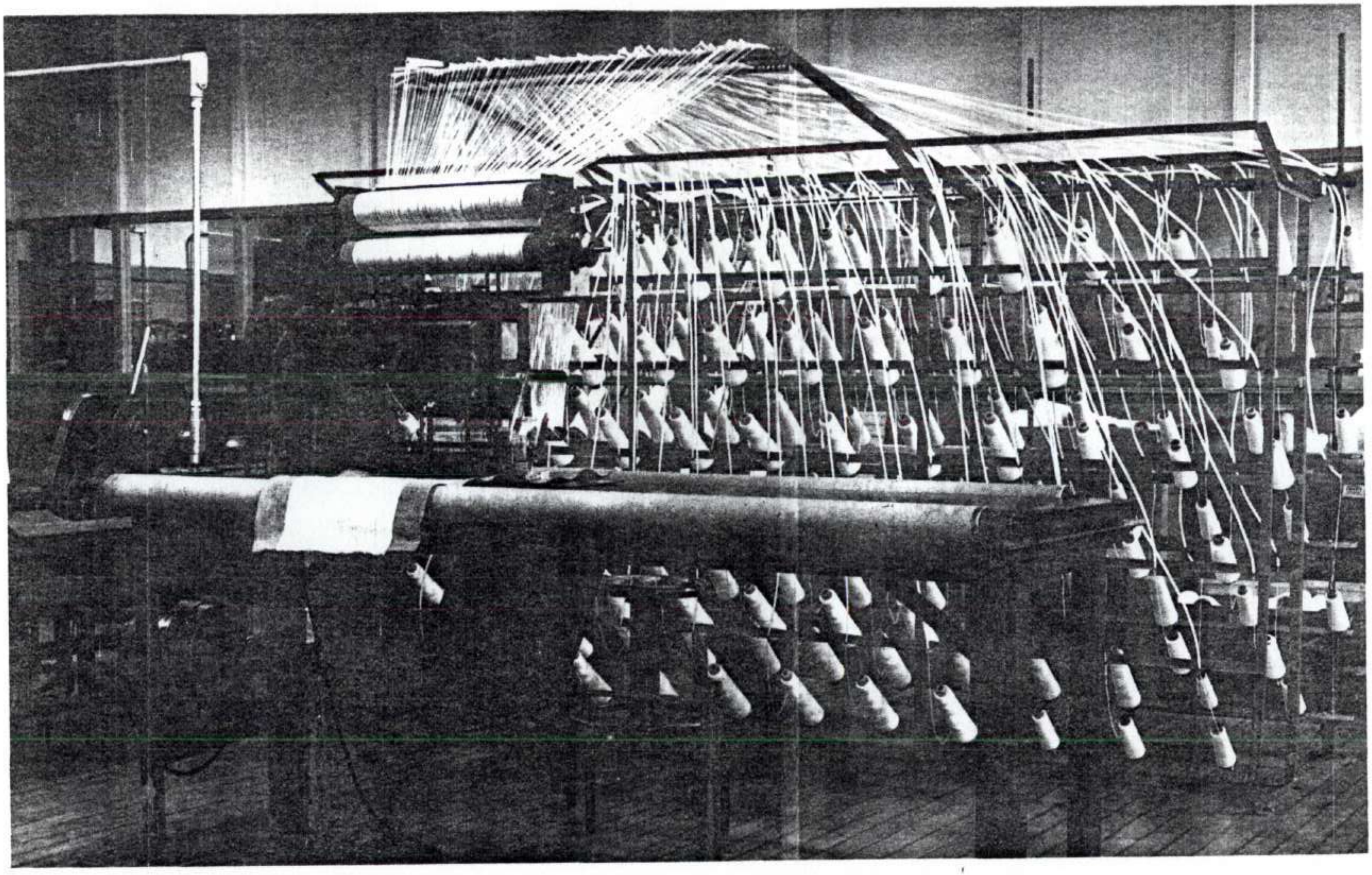

Figure 2. Tufting Machine, Table and Creel.

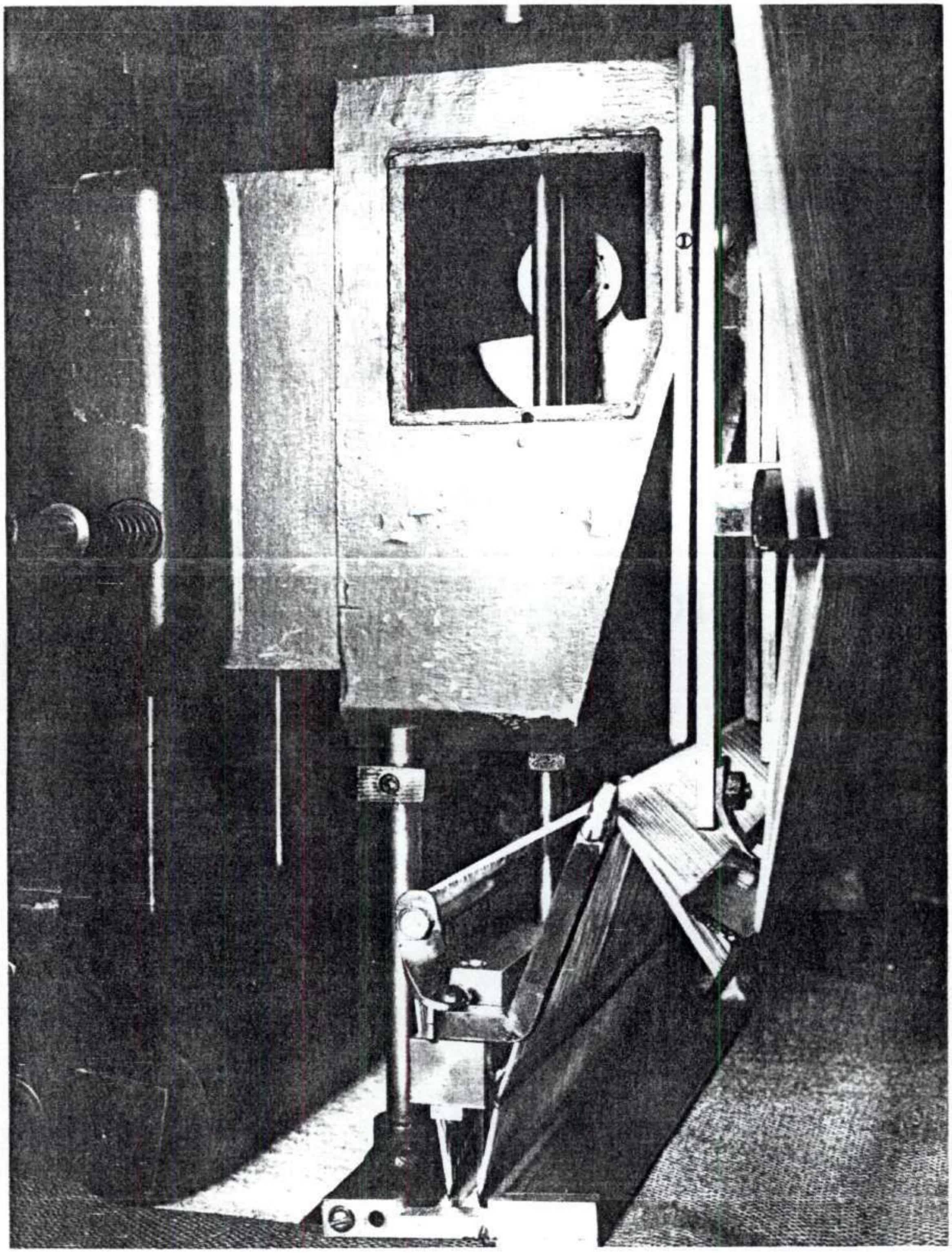

Figure 3. Needle Bar and Drive Mechanism.

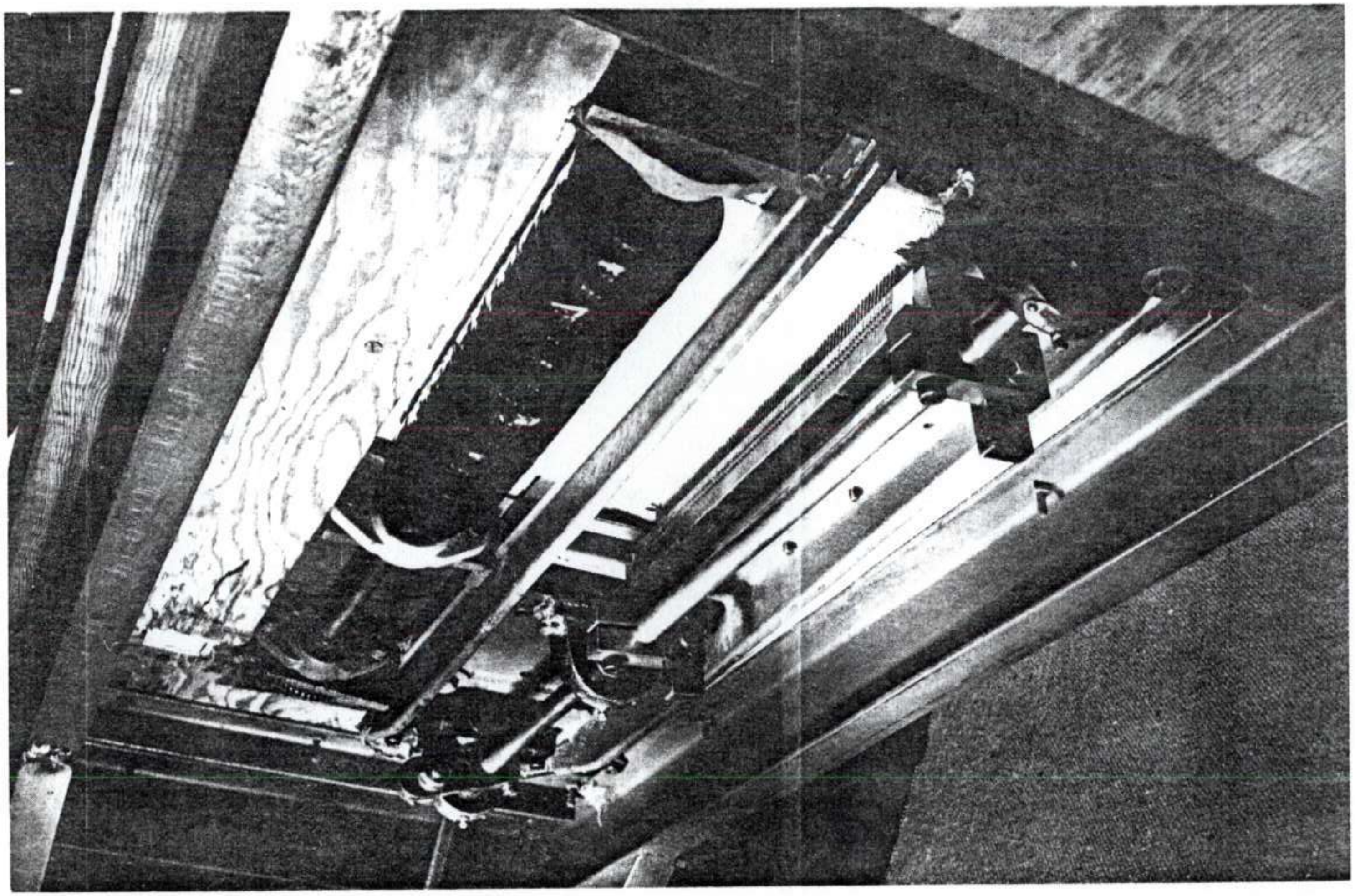

Figure 4. Looper Shaft, Looper Drive Mechanism, and Fabric Feed Roll.

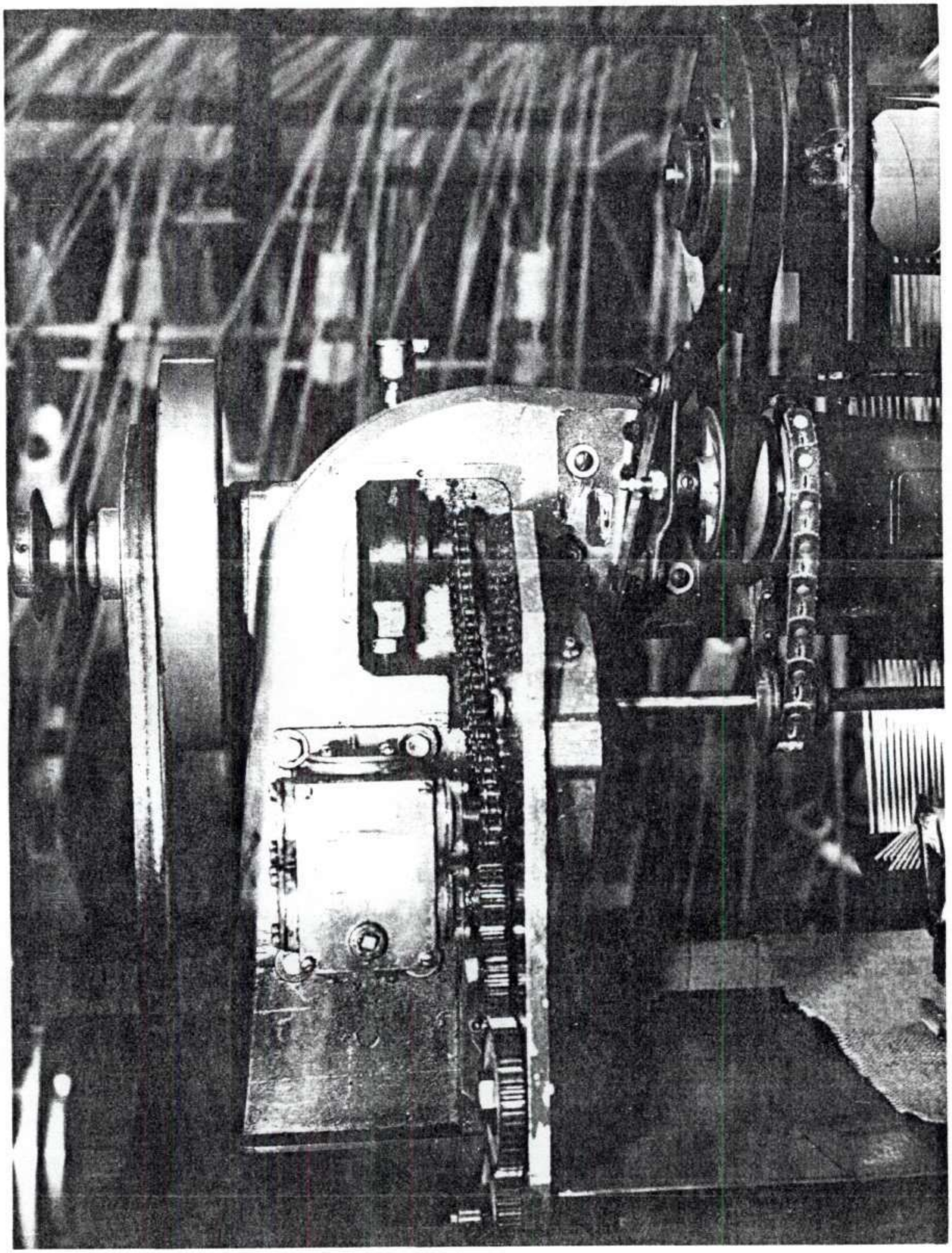

Figure 5. Fabric and Yarn Feed Rolls Drive Mechanisms.

rolls which are driven through a pulley arrangement by the main shaft. (See Figure 5.) The path of the yarn through the machine is shown in Figure 6.

Figures 3 and 4 also show the driving mechanisms for the needle bar and looper shaft.

An Instron Tensile Tester type TT-B, shown in Figure 7, was used for testing the breaking strength and breaking elongation of the tufted specimens.

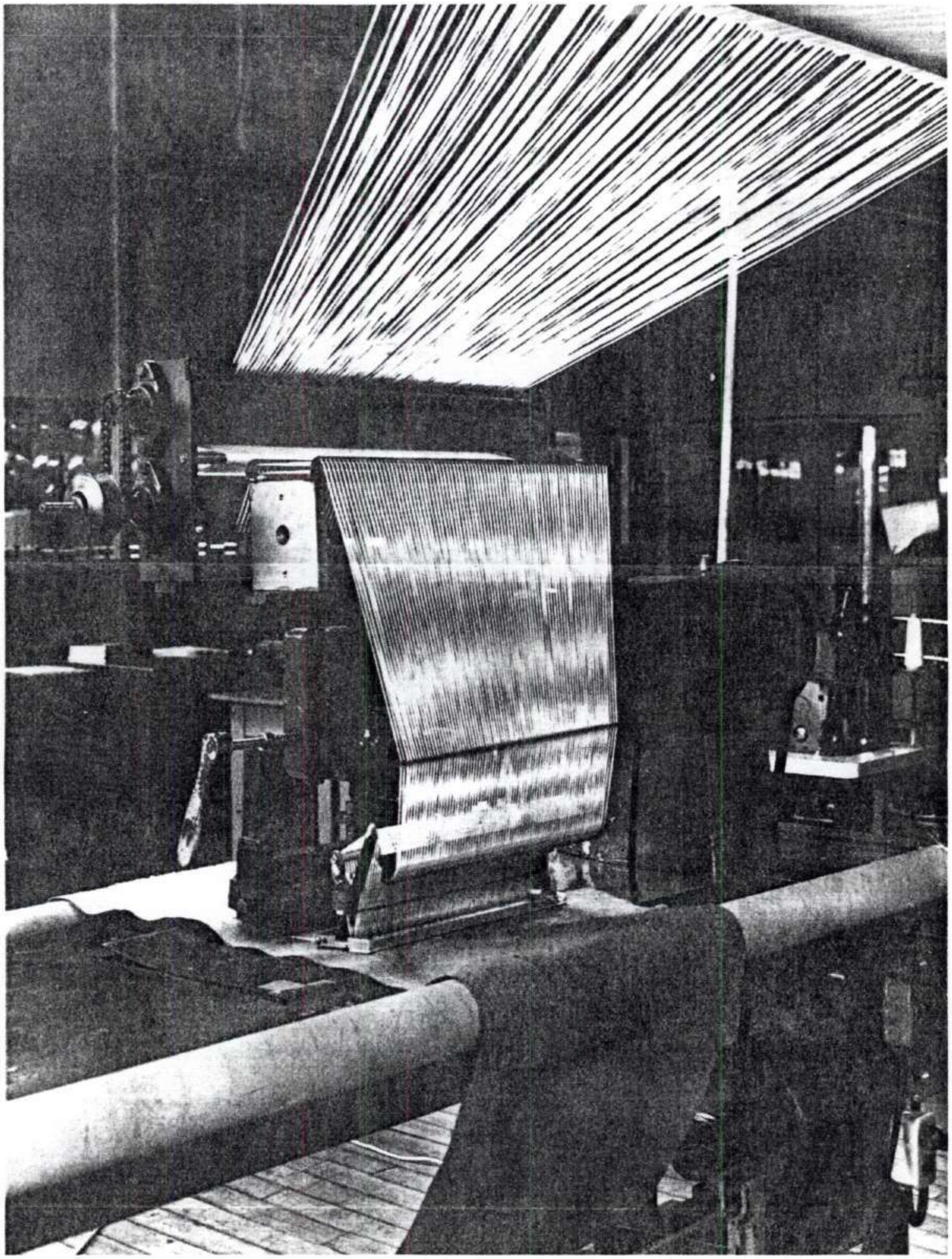

Figure 6. Yarn Path Through Machine.

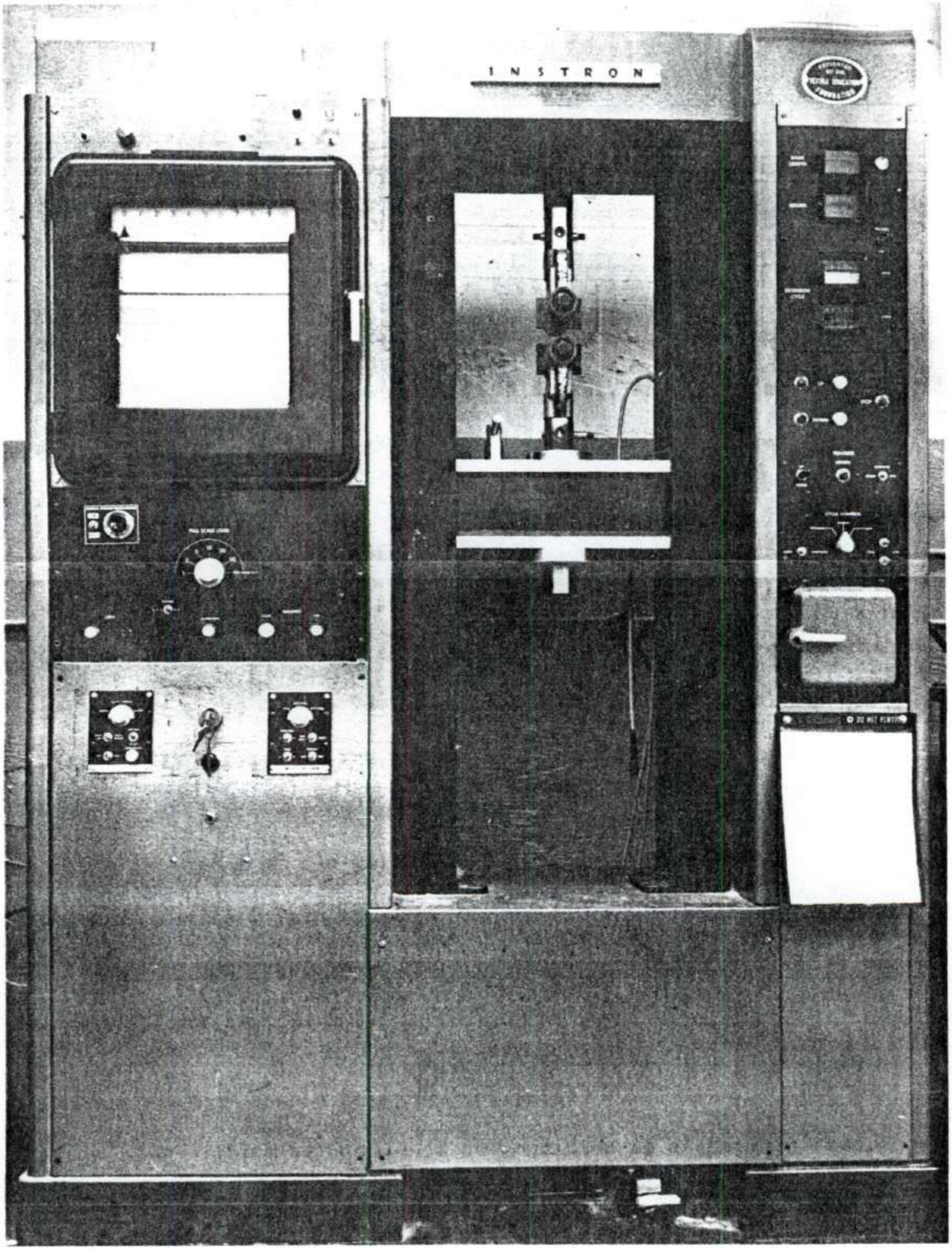

Figure 7. Instron Tensile Tester.

CHAPTER III

PROCEDURE

Tufting Samples

In order to ascertain the effect of yarn denier on the strength of jute carpet backing, samples were tufted with three different size nylon carpet yarns--1300 denier, 2600 denier, and 3700 denier. Fabric A was used for the 1300 denier yarn, and fabric B was used for the 2600 denier and 3700 denier yarns.

With each of the three size yarns stated above, the samples were tufted with stitches per inch varying from approximately eight to 13. The number of stitches was determined by the speed of the feed roll. The speed of the feed roll was determined by steel change gears pictured in Figure 5. The number of teeth in the driving gear is given on the data sheets in the Appendix.

The speed of the yarn feed rolls was kept constant in order to maintain constant yarn tensions throughout all experiments. All tufting was conducted in a standard atmosphere ($70^{\circ}F \pm 2^{\circ}F$, 65 per cent R. H. $\pm$ 2 per cent R. H.).

Testing Procedure

The samples were allowed to condition in a standard atmosphere before being tested. After conditioning, the samples were cut into warpwise and fillingwise specimens (see Appendix for determination of number of specimens) as shown in Figure 8.

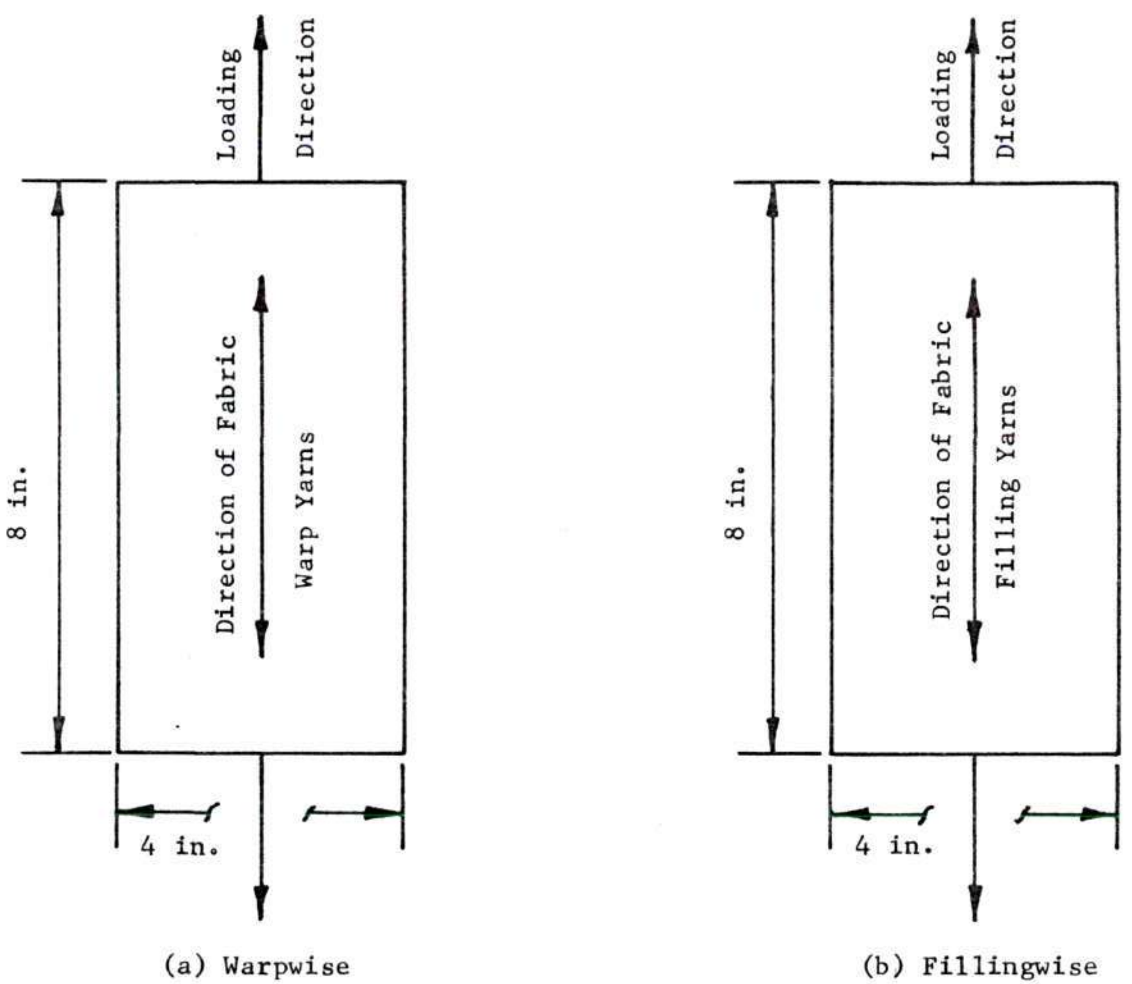

Figure 8. Instron Test Specimens: (a) Warpwise, (b) Fillingwise.

These specimens were then tested on the Instron Tensile Tester type TT-B for the breaking load and elongation of the tufted fabric by the Grab Test method according to ASTM Specification D-1682-64 (6). Specifications for the Instron test are given in Table 3.

Table 3. Instron Grab Test Specifications

	Warpwise Specimen	Fillingwise Specimen
Load Cell	D	D
Full Scale Load	200 pounds	100 pounds
Chart Speed	5 inches/minute	5 inches/minute
Jaw Speed	1 inch/minute	0.5 inch/minute
Gauge Length	3 inches	3 inches
Time to Break	20 ± 3 seconds	20 ± 3 seconds

Load-elongation curves were thus obtained for the specimens such as those shown in Figure 9. The breaking load and elongation correspond to points M and E. The data for each sample are given in the Appendix along with the average, the standard deviation, coefficient of variation, range, and per cent strength retained.

High Speed Movies

In order to see the fiber damage resulting from the needles piercing the filling yarns, high speed movies were made during the tufting process of both the first and second rows of needles. Movies were made at approximately eight stitches per inch and approximately

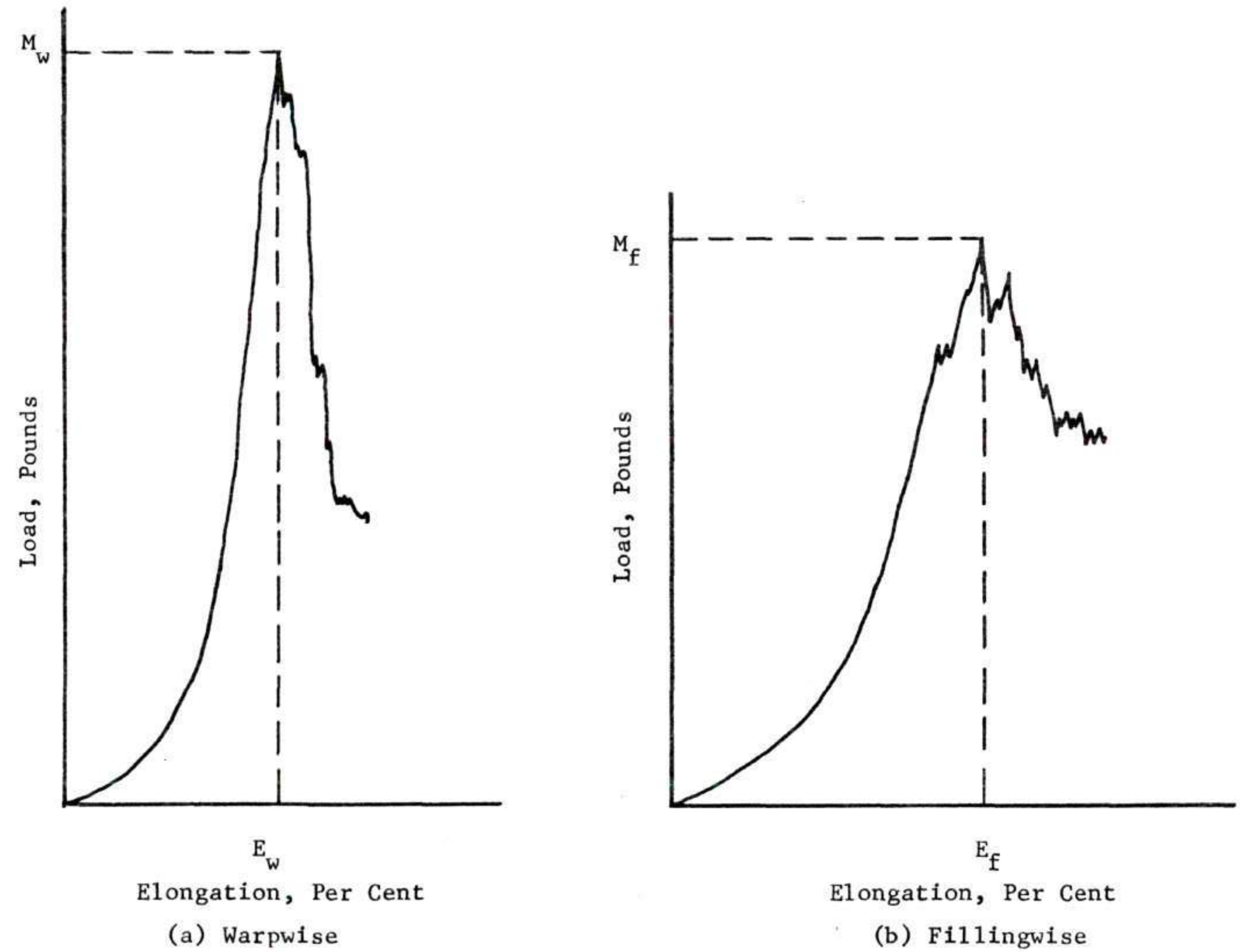

Figure 9. Representative Load - Elongation Curves: (a) Warpwise, (b) Fillingwise.

13 stitches per inch with the 2600 denier carpet yarn.

The camera used was a 16 mm Fastax operating at 3500 frames per second. The film used was Kodak 4-X Reversal Film Type 7277.

CHAPTER IV

DISCUSSION OF THE RESULTS

Results of Untufted Fabric Tests

The raw data for the Instron test results on Fabrics A and B appear on the data sheets in the Appendix. Also calculated were the average ($\bar{y}$), the standard deviation (σ), the coefficient of variation ($\frac{\sigma}{\bar{y}}$), and the range. The range equals the maximum data point minus the minimum data point of the specimens. The large variations in the tensile properties contributed to the variations in the results of the tufted samples.

Effect of Number of Stitches Per Inch Tufted

The raw data for the Instron test results on the tufted samples appear on the data sheets in the Appendix. The average, standard deviation, coefficient of variation, range, and per cent strength retained are also given.

The calculated averages for the warpwise and fillingwise breaking strengths and elongations were plotted against the number of stitches per inch in Figures 10 through 21. The range was plotted around each average by means of a vertical line in order to give an indication of the spread of the data points.

A straight line was fitted through each set of averages by a least squares estimation of the slope and intercept of the line. The equation of each line appears on the corresponding figure.

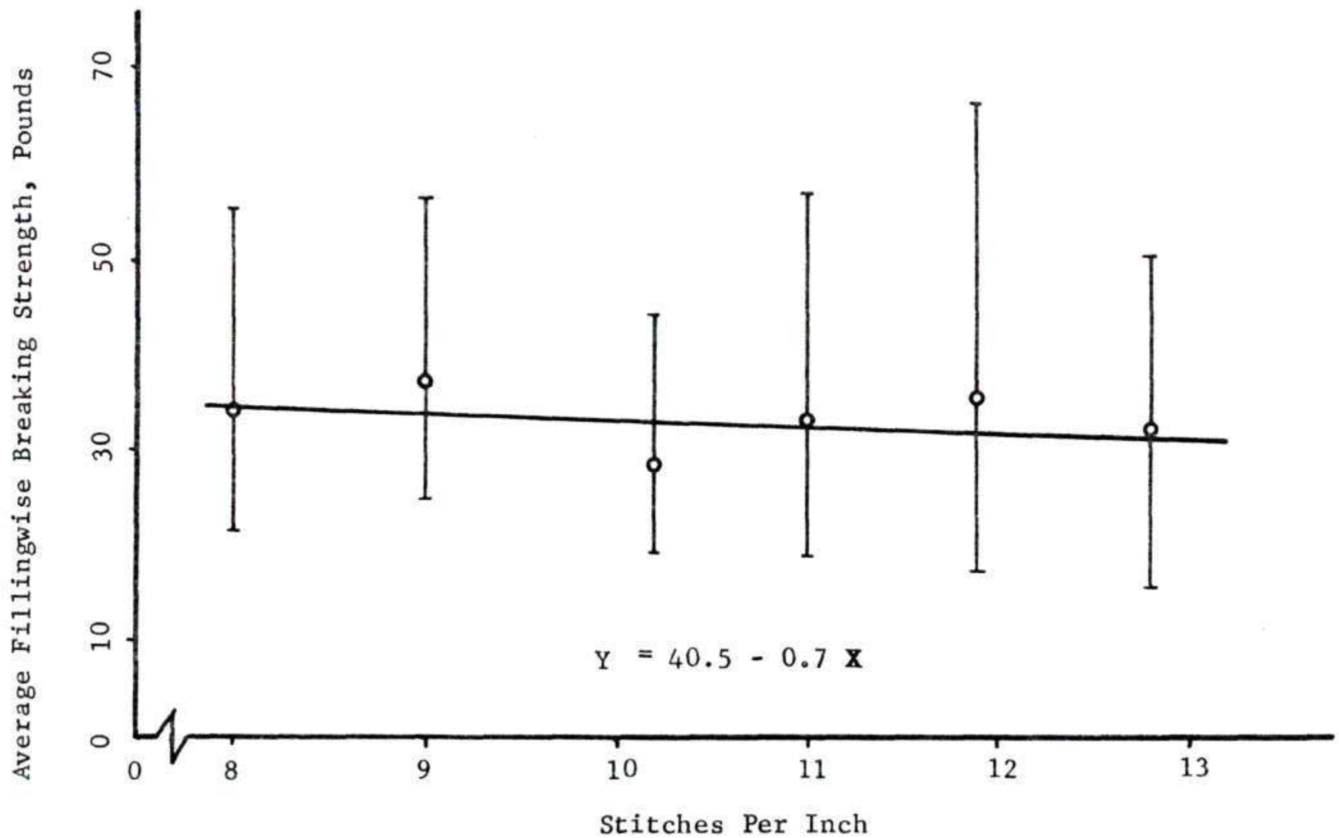

Figure 10. Average Fillingwise Breaking Streangth vs. Stitches Per Inch. 1300 Denier Face Yarn.

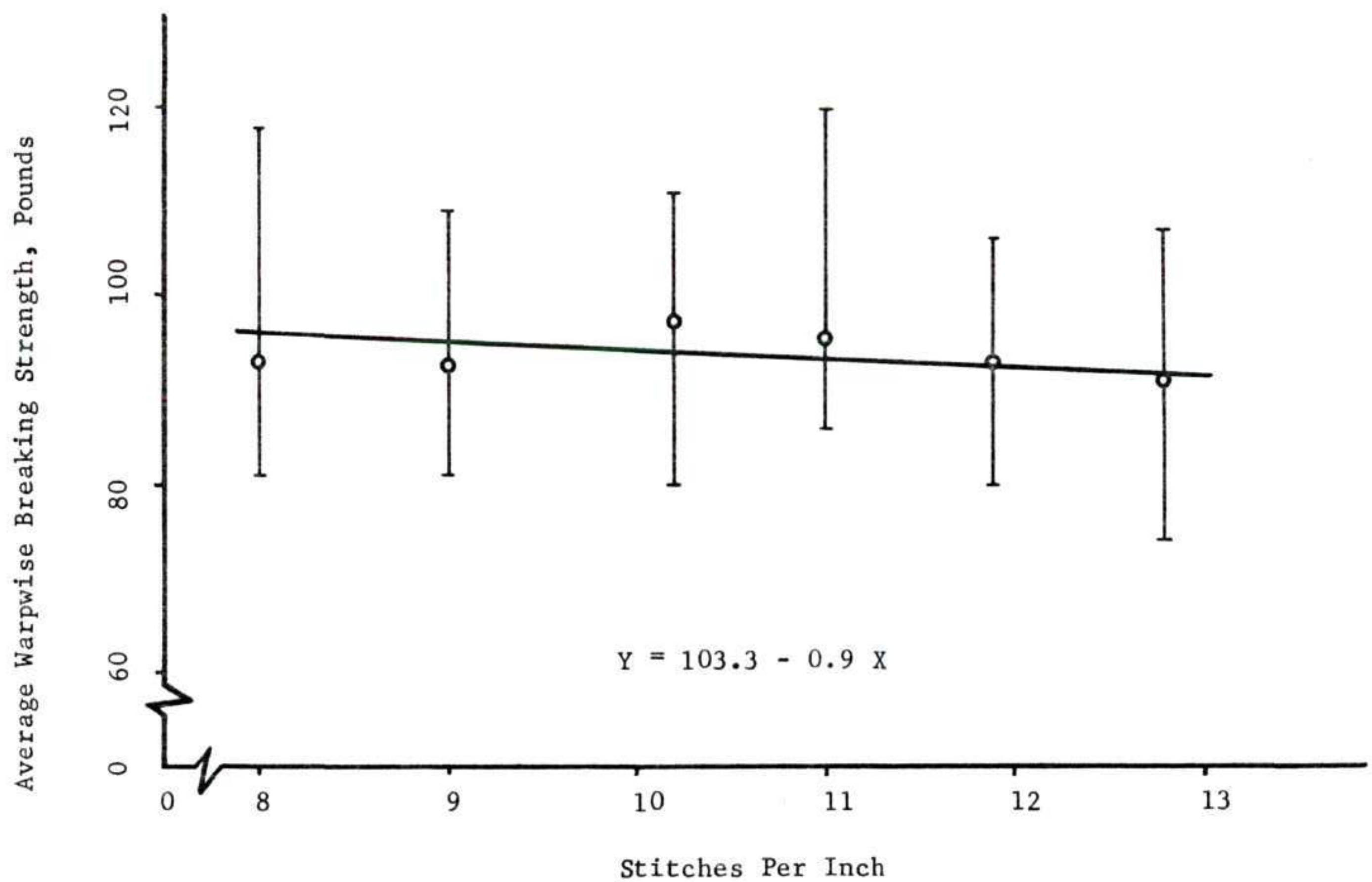

Figure 11. Average Warpwise Breaking Strength vs. Stitches Per Inch. 1300 Denier Face Yarn.

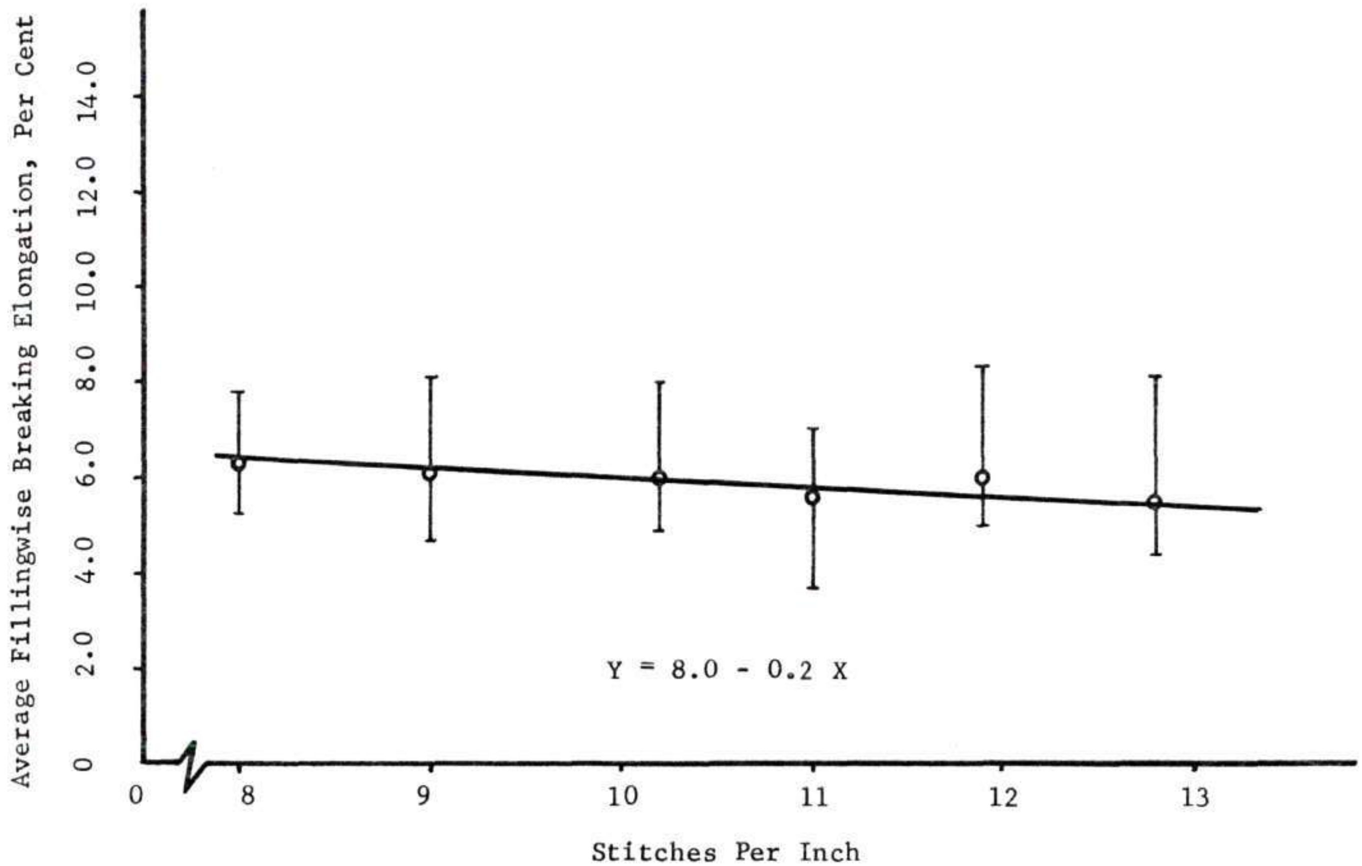

Figure 12. Average Fillingwise Breaking Per Cent Elongation vs. Stitches Per Inch. 1300 Denier Face Yarn.

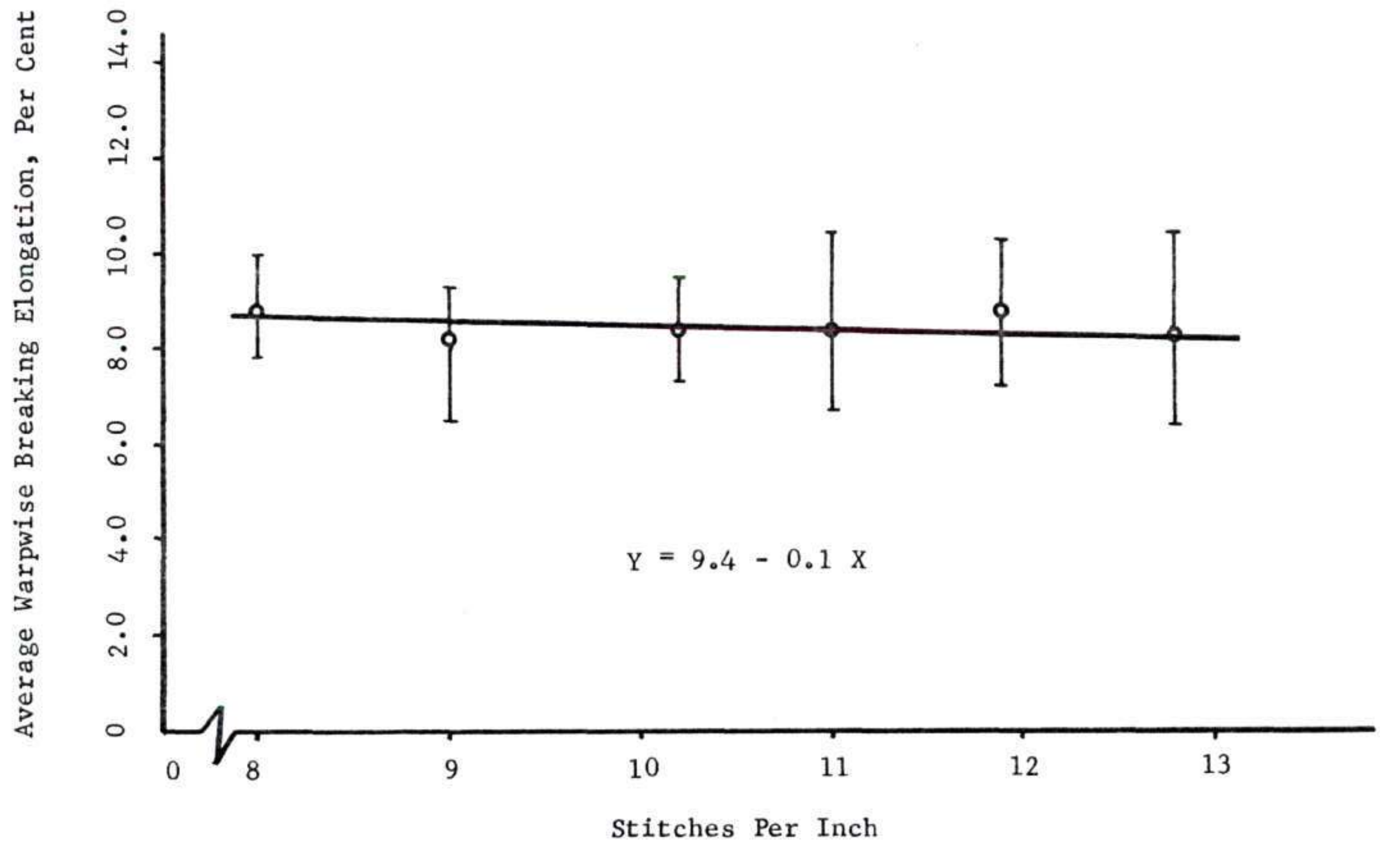

Figure 13. Average Warpwise Breaking Per Cent Elongation vs. Stitches Per Inch. 1300 Denier Face Yarn.

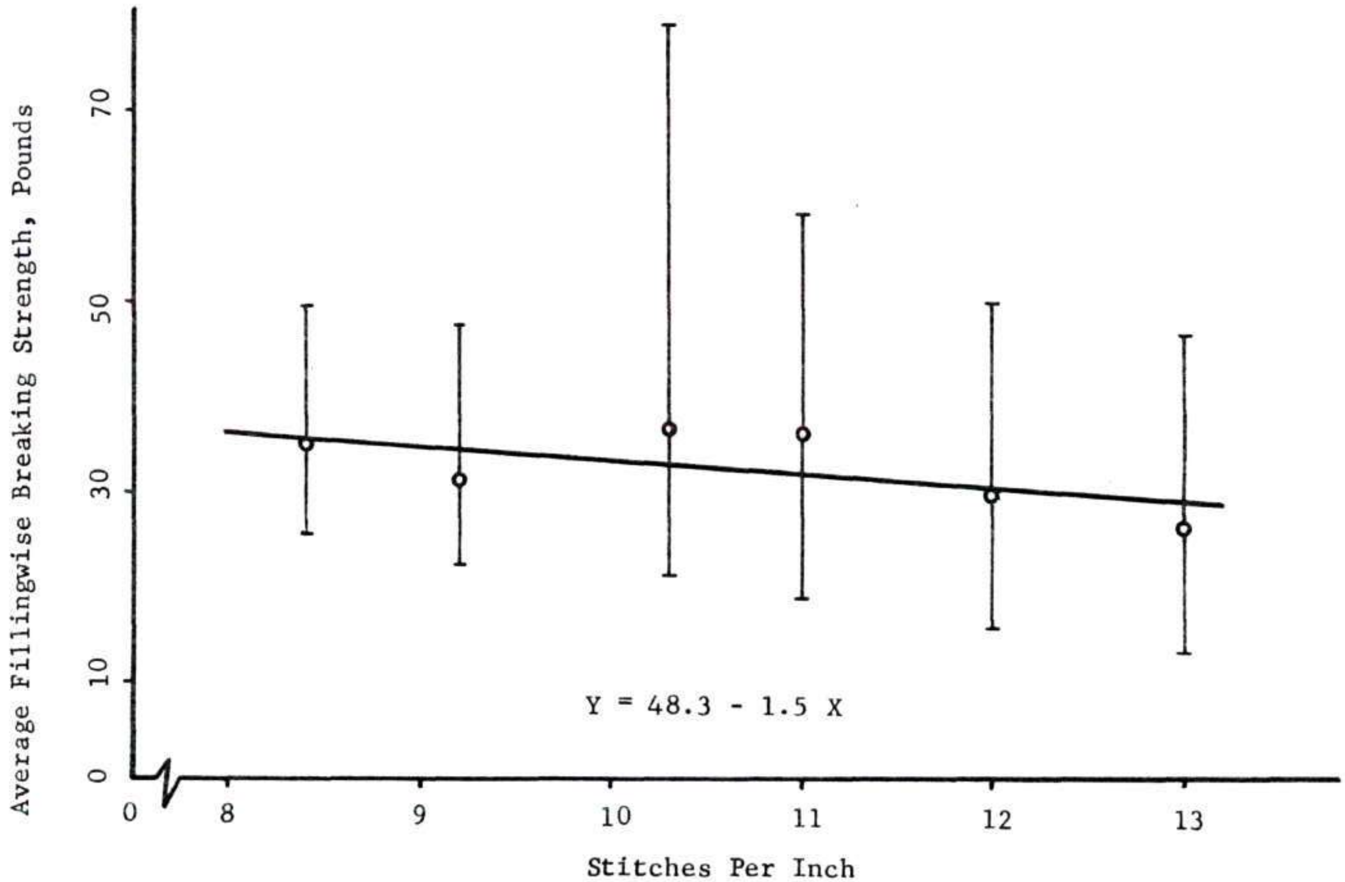

Figure 14. Average Fillingwise Breaking Strength vs. Stitches Per Inch. 2600 Denier Face Yarn.

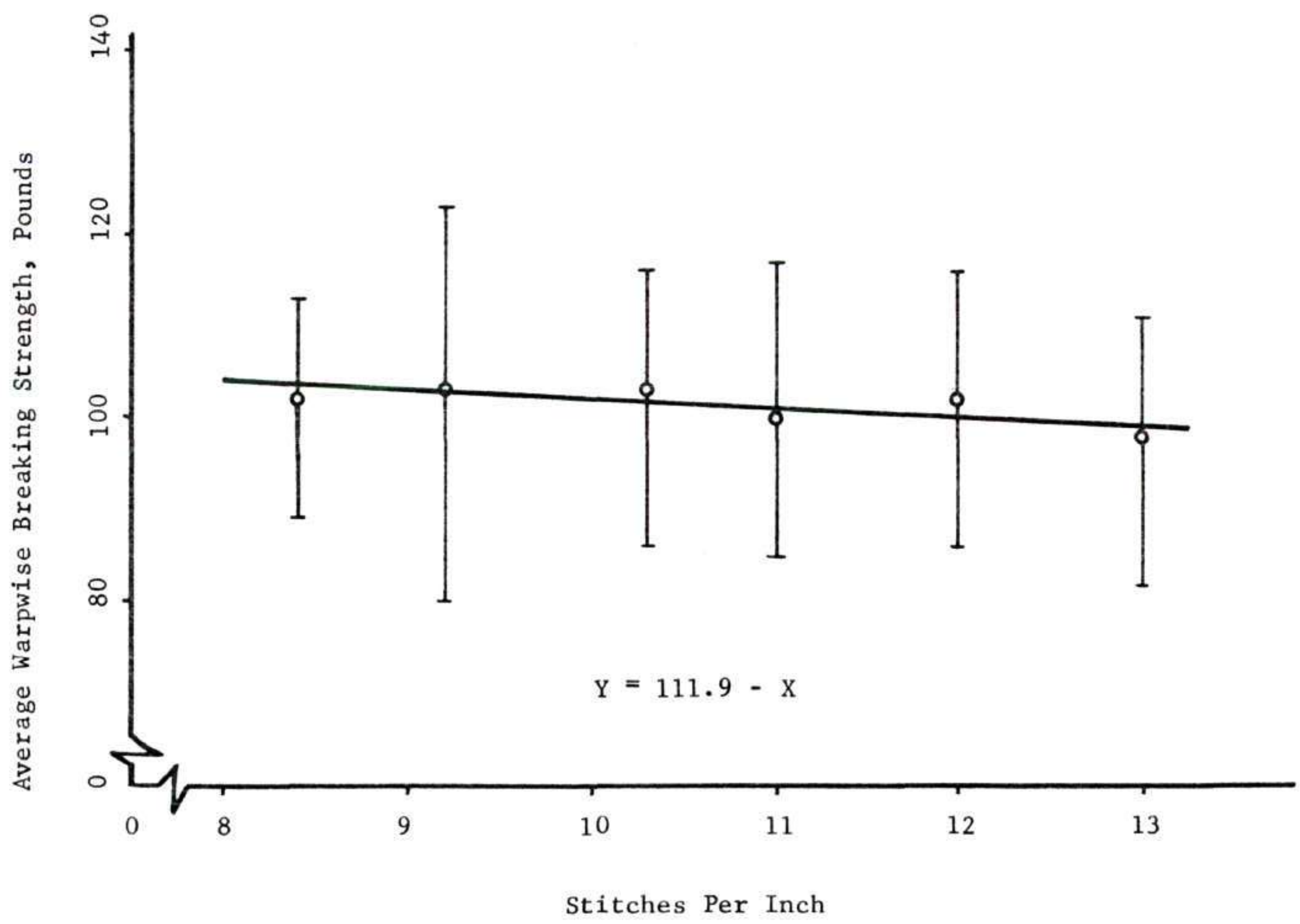

Figure 15. Average Warpwise Breaking Strength vs. Stitches Per Inch. 2600 Denier Face Yarn.

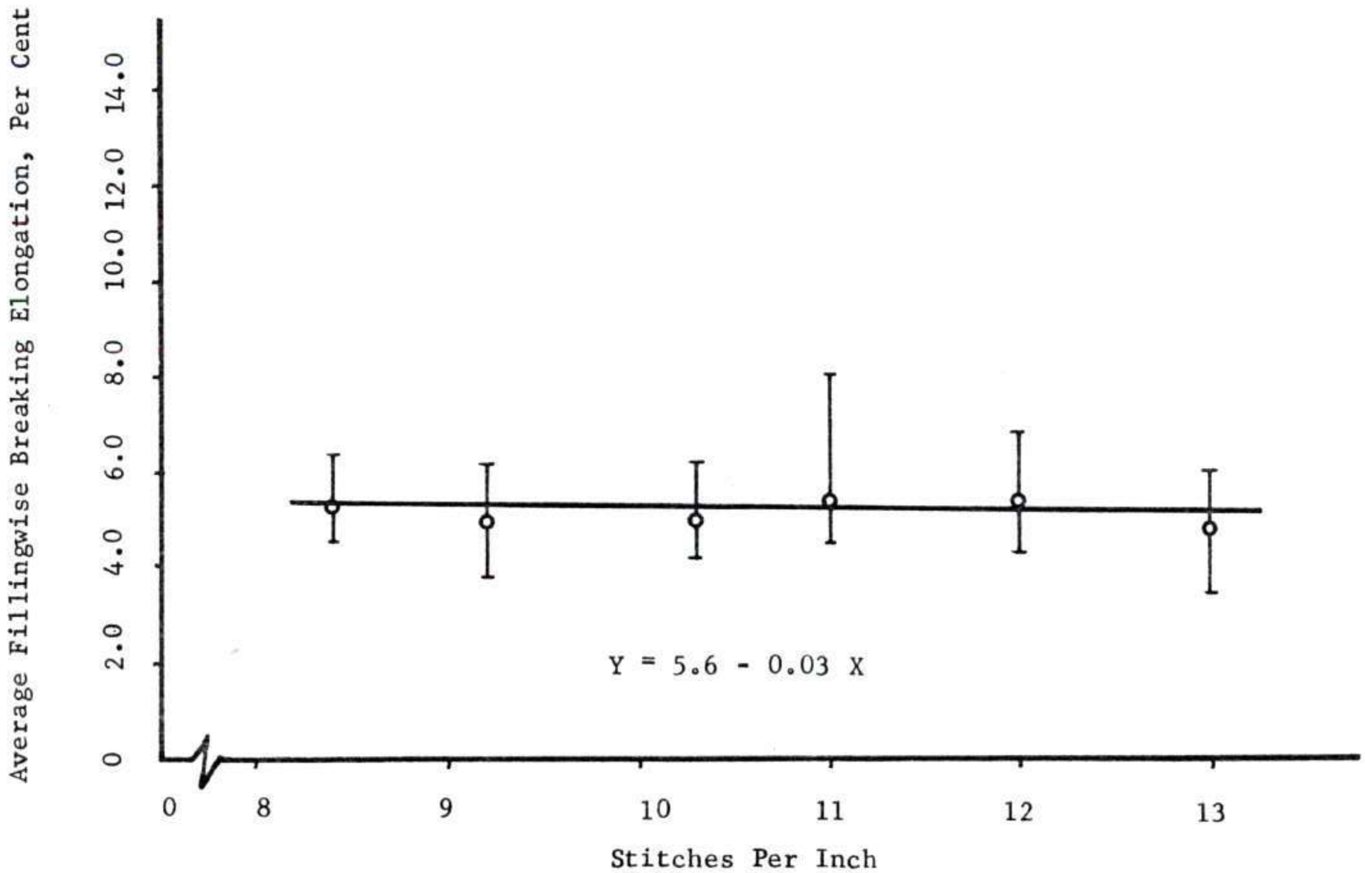

Figure 16. Average Fillingwise Breaking Per Cent Elongation vs. Stitches Per Inch. 2600 Denier Face Yarn.

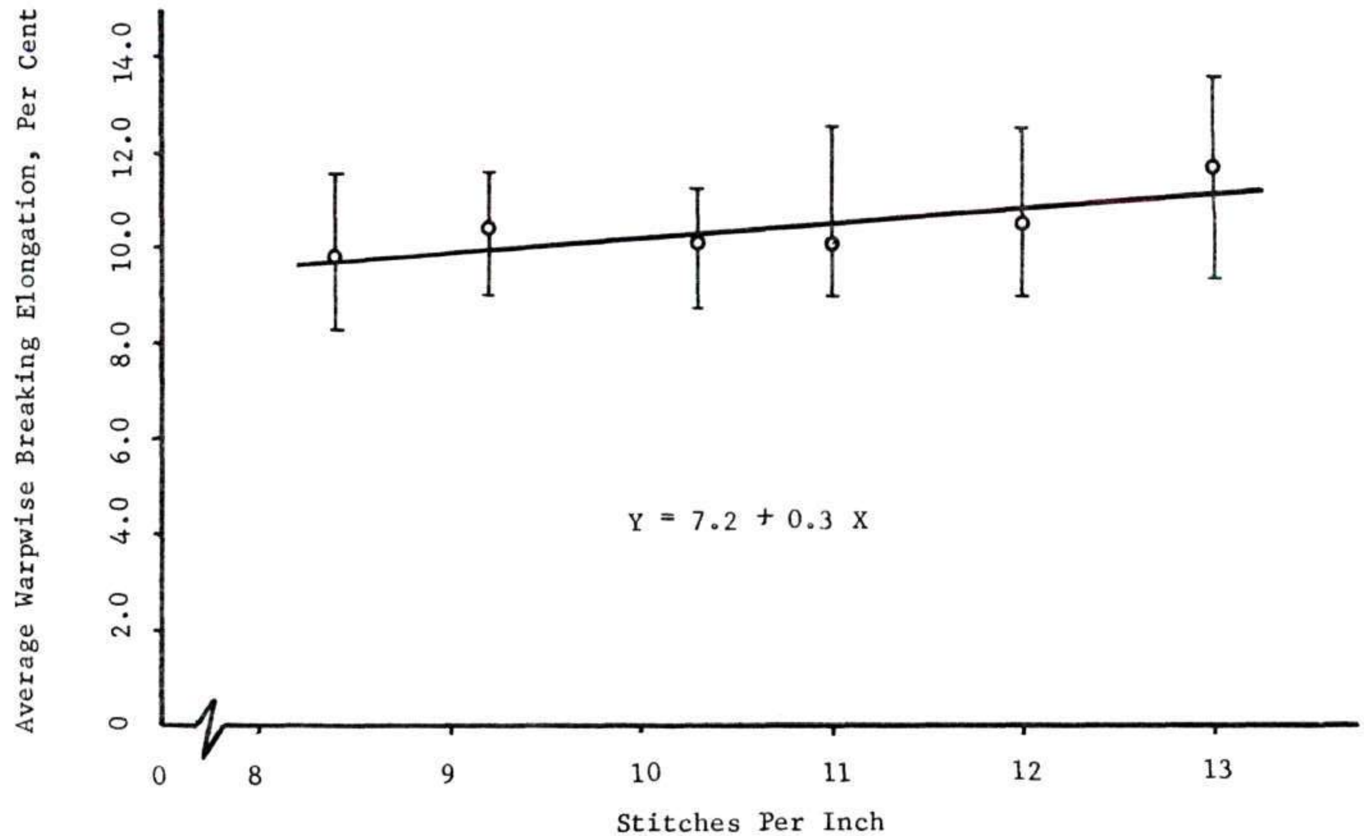

Figure 17. Average Warpwise Breaking Per Cent Elongation vs. Stitches Per Inch. 2600 Denier Face Yarn.

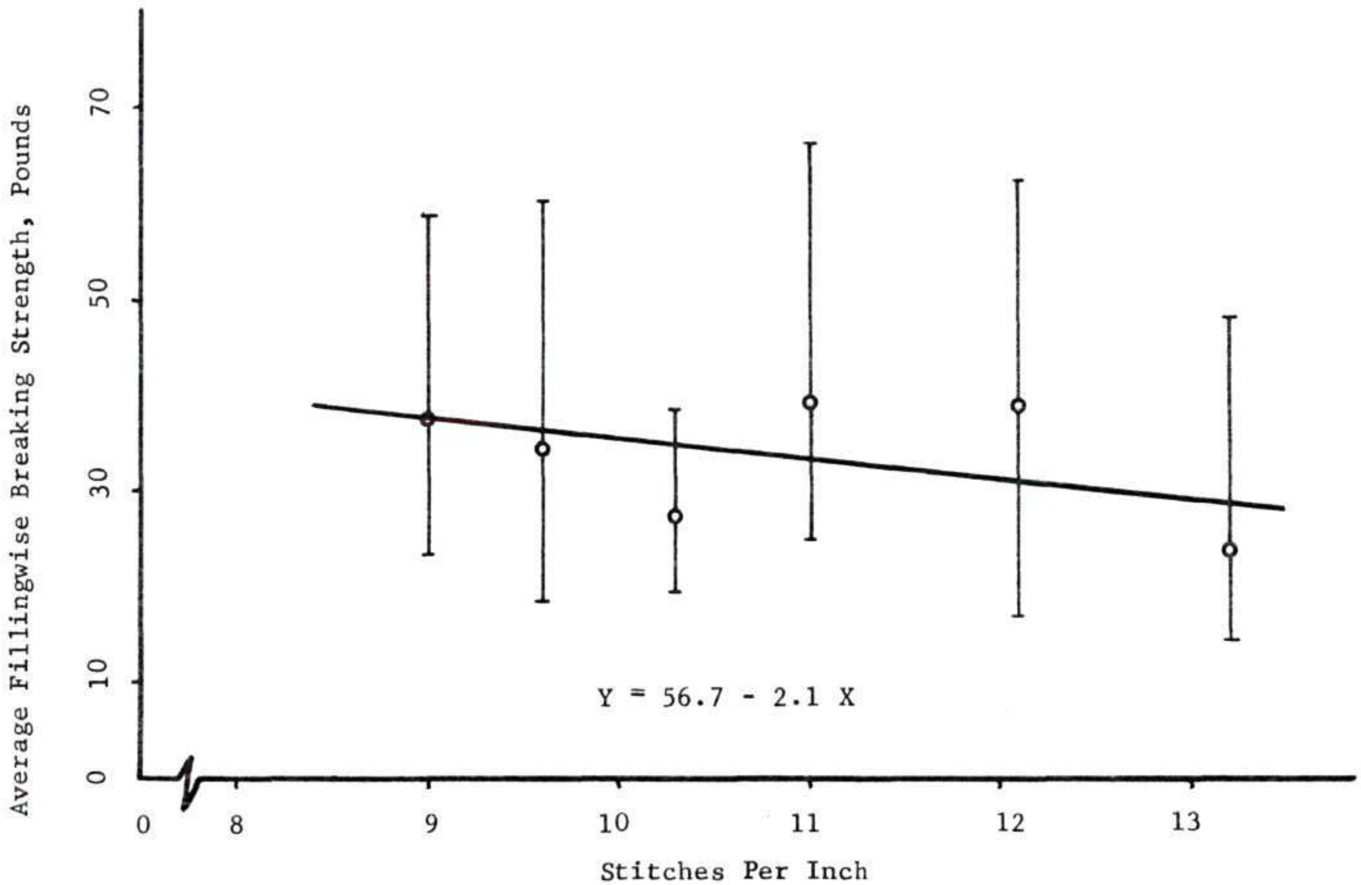

Figure 18. Average Fillingwise Breaking Strength vs. Stitches Per Inch. 3700 Denier Face Yarn.

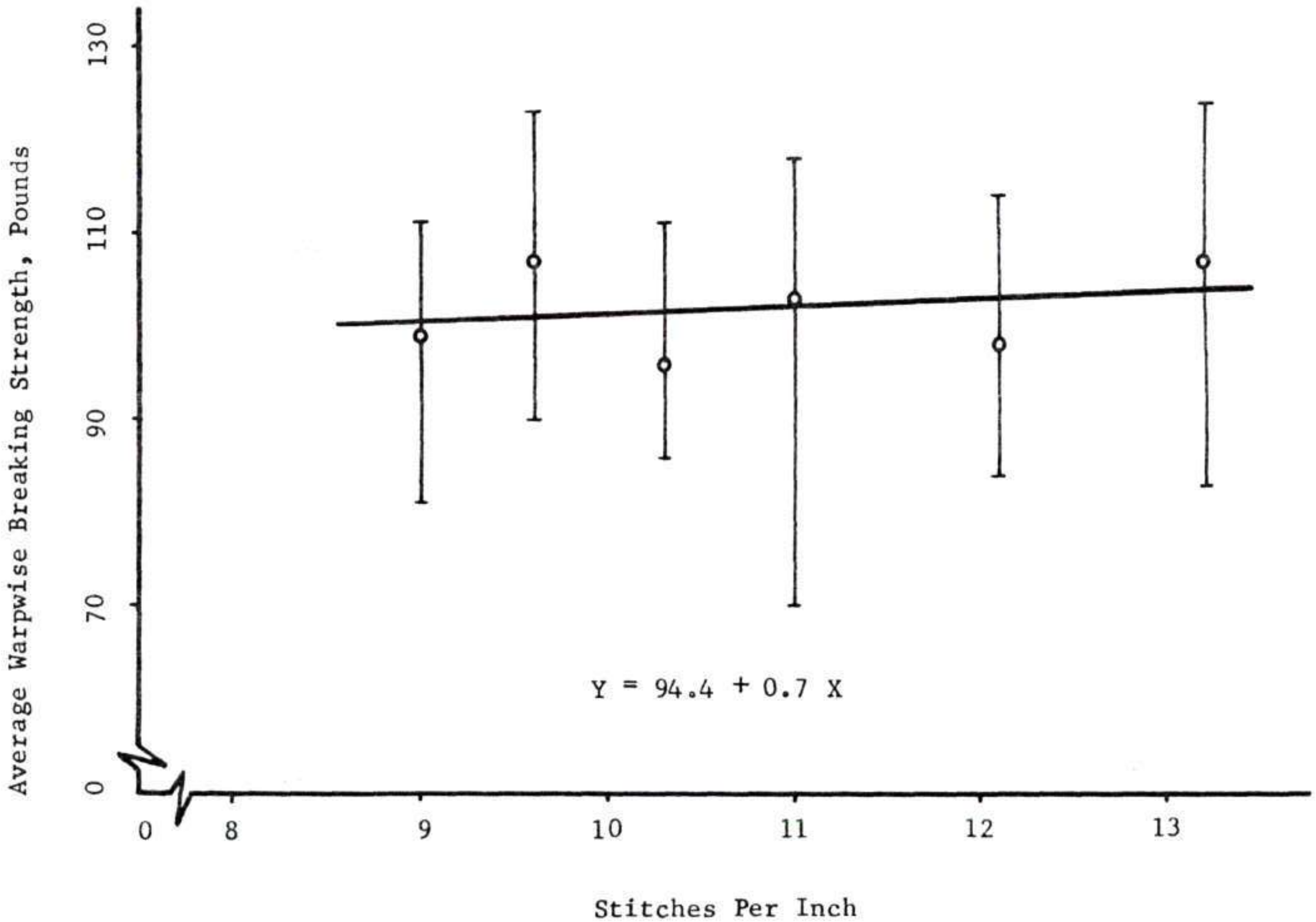

Figure 19. Average Warpwise Breaking Strength vs. Stitches Per Inch. 3700 Denier Face Yarn.

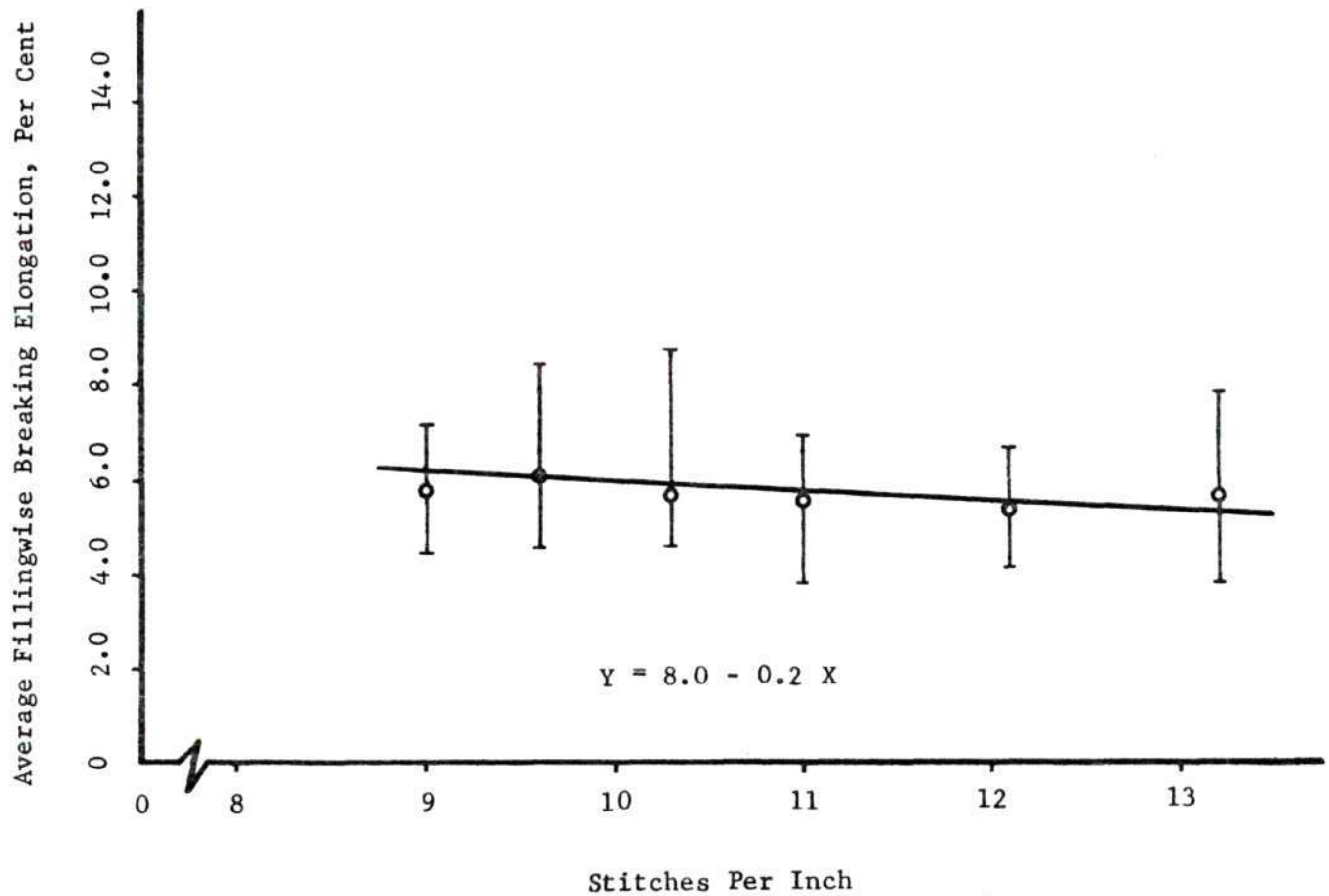

Figure 20. Average Fillingwise Breaking Per Cent Elongation vs. Stitches Per Inch. 3700 Denier Face Yarn.

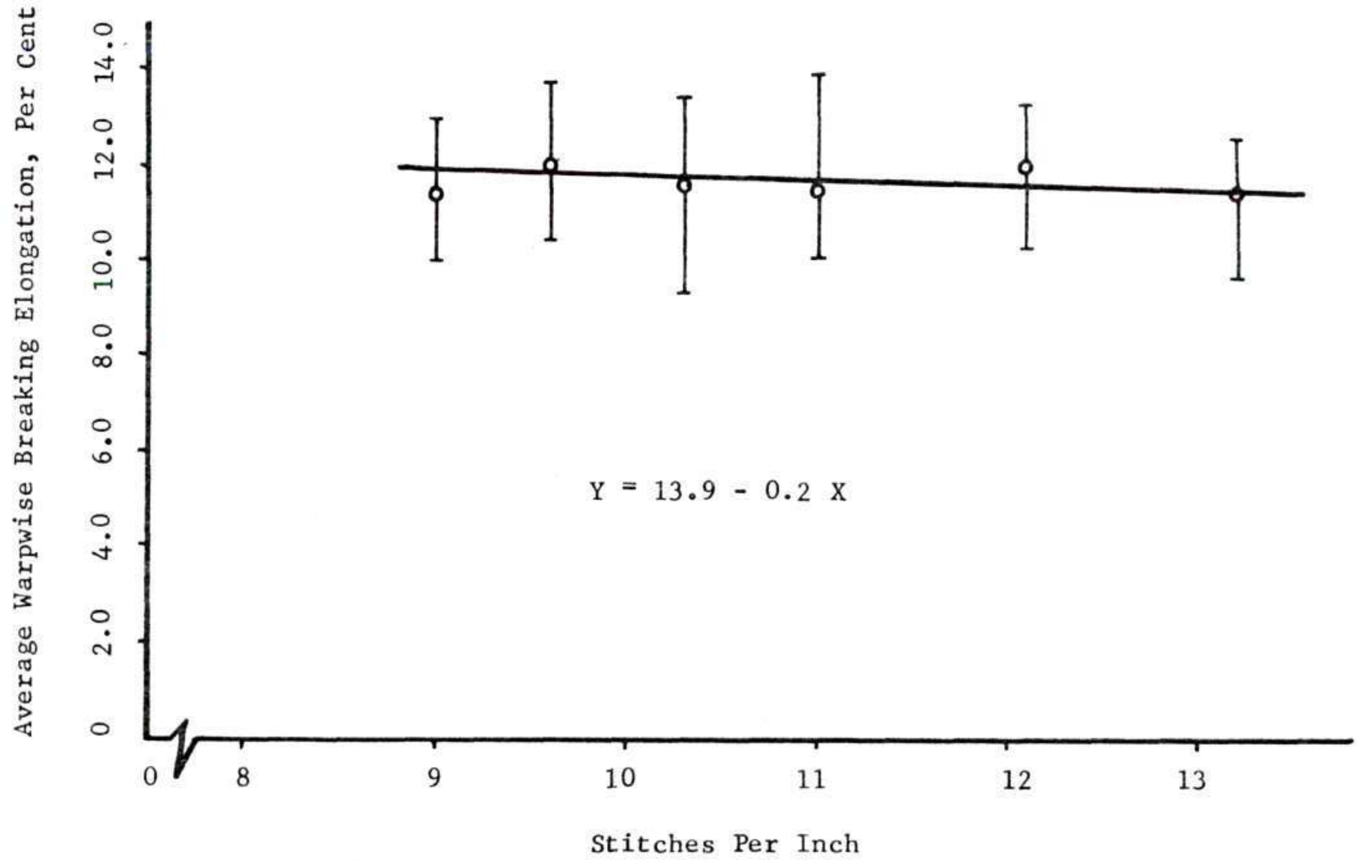

Figure 21. Average Warpwise Breaking Per Cent Elongation vs. Stitches Per Inch. 3700 Denier Face Yarn.

In order to determine if the slopes of the lines differed significantly from zero, i.e. if a relation did exist, significance tests were carried out for each slope (7). A level of significance of five per cent was selected. The hypothesis tested was that the estimate of the slope B equalled zero ($B = B_o = 0$). The test statistic was

$$t = \frac{b - B_o}{s_{y/x}\sqrt{\dfrac{1}{\sum (x_i - \bar{x})^2}}}$$

where

t = test statistic,

b = least squares estimator of the slope B,

B_o = the hypothesized value of the slope, $B_o = 0$,

$s_{y/x}$ = the estimate of the standard deviation of y about the mean $A + Bx$,

x_i = individual stitches per inch value,

$\bar{x}$ = average of the stitches per inch.

The criterion for rejection of the hypothesis was that

$$|t| \geq t_{\frac{\alpha}{2};\, n - 2}$$

where

α = five per cent as designated by the level of significance,

n = six, the number of averages for each curve.

For this case $t_{\frac{\alpha}{2};\, n - 2} = t_{0.025;\, 4} = 2.776$. Table 4 gives the results of the tests.

Table 4. Significance Test Results

Parameter Represented by Y = A + BX	Equation of Line	$s_{y/x}$ (lbs or %)	t	Conclusion
Fillingwise Breaking Strength, 1300 Denier	Y=40.5-0.7X	3.0	0.9	Fail to reject hypothesis
Warpwise Breaking Strength, 1300 Denier	Y=103-0.9X	1.8	1.8	Fail to reject hypothesis
Fillingwise Breaking Elongation, %, 1300 Denier	Y-8.0-0.2X	0.1	6.7	Reject hypothesis
Warpwise Breaking Elongation, %, 1300 Denier	Y=9.4-0.1X	0.2	1.8	Fail to reject hypothesis
Fillingwise Breaking Strength, 2600 Denier	Y=48.3-1.5X	3.5	1.7	Fail to reject hypothesis
Warpwise Breaking Strength, 2600 Denier	Y=111.9-1.0X	1.8	2.0	Fail to reject hypothesis
Fillingwise Breaking Elongation, %, 2600 Denier	Y=5.6-0.03X	0.3	0.4	Fail to reject hypothesis
Warpwise Breaking Elongation, %, 2600 Denier	Y=7.2+0.3X	0.5	2.3	Fail to reject hypothesis
Fillingwise Breaking Strength, 3700 Denier	Y=56.7-2.1X	6.1	1.2	Fail to reject hypothesis
Warpwise Breaking Strength, 3700 Denier	Y=94.4+0.7X	5.2	0.5	Fail to reject hypothesis
Fillingwise Breaking Elongation, %, 3700 Denier	Y=8.0-0.2X	0.2	3.3	Reject hypothesis
Warpwise Breaking Elongation, %, 3700 Denier	Y=13.9-0.2X	3.6	0.2	Fail to reject hypothesis

Only two of the slopes significantly differed from zero at the five per cent significance level. The relatively large values of $s_{y/x}$ which appear in the denominator of the test statistic contributed to this fact. This large value of $s_{y/x}$ resulted from the spread of the averages about the computed lines.

The fact that ten of the 12 values of the slopes computed were negative indicated that a relationship between increasing stitches per inch and decrease of strength and elongation did exist.

The coefficient of variation for the fillingwise breaking strength was plotted against the number of stitches per inch in Figure 22. A value corresponding to the coefficient of variation of the untufted fabric was taken to be the value at zero stitches per inch when exponential curves of the form

$$y = Ae^{Bx}$$

were fitted to the data by the least squares method. The equations and correlation coefficients are given on Figure 22. It must be noted that the equations would only be good for values of stitches per inch given in Figure 22, since an infinite value of coefficient of variation at an infinite value of stitches per inch would be impossible. This increase with increasing stitches was indicative of an increasing amount of damage to the filling yarns.

The high speed movies taken at approximately eight and approximately 13 stitches per inch were observed by means of a Bell & Howell Analyst projector. Visual analysis indicated more direct hits at 13 stitches per inch than at eight stitches per inch. A direct hit

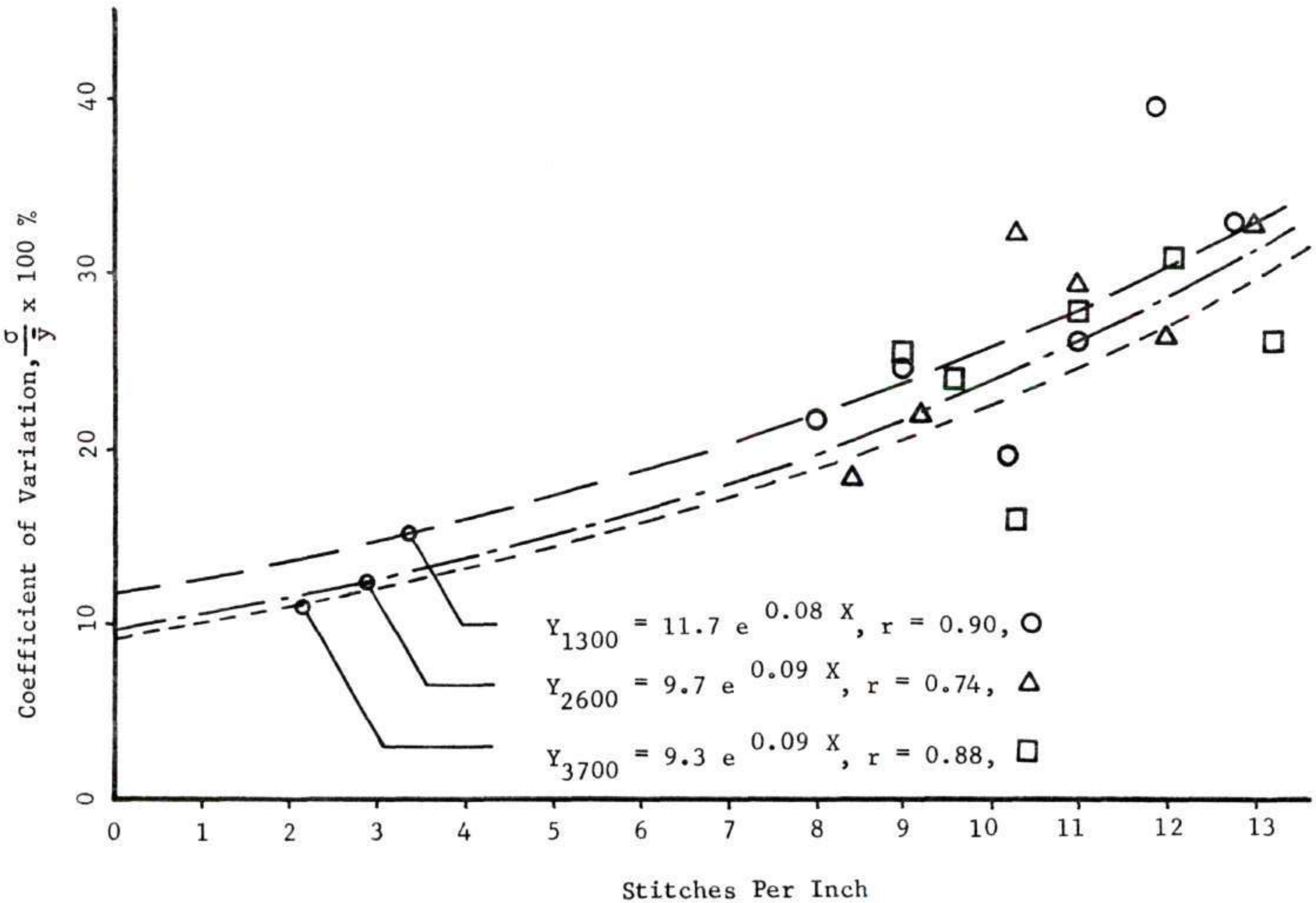

Figure 22. Fillingwise Breaking Strength Coefficient of Variation vs. Stitches Per Inch.

occurred when a needle on its downward path pierced the filling or warp yarn directly rather than being deflected by the yarn. The damage to the yarn was apparent as the individual fibers were seen to be broken by the piercing needle.

Effect of Yarn Denier

The original design of the experiment called for a determination of the effect of yarn size on the strength of the tufted fabric. The fact that two different fabrics with different strength and elongation properties were used and the fact that an integral number of stitches per inch tufted was not obtainable for each yarn size used made a comparison between the strength and elongation properties of the tufted samples and the yarn size difficult.

The per cent strength retained was plotted against stitches per inch in Figure 23 in order to compare the relative values tufted with different size yarns, but no relation was apparent.

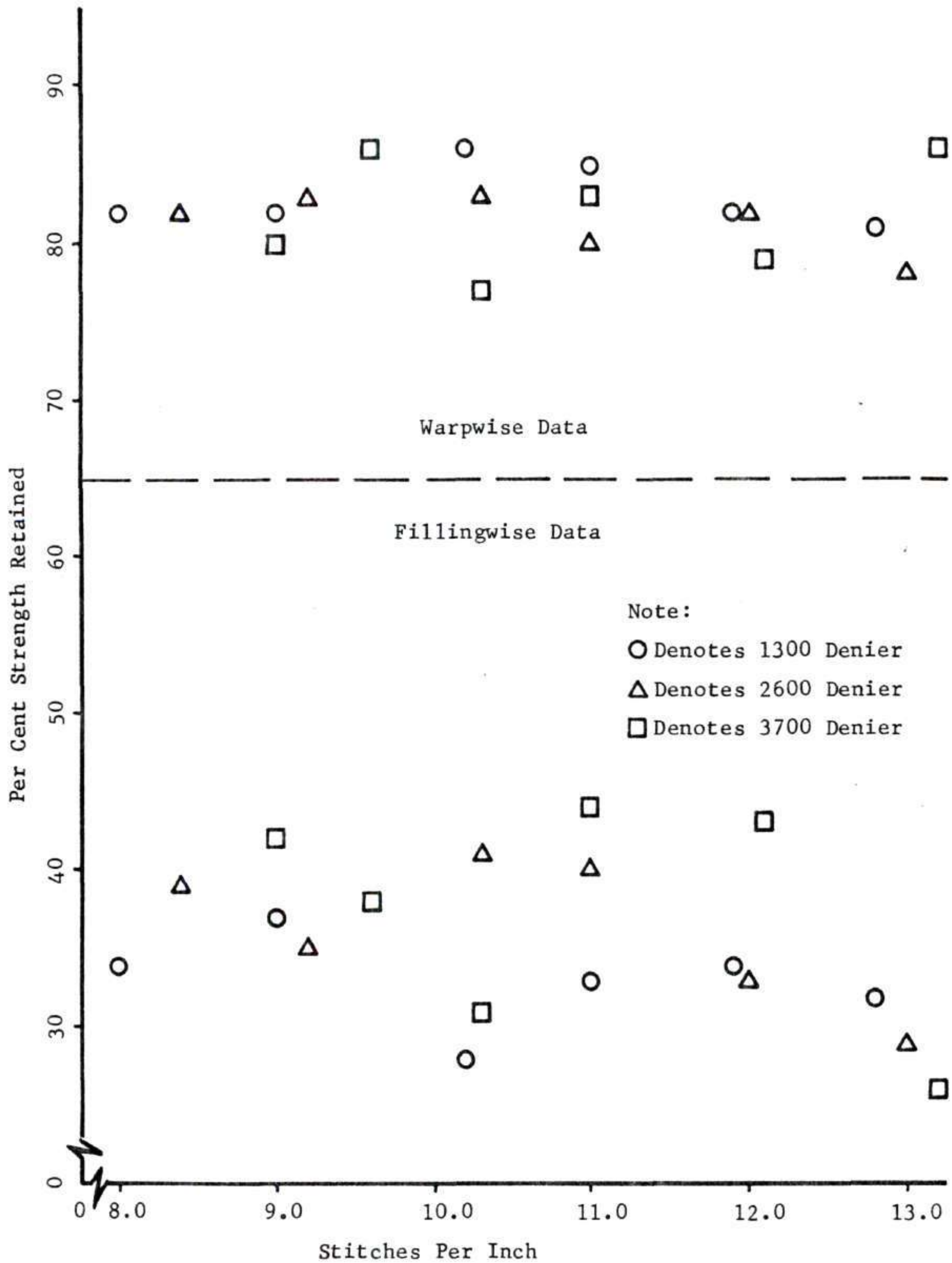

Figure 23. Per Cent Strength Retained vs. Stitches Per Inch.

CHAPTER V

CONCLUSIONS

It was concluded that increasing the number of stitches per inch decreased the fillingwise and warpwise breaking strength and breaking elongation of the tufted fabric during 5/64 inch gauge tufting, since the slopes computed for the data of breaking strength and breaking elongation of the tufted fabrics versus stitches per inch were, with the exception of two, all negative.

The fact that the coefficients of variation as computed for the fillingwise breaking strength data increased with increasing number of stitches per inch indicated also that breaking strength in the filling direction decreased with increasing number of stitches per inch.

Visual observations of the tufting process by means of high speed movies indicated that more damage occurred to the filling yarns at approximately 13 stitches per inch than at eight stitches per inch. These visual observations indicated a decrease in fillingwise strength with increasing stitches per inch.

From Figure 23 showing per cent strength retained versus stitches per inch, it was concluded that the yarn size had no effect on the strength of the tufted fabric. Figure 23 of per cent strength retained did show the major decrease of strength in the fillingwise direction of the tufted samples during 5/64 inch gauge tufting.

CHAPTER VI

RECOMMENDATIONS

The test results showed such a large amount of variation that conclusive results were unobtainable. Further research with jute carpet backing should be done on more uniform fabrics in order to obtain better results without having to test an unusually large number of samples.

A related topic for further study would be to determine the effect of varying the needle gauge and shape and the stitches per inch on the strength of the tufted fabric. Another related topic would be to determine the effect of varying the speed of tufting, i.e., the number of stitches per minute, on the strength of the tufted fabric.

APPENDIX

DETERMINATION OF SPECIMEN SIZE

The general equation used was as follows:

$$n = \frac{t^2 \ \sigma^2}{E^2}$$

where,

n = number of test specimens,

E = desired precision of the mean of the test results expressed in the units of the property under test,

σ = standard deviation of individual test results,

t = constant depending on the probability level,

according to ASTM Designation: D 2264-64T (8). The value of t used corresponds to a 90 per cent probability level. The values of σ were determined from previous grab tests as ten pounds warpwise and 15 pounds fillingwise. A desired precision of five pounds was chosen. Therefore,

$$n_{warp} = \frac{(1.645)^2 \ (10)^2}{(5)^2} = 11 \text{ specimens}$$

$$n_{filling} = \frac{(1.645) \ (15)^2}{(5)^2} = 24 \text{ specimens}$$

DATA SHEET
BREAKING STRENGTH OF UNTUFTED JUTE FABRIC

Sample Number 1 Fabric A, 15 x 13, 9 ounce, Plain Weave

Specimen Number	Warpwise Breaking Strength (lbs)	Warpwise Breaking % Elongation	Fillingwise Breaking Strength (lbs)	Fillingwise Breaking % Elongation
1	102	6.9	91	5.7
2	127	6.4	92	6.1
3	105	6.8	98	6.7
4	125	6.9	107	6.3
5	115	7.1	113	6.8
6	117	7.3	100	6.7
7	102	8.2	104	5.9
8	120	7.6	94	6.5
9	100	6.7	97	5.8
10	108	7.3	122	6.3
11	119	6.7	91	6.8
12	103	7.1	133	6.7
13	109	7.1	88	5.0
14	109	7.2	80	6.0
15	109	6.0	108	5.2
16	114	7.2	102	5.8
17	115	6.0	120	6.2
18	117	7.8	119	6.2
19	107	8.0	114	6.6
20	129	8.7	104	6.9
21			99	5.9
22			100	5.9
23			102	6.2
24			89	5.6
25			87	5.9
26			88	6.4
27			86	5.8
28			90	5.7
29			111	6.5
30			90	5.7
Average, $\bar{y}$	113	7.2	101	6.1
Standard Deviation,	8.4	0.7	12.4	0.5
Coefficient of Variation, %, $\sigma/\bar{y} \times 100$	7.4	9.3	12.3	7.7
Maximum	129	8.7	133	6.9
Minimum	100	6.0	80	5.0
Range	29	2.7	53	1.9

DATA SHEET
BREAKING STRENGTH OF UNTUFTED JUTE FABRIC

Sample Number 2 Fabric B, 15 x 13, 9 ounce, Plain Weave

Specimen Number	Warpwise		Fillingwise	
	Breaking Strength (lbs)	Breaking % Elongation	Breaking Strength (lbs)	Breaking % Elongation
1	126	8.0	98	5.8
2	132	8.0	82	5.0
3	146	8.7	76	5.1
4	118	10.1	102	6.3
5	135	10.0	103	5.8
6	125	9.2	103	6.0
7	114	9.5	90	5.9
8	121	9.1	98	6.2
9	127	8.2	84	5.6
10	131	9.2	94	5.7
11	114	9.2	86	6.0
12	145	9.1	79	5.7
13	122	9.8	81	5.3
14	119	9.5	79	5.2
15	124	9.9	88	5.2
16	127	9.7	95	5.5
17	105	7.3	87	5.6
18	109	8.7	85	6.1
19			104	6.1
20			81	5.3
21			91	6.4
22			98	6.0
23			78	6.1
24			92	5.9
25			98	5.7
26			95	6.3
27			97	6.3
28			91	5.6
29			78	4.9
30			94	6.0
Average, $\bar{y}$	124	9.1	90	5.8
Standard Deviation,	10.6	0.8	8.4	0.4
Coefficient of Variation, %, $\sigma / \bar{y} \times 100$	8.6	8.4	9.3	7.1
Maximum	146	10.1	104	6.4
Minimum	105	7.3	76	4.9
Range	41	2.8	28	1.5

DATA SHEET
BREAKING STRENGTH OF TUFTED FABRIC

Sample Number 3 Stitches Per Inch 8.0
Yarn Denier 1300 Teeth in Driving Gear 32

Specimen Number	Warpwise		Fillingwise	
	Breaking Strength (lbs.)	Breaking Per Cent Elongation	Breaking Strength (lbs.)	Breaking Per Cent Elongation
1	94	8.2	35.3	6.4
2	118	8.0	55.5	7.4
3	84	7.8	33.0	6.7
4	92	9.0	40.8	7.1
5	86	8.3	39.1	5.5
6	92	8.2	36.8	5.9
7	84	9.5	30.8	6.1
8	81	9.6	29.0	6.0
9	85	8.2	39.4	7.1
10	91	10.0	44.0	6.0
11	98	8.7	39.7	5.8
12	84	8.7	33.3	5.9
13	115	8.3	32.7	7.1
14	89	8.6	-	-
15	95	9.5	40.8	7.8
16	99	9.5	34.6	6.0
17			23.4	6.5
18			23.7	6.1
19			21.5	5.4
20			40.5	5.2
21			30.0	7.2
22			28.0	6.9
23			30.6	7.1
24			24.3	5.7
25			32.0	6.5
26			36.8	5.3
27				
28				
29				
30				
Average, $\bar{y}$	93	8.8	34.2	6.3
Standard Deviation, σ	10.3	0.7	7.4	0.7
Coefficient of Variation, $\sigma / \bar{y} \times 100$ %	11.1	7.5	21.7	11.1
Maximum	118	10.0	55.5	7.8
Minimum	81	7.8	21.5	5.2
Range	37	2.2	34.0	2.6
Per Cent Strength Retained	82		34	

DATA SHEET
BREAKING STRENGTH OF TUFTED FABRIC

Sample Number 4 Stitches Per Inch 9.0
Yarn Denier 1300 Teeth in Driving Gear 35

Specimen Number	Warpwise		Fillingwise	
	Breaking Strength (lbs.)	Breaking Per Cent Elongation	Breaking Strength (lbs.)	Breaking Per Cent Elongation
1	85.2	8.0	50.7	5.0
2	95.4	8.3	51.1	4.9
3	92.1	8.0	53.5	4.9
4	91.6	6.5	25.6	4.9
5	86.0	8.7	50.9	6.0
6	109.0	8.7	30.0	5.3
7	84.5	7.8	46.8	5.8
8	100.2	8.0	29.3	7.8
9	88.3	8.0	40.8	4.7
10	97.6	8.7	56.9	5.8
11	81.0	8.2	35.0	6.5
12	87.0	7.8	37.4	5.5
13	90.0	7.0	39.9	6.3
14	95.0	8.7	26.0	6.8
15	94.0	8.9	31.6	7.8
16	92.0	8.5	32.8	8.1
17	100.0	9.3	42.1	7.3
18	101.0	8.7	30.3	5.7
19			31.0	6.6
20			40.4	7.3
21			43.8	4.7
22			39.3	5.8
23			29.3	5.2
24			27.1	5.9
25			32.2	6.0
26			31.4	6.4
27			25.0	6.4
28				
29				
30				
Average, $\bar{y}$	92.8	8.2	37.4	6.1
Standard Deviation, σ	6.9	0.7	9.2	1.0
Coefficient of Variation, $\sigma / \bar{y} \times 100$ %	7.4	8.0	24.7	16.0
Maximum	109.0	9.3	56.9	8.1
Minimum	81	6.5	25.0	4.7
Range	28	2.8	31.9	3.4
Per Cent Strength Retained	82		37.0	

DATA SHEET
BREAKING STRENGTH OF TUFTED FABRIC

Sample Number 5 Stitches Per Inch 10.2
Yarn Denier 1300 Teeth in Driving Gear 41

Specimen Number	Warpwise		Fillingwise	
	Breaking Strength (lbs.)	Breaking Per Cent Elongation	Breaking Strength (lbs.)	Breaking Per Cent Elongation
1	90	7.4	31.9	5.7
2	111	8.5	21.6	7.0
3	95	7.3	30.4	8.0
4	96	7.7	31.5	6.7
5	109	8.7	27.8	7.0
6	92	8.7	44.3	7.9
7	103	7.6	32.1	5.2
8	107	8.0	27.7	5.6
9	107	9.5	29.5	5.1
10	86	9.0	22.2	7.1
11	97	9.3	33.5	6.6
12	100	7.9	19.7	6.5
13	103	8.0	34.6	7.3
14	-	-	25.8	5.4
15	98	9.3	19.5	5.7
16	92	8.2	23.0	5.3
17	86	9.1	28.3	5.1
18	80	8.9	25.8	5.3
19			29.7	5.4
20			26.7	6.1
21			21.9	6.2
22			26.3	5.9
23			36.6	5.8
24			31.9	5.8
25			30.0	5.2
26			22.9	4.9
27			35.5	5.1
28				
29				
30				
Average, $\bar{y}$	97.2	8.4	28.5	6.0
Standard Deviation, σ	8.6	0.7	5.6	0.9
Coefficient of Variation, $\sigma/\bar{y} \times 100$ %	8.8	8.2	19.7	14.5
Maximum	111	9.5	44.3	8.0
Minimum	80	7.3	19.5	4.9
Range	31	2.2	24.8	3.1
Per Cent Strength Retained	86		29	

DATA SHEET

BREAKING STRENGTH OF TUFTED FABRIC

Sample Number 6 | Stitches Per Inch 11.0

Yarn Denier 1300 | Teeth in Driving Gear 44

Specimen Number	Warpwise		Fillingwise	
	Breaking Strength (lbs.)	Breaking Per Cent Elongation	Breaking Strength (lbs.)	Breaking Per Cent Elongation
1	93	7.6	34.7	4.8
2	86	7.2	23.6	3.7
3	96	7.2	19.0	5.9
4	92	6.7	57.2	4.6
5	105	7.3	41.4	4.5
6	86	7.3	31.9	4.3
7	120	8.0	47.2	5.3
8	92	8.2	33.5	4.5
9	91	9.0	20.3	5.2
10	86	8.7	38.1	5.5
11	98	8.6	30.7	7.0
12	98	9.1	30.0	5.1
13	89	10.5	37.3	5.8
14	95	9.6	29.6	4.7
15	101	9.6	26.7	5.8
16	96	8.4	48.2	6.0
17	104	8.7	34.5	6.5
18	93	9.6	33.6	6.9
19			24.0	6.0
20			30.6	6.2
21			45.6	6.8
22			38.2	6.2
23			30.5	5.8
24			28.5	5.9
25			21.3	6.3
26			36.7	6.9
27			30.0	5.2
28				
29				
30				
Average, $\bar{y}$	95.6	8.4	33.4	5.6
Standard Deviation, σ	8.1	1.0	8.8	0.9
Coefficient of Variation, $\sigma / \bar{y} \times 100$ %	8.5	12.2	26.4	15.4
Maximum	120	10.5	57.2	7.0
Minimum	86	6.7	19.0	3.7
Range	34	3.8	38.2	3.3
Per Cent Strength Retained	93		34	

DATA SHEET
BREAKING STRENGTH OF TUFTED FABRIC

Sample Number 7 Stitches Per Inch 11.9
Yarn Denier 1300 Teeth in Driving Gear 49

Specimen Number	Warpwise		Fillingwise	
	Breaking Strength (lbs.)	Breaking Per Cent Elongation	Breaking Strength (lbs.)	Breaking Per Cent Elongation
1	90	8.3	55	5.6
2	97	8.5	48.3	-
3	90	8.0	31.4	5.0
4	84	8.5	21.9	5.0
5	100	8.5	47.2	5.1
6	89	10.3	25.3	5.0
7	80	8.0	30.0	5.5
8	91	10.0	66.6	5.7
9	93	7.3	37.7	5.2
10	87	7.8	35.3	5.5
11	106	9.3	51.0	6.3
12	96	9.3	28.1	5.9
13	91	8.0	19.5	5.8
14	101	10.1	60.9	5.8
15	89	8.9	38.1	5.9
16	90	9.7	63.1	5.6
17	103	9.7	30.0	6.0
18			21.5	5.8
19			20.4	5.6
20			20.2	5.0
21			41.7	5.3
22			29.6	5.2
23			21.7	8.3
24			17.3	-
25			34.2	5.7
26			34.2	5.6
27				
28				
29				
30				
Average, $\bar{y}$	9.3	8.8	35.8	6.0
Standard Deviation, σ	6.7	0.9	14.2	1.7
Coefficient of Variation, $\sigma / \bar{y} \times 100$ %	7.2	10.0	39.7	28.3
Maximum	106	10.3	66.6	8.3
Minimum	80	7.3	17.3	5.0
Range	26	3.0	49.3	3.3
Per Cent Strength Retained	82		36	

DATA SHEET
BREAKING STRENGTH OF TUFTED FABRIC

Sample Number 8 Stitches Per Inch 12.8
Yarn Denier 1300 Teeth in Driving Gear 52

Specimen Number	Warpwise		Fillingwise	
	Breaking Strength (lbs.)	Breaking Per Cent Elongation	Breaking Strength (lbs.)	Breaking Per Cent Elongation
1	87	7.8	36.8	5.1
2	94	8.4	20.7	6.0
3	84	7.4	40.0	5.7
4	83	7.8	38.3	5.7
5	104	8.0	26.0	5.1
6	105	7.8	18.5	5.1
7	81	6.4	38.3	4.8
8	99	9.0	44.4	5.1
9	87	8.0	50.0	6.3
10	89	7.3	43.5	5.1
11	99	9.3	15.7	5.7
12	102	10.5	26.2	5.2
13	107	9.1	25.1	5.9
14	79	8.5	45.5	4.4
15	79	9.1	42.1	5.1
16	74	8.4	30.0	5.5
17			28.7	5.3
18			17.4	8.1
19			50.6	5.4
20			43.9	5.6
21			37.1	6.1
22			39.9	6.0
23			37.0	5.2
24			22.1	6.0
25			26.3	5.3
26			17.5	4.5
27			24.1	5.5
28			18.2	5.2
29				
30				
Average, $\bar{y}$	91	8.3	32.3	5.5
Standard Deviation, σ	10.3	0.9	10.6	0.7
Coefficient of Variation, $\sigma / \bar{y} \times 100$ %	11.4	11.3	33.0	12.3
Maximum	107	10.5	50.6	8.1
Minimum	74	6.4	15.7	4.4
Range	33	4.1	34.9	3.7
Per Cent Strength Retained	80		32	

DATA SHEET
BREAKING STRENGTH OF TUFTED FABRIC

Sample Number 9 Stitches Per Inch 8.4
Yarn Denier 2600 Teeth in Driving Gear 32

Specimen Number	Warpwise		Fillingwise	
	Breaking Strength (lbs.)	Breaking Per Cent Elongation	Breaking Strength (lbs.)	Breaking Per Cent Elongation
1	103	9.2	48.4	6.2
2	101	10.2	31.6	5.0
3	113	9.1	31.6	6.3
4	111	10.7	45.0	5.4
5	113	8.7	35.1	4.5
6	109	10.1	39.8	5.1
7	89	11.6	29.0	5.1
8	92	10.3	27.9	4.6
9	96	8.3	39.4	5.9
10	91	9.1	30.3	5.0
11	103	9.6	38.2	5.5
12	103	9.7	36.1	5.1
13	107	10.5	35.1	4.9
14	89	10.1	31.6	5.8
15	107	10.0	25.9	5.4
16	108	9.6	38.0	4.9
17			27.0	6.1
18			28.6	5.1
19			49.7	5.3
20			39.6	6.4
21			25.5	4.8
22			32.0	4.9
23			33.8	5.2
24			39.4	5.7
25			30.3	5.2
26			41.2	4.9
27				
28				
29				
30				
Average, $\bar{y}$	102	9.8	35.0	5.3
Standard Deviation, σ	8.1	0.8	6.5	0.5
Coefficient of Variation, $\sigma/\bar{y} \times 100$ %	8.0	8.1	18.5	9.7
Maximum	113	11.6	49.7	6.4
Minimum	89	8.3	25.5	4.5
Range	24	3.3	24.2	1.9
Per Cent Strength Retained	82		39	

DATA SHEET
BREAKING STRENGTH OF TUFTED FABRIC

Sample Number 10 Stitches Per Inch 9.2
Yarn Denier 2600 Teeth in Driving Gear 35

Specimen Number	Warpwise Breaking Strength (lbs.)	Warpwise Breaking Per Cent Elongation	Fillingwise Breaking Strength (lbs.)	Fillingwise Breaking Per Cent Elongation
1	120	9.7	28.9	5.0
2	114	11.1	22.7	4.8
3	115	9.0	26.4	4.7
4	123	11.1	34.3	5.6
5	103	9.0	32.0	4.6
6	88	9.6	34.1	5.2
7	108	11.4	39.0	5.7
8	105	11.0	47.9	6.2
9	93	10.2	29.6	4.9
10	90	10.7	41.6	5.6
11	101	10.8	25.0	-
12	102	11.6	38.9	5.3
13	100	10.5	23.2	4.7
14	97	10.9	32.5	4.9
15	110	9.8	30.4	5.3
16	80	9.9	29.3	4.8
17	110	10.8	27.7	4.8
18	97	10.5	23.1	3.7
19			45.2	4.2
20			25.4	5.3
21			27.5	4.6
22			37.0	5.1
23			30.4	5.8
24			28.5	5.1
25			22.7	4.0
26				
27				
28				
29				
30				
Average, $\bar{y}$	103	10.4	31.3	5.0
Standard Deviation, σ	11.0	0.8	6.8	0.6
Coefficient of Variation, $\sigma / \bar{y} \times 100$ %	10.7	7.2	21.9	11.3
Maximum	123	11.6	47.9	6.2
Minimum	80	9.0	22.7	3.7
Range	43	2.6	25.2	2.5
Per Cent Strength Retained	83		35	

DATA SHEET
BREAKING STRENGTH OF TUFTED FABRIC

Sample Number 11 Stitches Per Inch 10.3
Yarn Denier 2600 Teeth in Driving Gear 41

Specimen Number	Warpwise		Fillingwise	
	Breaking Strength (lbs.)	Breaking Per Cent Elongation	Breaking Strength (lbs.)	Breaking Per Cent Elongation
1	109	10.0	43.3	5.1
2	86	9.7	28.0	4.5
3	101	9.2	32.7	4.9
4	109	9.5	34.5	5.7
5	93	11.3	36.6	5.3
6	108	10.9	36.4	4.9
7	105	10.5	26.7	4.1
8	111	10.8	32.0	4.3
9	107	9.8	36.0	4.8
10	109	9.3	31.5	4.3
11	107	11.3	28.1	5.6
12	110	9.8	31.9	4.7
13	97	9.6	30.8	4.9
14	98	9.3	21.5	4.6
15	91	8.7	25.6	4.9
16	87	11.0	27.1	5.3
17	116	11.1	32.9	5.1
18			36.1	5.1
19			30.0	-
20			52.9	4.9
21			52.3	5.1
22			79.5	5.2
23			36.1	4.9
24			50.2	5.1
25			47.7	6.0
26				
27				
28				
29				
30				
Average, $\bar{y}$	103	10.1	36.8	5.0
Standard Deviation, σ	8.8	0.8	11.9	0.4
Coefficient of Variation, $\sigma / \bar{y} \times 100$ %	8.5	8.0	32.5	8.7
Maximum	116	11.3	79.5	6.0
Minimum	86	8.7	21.5	4.1
Range	30	2.6	58.0	1.9
Per Cent Strength Retained	83		41	

DATA SHEET

BREAKING STRENGTH OF TUFTED FABRIC

Sample Number 12 Stitches Per Inch 11.0

Yarn Denier 2600 Teeth in Driving Gear 43

Specimen Number	Warpwise		Fillingwise	
	Breaking Strength (lbs.)	Breaking Per Cent Elongation	Breaking Strength (lbs.)	Breaking Per Cent Elongation
1	93	10.1	21.0	6.8
2	103	9.7	59.5	5.2
3	117	11.0	34.4	4.5
4	108	10.6	31.0	5.0
5	108	9.4	41.4	4.8
6	95	9.3	49.8	4.9
7	85	9.5	42.2	5.3
8	104	10.8	27.5	5.3
9	108	10.1	36.9	4.9
10	100	10.9	42.7	5.1
11	87	9.0	58.5	5.0
12	91	9.6	32.1	6.7
13	110	12.6	39.7	5.8
14	100	10.5	31.8	5.4
15	89	9.1	38.1	4.8
16	95	9.5	35.1	5.0
17			36.0	6.0
18			58.3	5.3
19			26.3	8.1
20			33.3	4.8
21			25.1	6.7
22			26.6	4.5
23			19.0	4.7
24			33.9	5.2
25			38.3	4.9
26			22.9	5.1
27				
28				
29				
30				
Average, $\bar{y}$	100	10.1	36.2	5.4
Standard Deviation, σ	9.0	0.9	10.8	0.8
Coefficient of Variation, $\sigma / \bar{y} \times 100$ %	9.0	8.9	29.7	15.4
Maximum	117	12.6	59.5	8.1
Minimum	85	9.0	19.0	4.5
Range	32	3.6	40.5	3.6
Per Cent Strength Retained	80		40	

DATA SHEET
BREAKING STRENGTH OF TUFTED FABRIC

Sample Number 13 Stitches Per Inch 12.0
Yarn Denier 2600 Teeth in Driving Gear 47

Specimen Number	Warpwise		Fillingwise	
	Breaking Strength (lbs.)	Breaking Per Cent Elongation	Breaking Strength (lbs.)	Breaking Per Cent Elongation
1	101	11.1	19.8	5.5
2	102	9.7	45.0	5.6
3	99	10.1	20.0	4.3
4	93	10.8	21.7	4.8
5	100	10.5	37.9	5.3
6	109	11.4	26.2	4.9
7	103	10.7	30.5	5.0
8	94	12.5	20.3	4.4
9	88	9.0	32.6	5.7
10	116	9.8	25.7	4.7
11	105	10.0	49.8	5.6
12	111	10.8	30.1	6.0
13	81	11.1	26.1	6.2
14	107	10.0	30.6	6.8
15	104	10.7	22.3	6.9
16	110	9.7	27.0	4.7
17	103	11.2	35.0	5.2
18			33.1	6.2
19			32.0	6.7
20			34.0	4.8
21			30.9	5.8
22			41.9	5.0
23			32.4	5.5
24			21.3	5.8
25			15.8	5.0
26			28.0	5.0
27			36.6	5.7
28				
29				
30				
Average, $\bar{y}$	102	10.5	29.9	5.4
Standard Deviation, σ	8.5	0.8	7.9	0.7
Coefficient of Variation, $\sigma / \bar{y} \times 100$ %	8.4	7.6	26.5	12.7
Maximum	116	12.5	49.8	6.9
Minimum	81	9.0	15.8	4.3
Range	35	3.5	34.0	2.6
Per Cent Strength Retained	82		33	

DATA SHEET
BREAKING STRENGTH OF TUFTED FABRIC

Sample Number 14 Stitches Per Inch 13.0
Yarn Denier 2600 Teeth in Driving Gear 52

Specimen Number	Warpwise		Fillingwise	
	Breaking Strength (lbs.)	Breaking Per Cent Elongation	Breaking Strength (lbs.)	Breaking Per Cent Elongation
1	102	9.4	13.2	3.4
2	93	11.1	26.0	4.7
3	111	12.7	29.6	5.3
4	100	12.7	25.4	4.8
5	92	9.4	19.0	-
6	107	11.8	29.6	5.7
7	103	13.7	22.4	3.9
8	99	11.6	16.7	4.7
9	107	12.6	33.1	5.3
10	82	11.0	22.2	5.9
11	89	12.4	37.4	6.0
12	82	10.3	20.0	4.9
13	100	13.2	36.2	4.8
14	93	11.1	31.1	4.0
15	110	11.3	15.1	4.0
16	87	12.2	17.0	6.0
17			26.7	4.7
18			30.9	5.5
19			23.4	4.2
20			26.1	3.8
21			46.7	5.1
22			25.1	4.2
23			38.5	4.3
24			33.1	4.2
25			18.0	-
26				
27				
28				
29				
30				
Average, $\bar{y}$	97	11.7	26.5	4.8
Standard Deviation, σ	9.1	1.2	8.1	0.7
Coefficient of Variation, $\sigma / \bar{y} \times 100$ %	9.3	10.4	30.4	15.4
Maximum	111	13.7	46.7	6.0
Minimum	82	9.4	13.2	3.4
Range	29	4.3	33.5	2.6
Per Cent Strength Retained	78		29	

DATA SHEET
BREAKING STRENGTH OF TUFTED FABRIC

Sample Number 15 Stitches Per Inch 9.0
Yarn Denier 3700 Teeth in Driving Gear 33

Specimen Number	Warpwise		Fillingwise	
	Breaking Strength (lbs.)	Breaking Per Cent Elongation	Breaking Strength (lbs.)	Breaking Per Cent Elongation
1	110	11.6	32.0	6.4
2	97	10.0	45.5	5.5
3	97	12.2	37.5	6.2
4	81	10.5	54.0	6.4
5	93	10.7	33.3	6.7
6	104	11.0	25.1	5.2
7	86	11.2	45.9	6.2
8	98	13.0	59.0	6.3
9	109	10.3	30.7	6.2
10	98	11.3	49.1	5.7
11	111	12.9	27.7	5.2
12	109	12.1	23.1	4.6
13	107	11.6	38.6	5.9
14	89	11.8	36.7	5.7
15	97	11.4	24.5	5.0
16	93	11.3	32.5	6.0
17			39.6	6.1
18			32.5	5.7
19			28.9	6.4
20			39.0	5.8
21			40.0	5.5
22			44.3	5.7
23			30.0	5.1
24			26.7	4.5
25			49.2	5.6
26			50.6	7.2
27				
28				
29				
30				
Average, $\bar{y}$	99	11.4	37.5	5.8
Standard Deviation, σ	8.8	0.8	9.6	0.6
Coefficient of Variation, $\sigma / \bar{y} \times 100$ %	8.9	7.2	25.5	10.7
Maximum	111	13.0	59.0	7.2
Minimum	81	10.0	23.1	4.5
Range	30	3.0	35.9	2.7
Per Cent Strength Retained	80		42	

DATA SHEET
BREAKING STRENGTH OF TUFTED FABRIC

Sample Number 16 Stitches Per Inch 9.6
Yarn Denier 3700 Teeth in Driving Gear 35

Specimen Number	Warpwise		Fillingwise	
	Breaking Strength (lbs.)	Breaking Per Cent Elongation	Breaking Strength (lbs.)	Breaking Per Cent Elongation
1	109	11.6	37.3	4.6
2	114	12.5	34.1	6.0
3	101	11.6	33.8	5.7
4	105	11.7	43.0	6.3
5	98	10.7	18.6	6.3
6	123	13.6	46.0	6.0
7	109	12.0	30.0	6.3
8	113	11.4	39.6	6.1
9	99	12.3	60.4	5.5
10	116	13.7	20.0	8.5
11	107	10.4	32.2	6.0
12	105	13.0	27.5	6.3
13	109	11.5	33.6	6.2
14	119	12.6	34.3	6.7
15	97	13.2	30.0	5.8
16	90	10.9	38.2	5.8
17			38.5	6.1
18			21.4	5.3
19			32.0	8.0
20			34.2	5.9
21			30.2	5.8
22			32.0	6.5
23			30.6	6.2
24			38.9	6.1
25			27.6	6.5
26			37.9	5.7
27			40.3	5.3
28				
29				
30				
Average, $\bar{y}$	107	12.0	34.2	6.1
Standard Deviation, σ	8.5	1.0	8.2	0.7
Coefficient of Variation, $\sigma / \bar{y} \times 100$ %	7.9	8.0	24.1	12.1
Maximum	123	13.7	60.4	8.5
Minimum	90	10.4	18.6	4.6
Range	33	3.3	41.8	3.9
Per Cent Strength Retained	86		38	

DATA SHEET
BREAKING STRENGTH OF TUFTED FABRIC

Sample Number 17 Stitches Per Inch 10.3
Yarn Denier 3700 Teeth in Driving Gear 37

Specimen Number	Warpwise		Fillingwise	
	Breaking Strength (lbs.)	Breaking Per Cent Elongation	Breaking Strength (lbs.)	Breaking Per Cent Elongation
1	96	9.3	24.0	6.3
2	89	9.5	29.0	7.2
3	91	13.3	27.3	6.2
4	101	12.0	22.5	8.8
5	89	12.4	32.6	6.6
6	97	13.4	25.2	4.7
7	99	13.1	23.8	-
8	109	11.0	38.1	5.2
9	86	11.5	28.8	5.1
10	89	10.0	31.6	7.0
11	92	11.9	29.0	-
12	93	10.7	24.0	-
13	91	11.3	29.0	5.0
14	111	12.7	28.3	4.6
15	110	11.3	27.7	5.8
16			30.0	5.6
17			26.0	4.8
18			23.0	6.3
19			35.4	5.7
20			19.8	5.9
21			32.2	5.0
22			27.9	5.2
23			19.8	4.8
24			24.7	4.9
25				
26				
27				
28				
29				
30				
Average, $\bar{y}$	96	11.6	27.5	5.7
Standard Deviation, σ	7.9	1.3	4.4	1.0
Coefficient of Variation, $\sigma / \bar{y} \times 100\ \%$	8.3	11.0	16.1	17.7
Maximum	111	13.4	38.1	8.8
Minimum	86	9.3	19.8	4.6
Range	25	4.1	18.3	4.2
Per Cent Strength Retained	77		30	

DATA SHEET
BREAKING STRENGTH OF TUFTED FABRIC

Sample Number 18 Stitches Per Inch 11.0
Yarn Denier 3700 Teeth in Driving Gear 43

Specimen Number	Warpwise		Fillingwise	
	Breaking Strength (lbs.)	Breaking Per Cent Elongation	Breaking Strength (lbs.)	Breaking Per Cent Elongation
1	103	10.8	25.2	3.9
2	118	11.1	31.6	5.0
3	116	10.4	38.0	4.4
4	70	11.7	40.0	5.2
5	101	11.1	48.6	5.3
6	84	10.1	29.5	5.5
7	112	13.8	28.3	5.1
8	87	10.1	53.1	5.6
9	99	13.9	54.0	5.3
10	117	11.9	44.0	5.7
11	114	12.9	32.1	5.9
12	92	10.5	32.7	4.9
13	110	12.0	34.4	5.9
14	110	10.2	29.4	5.7
15	112	12.6	66.3	6.2
16	104	11.3	64.9	5.8
17			40.0	5.5
18			38.0	5.5
19			53.5	6.0
20			41.5	6.2
21			31.1	5.7
22			30.9	5.8
23			33.3	6.9
24			33.2	5.1
25			29.6	6.3
26			36.6	6.5
27				
28				
29				
30				
Average, $\bar{y}$	103	11.5	39.2	5.6
Standard Deviation, σ	13.3	1.2	10.9	0.6
Coefficient of Variation, $\sigma / \bar{y} \times 100$ %	12.9	10.5	27.9	11.2
Maximum	118	13.9	66.3	6.9
Minimum	70	10.1	25.2	3.9
Range	48	3.8	41.1	3.0
Per Cent Strength Retained	83		44	

DATA SHEET
BREAKING STRENGTH OF TUFTED FABRIC

Sample Number 19 Stitches Per Inch 12.1
Yarn Denier 3700 Teeth in Driving Gear 47

Specimen Number	Warpwise		Fillingwise	
	Breaking Strength (lbs.)	Breaking Per Cent Elongation	Breaking Strength (lbs.)	Breaking Per Cent Elongation
1	84	10.3	27.5	5.4
2	104	11.3	49.3	5.2
3	89	12.2	41.9	5.7
4	101	12.7	28.0	5.0
5	105	12.9	47.4	6.0
6	100	12.0	30.3	6.0
7	90	10.7	35.5	5.3
8	91	10.8	58.6	5.5
9	101	13.0	62.5	5.5
10	92	11.7	34.9	5.2
11	93	11.3	32.1	5.6
12	114	13.1	58.0	5.1
13	104	13.3	38.9	5.3
14	101	12.9	17.0	5.1
15	99	12.5	25.3	4.2
16	105	10.7	28.2	6.7
17			45.0	6.2
18			29.7	4.9
19			52.6	5.5
20			33.2	5.4
21			23.3	4.7
22			38.0	4.4
23			30.0	5.0
24			44.0	5.5
25			59.0	5.6
26			44.2	5.1
27				
28				
29				
30				
Average, $\bar{y}$	98	12.0	39.0	5.4
Standard Deviation, σ	7.5	1.0	12.1	1.2
Coefficient of Variation, $\sigma / \bar{y} \times 100$ %	7.7	8.1	31.0	20.7
Maximum	114	13.3	62.5	6.7
Minimum	84	10.3	17.0	4.2
Range	30	3.0	45.5	2.5
Per Cent Strength Retained	79		43	

DATA SHEET
BREAKING STRENGTH OF TUFTED FABRIC

Sample Number 20 Stitches Per Inch 13.2
Yarn Denier 3700 Teeth in Driving Gear 52

Specimen Number	Warpwise		Fillingwise	
	Breaking Strength (lbs.)	Breaking Per Cent Elongation	Breaking Strength (lbs.)	Breaking Per Cent Elongation
1	102	10.7	21.8	-
2	99	-	29.8	7.9
3	105	12.6	48.4	5.6
4	83	10.2	23.6	4.6
5	101	11.0	32.8	6.0
6	109	-	23.4	4.6
7	118	12.3	21.9	5.0
8	106	10.3	25.0	6.3
9	124	11.0	23.0	-
10	110	11.0	22.3	7.2
11	101	9.8	21.0	-
12	102	10.6	22.0	4.6
13	108	10.5	21.9	6.0
14	108	10.5	20.4	-
15	108	9.7	20.3	4.7
16	121	12.3	22.0	6.8
17			24.5	6.0
18			20.0	-
19			14.5	-
20			21.5	-
21			31.2	3.9
22			16.1	4.2
23			20.7	7.6
24			25.0	-
25			25.0	-
26			23.2	-
27				
28				
29				
30				
Average, $\bar{y}$	107	11.4	23.9	5.7
Standard Deviation, σ	9.3	1.9	6.2	1.2
Coefficient of Variation, $\sigma / \bar{y} \times 100$ %	8.7	16.9	26.1	21.2
Maximum	124	12.6	48.4	7.9
Minimum	84	9.7	14.5	3.9
Range	41	2.9	33.9	4.0
Per Cent Strength Retained	86		26	

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