A STUDY OF THE EFFECTS OF VARYING BREAK DRAFTS AT THE DRAWING PROCESS ON THE PHYSICAL PROPERTIES OF ARNEL AND COMBED COTTON YARNS

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John Henry Marvin

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

SUMMARY

It has been demonstrated many times that a man-made fiber requires long periods of research before it is perfected. After a fiber such as Arnel is introduced for conversion into yarns, many problems have to be solved to determine the best processing methods due to the inherent characteristics peculiar to it. A good drawing process is very vital for obtaining the ultimate desirable physical properties for yarns in the best interest of quality and operational cost.

The objective of this study was to determine the optimum break draft at the drawing process for Arnel and combed cotton blends. This problem was approached by introducing five break draft variations at the drawing frame and following the effects on the products through the subsequent processes to the yarn form. Arnel dull and bright luster picker laps were processed into card slivers. These card slivers and combed cotton slivers were run separately on the drawing frame. They were also run in 25 per cent increments of Arnel-cotton so as to have nine different stock compositions and 45 lots for comparison purposes. The drawing slivers were made into the same hank rovings except for a slight twist difference when the cotton fiber percentage was predominant. And finally, the rovings were spun into common yarns with no changes for all the lots.

Uniformity tests were performed on the slivers, rovings and yarns. Tensile strength and elongation tests were also made on the yarns.

Computations were made from the results for statistical analysis and evaluations. The three largest break drafts were significantly better than the two smallest. Apparently the medium draft used was more desirable for uniformity. There were only small differences in the yarn strengths and elongations among the various drafts and blends.

It is recommended that further study be made on other drafts, especially a much higher amount. Selection of the Arnel card slivers from several mills in order to have a better sampling is a second recommendation. The investigation of other drafting systems and staple lengths is a third study that could give more over-all conclusive proof as to the effects of break drafts on the physical properties of Arnel-combed cotton yarns.

CHAPTER I

INTRODUCTION

Secondary acetate and Arnel or cellulose triacetate has been known for almost one hundred years but the secondary was generally accepted to be superior of the two fibers. In recent years textile technology has made it possible to translate the structural characteristics of the cellulose triacetate into textile performance (1).

The use of roller drafting has been practiced for about two hundred years. Improvements have been made in this system of converting a large strand of fibers into a small strand. These changes have resulted from the efforts of many researchers over the years; however, mention of only a few will be necessary here.

Professor Vasilieff (2) in 1902 developed the theory of floating fibers. As the fibers move from one pair of rolls forward to the next rolls their speed is constant at one position and variable at another. Grishin (3) continued the work of Vasilieff recently and also made a study of the past research on drafting. He divided all the theories of drafting into four principal categories according to the mode of approach as follows: (a) descriptive or qualitative approach, (b) mechanical approach, (c) statistical approach, (d) combined approach. These methods deal with common sense considerations, mathematical calculations of the number of fibers in every cross section of the strand or calculations of the speed of the fiber, laws of statistics or theory of probability, and a combination of the last two approaches.

This study primarily deals with blends. Considerable literature has been published on the reasons for blending. Speakman (4) related three reasons for it: first, to produce a cheaper product; second, for a correction of defect; and third, for the production of new effects. Blends of cotton with Arnel staple enhance its abrasion resistance and durability. There is also an aid in the styling properties and a cotton-like hand (5). Blends of Arnel and other fibers are suitable for the new ease-of-care textiles.

The amount of break draft on a yarn manufacturing machine is still an open argument (6). When conventional drafting was in use by all the manufacturers, the break draft was small, but since the advent of the long draft the break drafts have been increased. The amount of break draft depends on the individual mill's equipment and the type of stock in process. It would be advantageous to have a system for determining the optimum break draft without having to depend entirely on empirical methods.

The Problem.--The object of this work was to determine the effects of varying break drafts at the drawing process on the properties of yarns made from blends of Arnel and combed cotton. The variable was introduced at the drawing frame since it was the process that was entirely dependent upon roller drafting.

In order to produce a quality yarn, the optimum draft is very vital at the initial roller drafting for successful subsequent processing of the fibers from the sliver form into rovings and yarns. Four 25-percent increments of blends and five drafts were selected to determine what differences in physical properties the yarns might possess. The all

combed cotton yarns were made to be used as controls for the evaluation and analysis of the blends.

The Approach.--Bright and dull luster Arnel card slivers were needed for processing into drawing slivers. Combed cotton slivers were also needed for this process. It was deemed appropriate for the Celanese Corporation to supply the Arnel fiber in the form of picker laps and the cotton in the form of combed sliver. The machines, settings and speeds chosen were considered practical for the conversion of this type of stock into yarn.

The Arnel laps were carded as uniformly as possible on a roller top card. Card slivers delivered at this process were collected into the number of cans necessary to supply two deliveries of the four-delivery drawing frame. A four-over-five drawing frame was converted into a three-over-four type drafting unit. This required the cutting of a special size of sprocket gear in the A. French Textile School's machine shop in order to obtain a normal feed tension draft. Also the back rolls of this machine were taken out of their original use by the removal of the back top roll.

For each of the dull and bright stocks, three Arnel-cotton blends of 25 per cent increments were drawn with five different break drafts on five sets of draft gears. Three 100 per cent blends were also run, first the combed cotton, second the Arnel bright and third the Arnel dull. This first process drawing was collected and run through the same machine a second time. Uniformity tests were made on a sample of the initial control lot to determine if the drawing frame was making a standard sliver. These tests were also carried out for the subsequent processes.

A quantity of sliver was run to have sufficient amounts for testing requirements in the three forms of stock: sliver, roving and yarn. Including all the above mentioned blends and break draft variations, there were 45 lots of second process drawing slivers that were converted into rovings on a FS-2 roving frame.

All the hank rovings were made as near to the same count as possible. Changes in twist and tension gears were made once, that was when the percentage of cotton was predominant rather than Arnel.

The 45 lots of rovings were spun into the same count yarn on a spinning frame equipped with a Shaw drafting system. There were no changes made on the spinning frame.

Tests were made on the stock at the different stages of the yarn manufacturing so as to determine if there was a correlation among the processes for a given draft used at the drawing frame. The various lots of second process drawing slivers, rovings and yarns were tested in the physical testing laboratory of the A. French Textile School. The uster evenness tester and its integrator were used to measure the uniformity of the three forms of stock in each of the 45 lots. Single strand tensile strength and elongation tests were also made on the yarns. Uniformity evaluations were made on a representative Arnel lap, each of the types of Arnel card slivers and the combed cotton sliver.

CHAPTER II

MATERIALS AND EQUIPMENT

All the materials used were shipped from Charlotte, North Carolina by the Celanese Corporation's processing laboratory. These materials consisted of three types of staple stock: One, an Arnel bright luster fiber; a second, an Arnel dull luster fiber; and the third, a cotton fiber. The two types of Arnel fiber were two and one-half denier, one and one-half inch staple length. The cotton fiber had a staple length of one and three-sixteenths and a micronaire reading of 4.3. As related in Chapter I, the Arnel was in the form of picker laps and the cotton in the form of combed sliver.

All the equipment used for the processing of the Arnel and cotton fibers into yarns was the standard laboratory machines found in the A. French Textile School. The Arnel picker laps were processed on a 40-inch Saco Lowell Model 1948 roller top card. This card was equipped with a long nose feed plate and a licker-in covered with fillet recommended for long staple fibers.

The card slivers were next processed on a slightly coverted Saco Lowell Model D S-4 1957 drawing frame. In comparing this converted frame to other models, it was actually made into a Model D S-2, 3 over 4 drawing frame. Draft variations were made by changing the standard draft gears furnished by the machine manufacturer.

After the card sliver was run through the drawing frame one time, it was processed a second time on the same machine. A 0.015 type disc was used on the middle top roll to give a clearance with the small bottom second roll as would be the practice for running cotton staple. Roll weighting for the top drawing rolls were the central lever type below the roll beam as was commonly used on the old Saco Lowell controlled draft drawing.

The second process drawing was made into roving on a Saco Lowell 10 by 5 slubber, Model 1948, equipped with the FS-2 drafting system. Conversion of the roving into yarn was performed on a 1948 Saco Lowell SS-1 spinning frame with the Shaw drafting unit. This frame had separators, 4-inch gauge, 2-1/2-inch diameter rings, and was equipped with a Pneumafil Cleaner, Model Number C-2-83. American square pointed, two-flange, circles 1-1/2, number 4-0, EC Lowboy travelers were used.

Sliver, roving and yarn weights were made on a Whitin machine works 980 grain scale. Browne and Sharpe Company roving and yarn reels were used to obtain the standard lengths for the necessary sizings of the various lots of stock. The processing laboratories were conditioned by the A. French Textile School's Worthington artificial refrigeration equipment with Niagara units. The conditions were as follows: Carding, 80° Fahrenheit and 65 per cent relative humidity; drawing, roving, and spinning 80° Fahrenheit and 60 per cent relative humidity.

All the testing was done in the physical testing laboratory under standard conditions of 70° Fahrenheit and 65 per cent relative humidity as maintained by the American Moistening Company equipment. Uniformity

tests were made on the card slivers, drawing slivers, the rovings and yarns with a Zellweger Model B 4 Uster evenness tester and a Type 1 TG-L 6 linear integrator. Yarns were tested for single end breaks and elongation on a vertical Suter single strand tester. This tester was of the plunger type with a 32 second descending cycle.

Table 1. Operating Data for Saco Lowell 1948 Roller Top Card

Doffer Speed--R. P. M.	8
Licker-in Speed--R. P. M.	210
Worker roll Speed--R. P. M.	8
Stripper roll Speed--R. P. M.	310
Settings:	
Feed plate to licker-in	0.022
Licker-in to cylinder	0.008
Stripper roll to worker roll	0.017
Worker roll to cylinder	0.010
Stripper roll to cylinder	0.010
Back knife plate to cylinder	0.034
Front knife plate to cylinder	0.029
Doffer to cylinder	0.007
Doffer comb to doffer	0.015
Licker-in screen to licker-in (toe)	0.1250
Licker-in screen to licker-in (heel)	0.029
Cylinder screen to cylinder (toe)	0.1875
Cylinder screen to cylinder (middle)	0.058
Cylinder screen to cylinder (heel)	0.029

Table 2. Operating Data for Saco Lowell Model DS-2 Drawing Frame

Front roll speed--R. P. M.		515
Calender roll speed--R. P. M. (73TG)		295
Tension gears		
All combed cotton		74
All Arnel and blends		73
Roll diameters (bottom)		
Front roll		1.125"
Second roll		0.750"
Third roll		1.375"
Fourth roll		1.375"
Roll settings (nip to nip) all Arnel and blends		
Third roll to front roll		2.375"
Fourth roll to third roll		2.065"
Roll settings (nip to nip) all combed cotton		
Third roll to front roll		2.375"
Fourth roll to third roll		1.813"
Delivery tension drafts		
All Arnel and blends		1.017
All combed cotton		1.038
Total drafts		
All combed cotton		8.36
All Arnel and blends		8.16
Feed tension draft		1.075
Draft gears and break drafts		
	66 DG	1.37
	55 DG	1.65
	50 DG	1.79
	47 DG	1.93
	38 DG	2.35

Table 2. Operating Data for Saco Lowell Model DS-2 Drawing Frame (Cont'd)

Draft gears and front drafts		
	32 DG	5.46
	39 DG	4.50
	42 DG	4.16
	45 DG	3.86
	55 DG	3.17
Front draft constant		175
Break draft constant		90
Clearance between second top roll and bottom second roll		0.015"
Doublings		8
Deliveries for breaker drawing		2
Deliveries for finisher drawing		2

Table 3. Operating Data for Saco Lowell Model FS-2 Roving Frame, Year 1948

Roll diameters		
Front roll		1.125"
Middle roll		1.070"
Back roll		1.000"
Roll settings (center to center), all Arnel and blends		
Middle to front		2.240"
Back to middle		2.000"
Roll settings (center to center), all combed cotton		
Middle to front		2.000"
Back to middle		1.500"
Drafts		
Break draft		1.87
Front draft (50 DG)		4.78
Draft constant		412
Twist constant		46
Change gears		
Lay gear		30
Twist gears		40, 52
Tension gears		45, 48, 51
Draft gears		48, 49, 50, 51
Front roll speed--R. P. M.		
	52 TG	225
	40 TG	173
Spindle speed--R. P. M.		700
Turns per inch		
100%, 75%, and 50% Arnel		0.90
100% cotton, 25% Arnel		1.15
Spindles		18

Table 4. Operating Data for 1948 Saco Lowell SS-1 Spinning Frame

Roll diameters	
Front	1.000"
Middle	1.063"
Back	0.875"
Roll settings (center to center)	
Middle to front	2.375"
Back to middle	1.750"
Turns per inch (39 TG-Z twist)	18.50
Spindle speed--R. P. M.	6500
Front roll--R. P. M.	105
Drafts	
Break draft	1.38
Front draft	11.22
Size traveler	4-0
Cylinder speed--R. P. M.	725
Cylinder diameter	10"
Whorl diameter	1.125"
Twist constant	785
Draft constant	647
Doublings	1
Spindles	24

CHAPTER III

PROCEDURE

The four 50-pound Arnel picker laps were placed in the processing laboratory to condition for 48 hours. In the preparatory plans for this study, it was estimated that 200 pounds of Arnel fiber would produce sufficient card sliver to eliminate unnecessary piecings for the first process drawing. This amount would also allow reruns to be made if necessary since it was not known just what difficulties would be encountered at the several machines.

Settings on the roller top card were checked and were adjusted when necessary to those listed in table 1. A production rate of 10 pounds per hour was used. A test run was made to determine the size draft gear required for each of the two luster Arnels. The weight of the sliver was checked on each of the 16 cans which contained equal yardage of sliver. When necessary, the draft gears were changed to produce as uniform a card sliver as possible. There were three draft gears used for carding the bright and four for carding the dull. Due to unevenness of the lap and the size draft gears available for the machine, the card sliver made was approximately two grains per yard heavier than the original plans required. The cylinder and doffer were stripped by a hand type stripping brush after the running of each lap.

A Saco Lowell D S-2 drawing frame was the next machine in the lap to yarn processes. The 16 cans of card sliver were separated into two

groups of eight cans each so that the average weight per yard fed to each drawing frame delivery would be better balanced.

The drawing frame was the position in the yarn manufacturing where the variable was introduced as has been mentioned in Chapter I. Five pairs of draft gears were obtained to be used as had been determined in the preparatory work. These draft gears, drafts and other operational data are given in table 2. Prior to the processing, the metal drawing frame rolls were thoroughly cleaned with mineral spirits and the cushion rolls were brushed with mica. Roll settings were made according to the staple in process and as recommended by the machine manufacturer.

The drawing frame used had two drafting zones, the back or break draft and the front draft. The break draft constant and the front draft constant were divided by the draft gears to be used at each respective zone to determine the drafts. Break drafts and front drafts were as follows:

Draft Number	Break Draft	Front Draft
1	1.37	5.46
2	1.65	4.47
3	1.79	4.17
4	1.93	3.89
5	2.35	3.18

When the break drafts were changed, the front draft was changed indirectly proportional so that the total draft would remain as near the same as the gear combinations would permit. The delivery tension draft change gear was increased one tooth over that used for the all Arnel and blends. This change in draft was from a 1.017 for the all Arnel and blends to a 1.038 for the all combed cotton.

The total drafts chosen were for the purpose of producing a 50-grain sliver to be run on the roving frame. There were, however, some variations in the grain-weight per yard delivered because of the variations in the Arnel card sliver. The average weight of the cotton slivers were slightly less than the Arnel card slivers.

When creeling the blends for the first process drawing, the Arnel and cotton slivers were arranged so that fiber distribution would be benefited. The all Arnel runs for each luster were processed first and then the Arnel ends were replaced with cotton as the blends required. Equal yardage was placed in 16 cans from the two deliveries, as determined by the use of a Veeder Root counter. Equal number of first and second delivery cans were put in place behind each of the third and fourth deliveries for the second process drawing. The first process drawing creel was broken back each time the second process was put in operation.

Sliver cans with springs were used for the drawing to make the ends more accessible and also to reduce stretching or breaking. Extra yardage for the all Arnel bright was run to be used for setting up the subsequent processes and the testing.

The drafting rolls on the F S-2 roving frame were set according to those considered good practice for other synthetics having a staple as the Arnel used in this study. Settings and speeds for this machine are listed in table 3. Roll clearers and rolls were brushed with mica thoroughly. Mica was added freely to the clearers and rolls before and during the running of each lot. New aprons were also put on before the

initial run was made. Six adjacent spindles were used for each of the 45 lots processed.

Proper gearing was determined for each of the lots of each blend. Constants for the drafts, twists, lays and tensions were used to calculate the gears needed. Two twist multipliers were chosen for the wide variation in the fiber composition of the drawing slivers. There was one twist multiplier for the all Arnels, 75 per cent Arnel, and 50 per cent Arnel, and another for the all cotton and 75 per cent cotton. The resultant turns per inch from these twist multipliers were further tested at the spinning process to determine if the unwinding and drafting of the roving was proper.

It was necessary to make some draft gear changes because of the slight differences in the drawing sliver weights among the many lots. When the bright Arnel lots were run, the draft gears were not changed within a given blend but the gear size was varied plus or minus one tooth from one blend to another. Due to the more uneven dull Arnel blend lots, there were draft changes within a given blend, but only one gear change for an individual blend.

The amount of tension necessary on the rovings was regulated by trial placements of the cone belt. Tension gears used for each blend are shown in table 3.

The second process drawing was made into roving and identified by marking with textile mill crayon before doffing. As near a 1.45 hank roving as possible was made for each lot and checks were made on the roving count when the draft gears were changed. The gear change on this machine gave a different attenuation in the front drafting zone.

After the spinning frame constants were determined, the gearing for the draft and twist were put in place to produce an average warp yarn. The details for this machine are shown in table 4. The six roving bobbins of each lot were placed side by side in the spinning frame creel and approximately 2000 yards of 22^S yarn was produced for each blend. When the run was completed, the yarn was marked similar to the roving. The six yarn bobbins of the same lot were placed in individual paper bags and the roving was bagged likewise when the spinning frame was creeled for another run. During the spinning, the most noticeable difference among the various lots was the larger number of ends down for the all Arnel dull. The traveler size was determined by observations of the balloon and they were changed several times on the trial run before the 4-0 traveler was decided upon.

Physical testing was performed on the slivers, rovings and yarns in the A. French School laboratory equipped and maintained for this purpose. The tests were conducted under standard conditions of 70 degrees Fahrenheit and 65 per cent relative humidity.

The evenness of the card slivers, drawing slivers, combed slivers, rovings and yarns was determined by the use of the Uster Evenness tester equipped with its attachment, the linear integrator. Accuracy of the tester was checked daily with the calibration tape according to the instructions given in the instruction manual (7).

Feeding speed for the sliver and roving was 8 yards per minute. The 25 per cent scale was used for sliver except for some of the Arnel card sliver. It was necessary to use both the 25 and 50 per cent scale to obtain the readings as shown in tables 6 and 7, Chapter IV. The 50

per cent scale was used for the roving, and the 100 per cent scale for the yarn. Five readings were recorded for each of the packages from the various lots in the sampling procedure. Data and statistics for the 30 specimens from each lot and process were summarized. These summaries are shown in the appendix tables.

Single strand elongation and break tests were made on the yarns on a Vertical Suter Single Strand Tester. An 18-inch gauge length was used. Five specimens were taken from the bobbins according to the ASTM instructions (8). The pound quadrant scale was used when 50 per cent or more of the yarn was cotton. When there was less than 50 per cent, the tester was set up for the gram scale.

An additional test was made to determine the unevenness of the picker lap. This uniformity test was made on the Saco Lowell Lap Meter and the results are given in table 5.

CHAPTER IV

DISCUSSION OF RESULTS

As explained earlier, every effort was made to produce a uniform product. The uniformity of the lap shown in table 5 demonstrates that the lap was not good and this introduced a variable which made the experiment and the analysis more difficult. Uniformity tests made on the card slivers and combed sliver are given in tables 6, 7, and 8. Some of the Arnel bright card sliver specimens tested were of good mean uster linear evenness; however, the Arnel slivers were considered uneven according to the uster standards (9). The combed sliver was of average mean linear unevenness.

Since there were differences in the two Arnels processed, they were analyzed separately. Comparison figures and tables for the physical properties of the products of each process are given in this chapter and the appendix.

The Arnel dull mean linear unevenness, Figures 1, 2, and 3, show that there are considerable differences in uniformity of the products between the blends. A general pattern is that the larger percentage of cotton is more uniform. It has been pointed out previously that the cotton was more uniform initially. The uniformity pattern also reveals that in all cases except one there is a decided improvement from the first to the second draft for the three processes. The third draft gave a better roving and yarn; however, there was a slightly poorer uniformity for two

Table 5. Uniformity of Picker Lap 2-Inch, 2.5 denier, Arnel dull Ounce Lap - 12

Specimen number	Weight per yard ounces	Specimen number	Weight per yard ounces
1	11.50	30	12.20
2	12.10	31	12.10
3	12.00	32	11.80
4	11.70	33	12.60
5	11.80	34	11.80
6	12.20	35	11.85
7	13.20	36	12.20
8	12.25	37	11.95
9	12.00	38	12.30
10	12.30	39	12.00
11	11.80	40	12.10
12	12.50	41	12.90
13	11.70	42	11.40
14	11.90	43	12.30
15	12.10	44	12.00
16	12.05	45	11.90
17	12.00	46	12.00
18	12.25	47	13.40
19	12.00	48	12.30
20	12.20	49	12.25
21	12.10	50	11.90
22	11.90	51	11.80

Table 5. Uniformity of Picker Lap 2-Inch, 2.5 denier, Arnel Dull Ounce Lap - 12 (Cont'd)

Specimen number	Weight per yard ounces	Specimen number	Weight per yard ounces
23	12.65	52	11.70
24	12.05	53	11.45
25	12.00	54	11.90
26	12.40	55	12.65
27	11.80	56	12.30
28	12.05	57	12.00
29	12.20	58	12.10

Average 12.10

Standard deviation 0.364

Coefficient of variation per cent 3.01

Table 6. Uniformity of Arnell Dull Card Sliver

Specimen number	Uster Value	Specimen number	Uster Value
1	4.73	16	4.76
2	4.43	17	4.98
3	4.27	18	5.13
4	5.64	19	4.76
5	5.13	20	4.65
6	6.12	21	4.87
7	5.61	22	4.41
8	4.50	23	5.50
9	5.65	24	5.00
10	5.15	25	5.47
11	5.75	26	6.03
12	4.78	27	4.75
13	5.54	28	7.13
14	4.30	29	6.84
15	4.80	30	4.56

Average	5.18
Standard deviation	0.713
Coefficient of variation per cent	13.80

Table 7. Uniformity of Arnel Bright Card Sliver

Specimen number	Uster Value	Specimen number	Uster value
1	3.29	16	7.13
2	3.23	17	4.84
3	4.30	18	3.87
4	5.83	19	5.39
5	4.31	20	4.90
6	3.13	21	5.62
7	3.20	22	8.05
8	4.08	23	5.68
9	3.72	24	6.67
10	2.73	25	7.31
11	2.97	26	6.30
12	3.90	27	5.00
13	5.65	28	4.05
14	3.65	29	5.15
15	3.41	30	7.90

Average	4.84
Standard deviation	1.516
Coefficient of variation per cent	31.30

Table 8. Uniformity of Combed Cotton Sliver

Specimen number	Uster value	Specimen number	Uster value
1	6.25	16	6.16
2	6.08	17	6.10
3	5.98	18	6.20
4	6.08	19	6.40
5	6.17	20	6.22
6	6.48	21	5.87
7	6.18	22	6.24
8	6.07	23	6.24
9	6.20	24	7.24
10	5.98	25	6.70
11	6.30	26	6.18
12	6.93	27	5.72
13	7.14	28	5.25
14	7.20	29	6.02
15	5.93	30	5.82

Average	6.24
Standard deviation	0.434
Coefficient of variation per cent	7.00

of the drawing sliver blends. Some of the fourth and fifth drafts also produced deviations from the trend of improvement with the higher drafts.

Since these variations are not constant for a given draft and blend from process to process, this may be attributed to experimental or sampling error. Thus a null hypothesis was established whereby it was assumed the true difference between the mean of the control and mean of the corresponding experiment is zero. Therefore, the observed difference is due to sampling variations. A statistical analysis of the samples from the control and blend experiment were expected to have a t distribution which is similar to a normal curve but more spread out.

The null hypothesis is accepted if $t < 2.58$. In these cases the difference is not significant since it could have occurred as a result of sampling variations. The hypothesis will be rejected if $t \geq 2.58$. If the t values are of this size, the difference between the means is significant, since there is only one chance in a hundred that a difference this large could have occurred as a result of random variation from sampling.

Neiswanger (10) gives the Students t distribution computation as follows:

The estimate of the population variance--

$$\sigma_s^2 = \frac{n(\sigma_1^2) + n(\sigma_2^2)}{n_1 + n_2 - 2}$$

The standard error of the difference--

$$\sigma_{\bar{x}_1 - \bar{x}_2} = \sigma_s \sqrt{\frac{1}{n} + \frac{1}{n}}$$

The t test to test the critical ratio (2.576 for 58 cases)--

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sigma_{\bar{x}_1 - \bar{x}_2}}$$

The symbols σ_1^2 is the variance of the control and σ_2^2, the variance of the blend. The number of samples or specimens n_1 and n_2 were 30 in every case. The difference of the sampling means, $\bar{x}_1 - \bar{x}_2$, denotes the control and the blend. All the tests were made at the 1 per cent level of significance by the use of the t table for which there was a 2.58 sigma limit.

A sample computation using the preceding steps for determing the t value is given below. The knowns were taken from Table 12, Comparison of yarn strength for cotton and Arnel dull, 25 per cent Arnel - 75 per cent cotton, draft 2.

$$\sigma_s^2 = \frac{30(.011449) + 30(.010816)}{30 + 30 - 2} = 0.1076$$

$$\sigma_{\bar{x}_1 - \bar{x}_2} = .1076 \sqrt{\frac{1}{30} + \frac{1}{30}}$$

$$= .02778$$

$$t = \frac{1.13 - .85}{.02778}$$

$$= 10.1$$

There is a small difference in the t values listed in the appendix tables and the ones that would result from the computation shown above. They were computed according to the description of the operation of the Statistical Interpretive System along with the Bell Interpretive System Program (11). The computations were made at the Rich Electronic Computer Center, Georgia Institute of Technology.

This t test is in one step rather than three and is as follows:

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{(n_1 - 1)\sigma_1^2 + (n_2 - 1)\sigma_2^2}{n_1 + n_2 - 2}} \sqrt{\frac{1}{n_1} + \frac{1}{n_2}}}$$

A sample computation for the same control and blend experiment as previously illustrated is given below:

$$t = \frac{1.13 - 0.85}{\sqrt{\frac{(30 - 1).011449 + (30 - 1).010816}{30 + 30 - 2}} \sqrt{\frac{1}{30} + \frac{1}{30}}}$$

$$= 10.3$$

Only 10 per cent of the Arnel dull uniformity t values were not significant and the majority were highly significant. The t tests that were significant at the 1 per cent point are listed below.

Sliver uniformity	25% Arnel dull-75% cotton	Draft 3, 4, 5
Sliver uniformity	50% Arnel dull-50% cotton	Draft 2, 3, 4, 5
Sliver uniformity	75% Arnel dull-25% cotton	All drafts
Sliver uniformity	100% Arnel dull	Draft 1, 2, 4, 5
Roving uniformity	25% Arnel dull-75% cotton	Draft 2, 3, 4
Roving uniformity	50% Arnel dull-50% cotton	All drafts
Roving uniformity	75% Arnel dull-25% cotton	All drafts
Roving uniformity	100% Arnel dull	All drafts
Yarn uniformity	All blends	All drafts

The t tests that were not significant at the 1 per cent point are as follows:

Sliver uniformity	25% Arnel dull-75% cotton	Draft 1, 2
Sliver uniformity	50% Arnel dull-50% cotton	Draft 1
Sliver uniformity	100% Arnel dull	Draft 3
Roving uniformity	25% Arnel dull-75% cotton	Draft 1, 2

A comparison of the t values with the mean uster values is in some instances less and for others more than those that do conform with the over-all uniformity pattern. Then statistically the statement can be made that there are 99 chances in 100 that the non-conformity is due merely to chance error of sampling. The smaller mean uster value is more desirable since this indicates a better uniformity quality.

The effect of the yarn count variations was accounted for by determining the count strength products. Yarn tensile strengths are virtually the same for all the drafts in each blend. There is one consistency in the t criterion, the two largest drafts are more significantly different from the control than the three smallest drafts. This is contrary to what is best for yarn strength.

The Arnel bright appears to be very much the same as the Arnel dull. The t tests which were significant at the 1 per cent point for this luster are as follows:

Sliver uniformity	25% Arnel bright-75% cotton	Draft 1, 2, 4, 5
Sliver uniformity	50% Arnel bright-50% cotton	Draft 2, 3, 4, 5
Sliver uniformity	75% Arnel bright-25% cotton	All drafts
Sliver uniformity	100% Arnel bright	Draft 1, 2, 4, 5

Roving uniformity	25% Arnel bright-75% cotton	Draft 1, 2, 3, 4
Roving uniformity	50% Arnel bright-50% cotton	All drafts
Roving uniformity	75% Arnel bright-25% cotton	All drafts
Roving uniformity	100% Arnel bright	All drafts
Yarn uniformity	25% Arnel bright-75% cotton	Draft 1, 2, 3, 4
Yarn uniformity	50% Arnel bright-50% cotton	All drafts
Yarn uniformity	75% Arnel bright-25% cotton	All drafts
Yarn uniformity	100T Arnel bright	All drafts

Five lots or only about 8 per cent of the uniformity t tests are not significantly different from the control. These tests are:

Sliver uniformity	25% Arnel bright-75% cotton	Draft 3
Sliver uniformity	50% Arnel bright-50% cotton	Draft 1
Sliver uniformity	100% Arnel bright	Draft 3
Roving uniformity	25% Arnel bright-75% cotton	Draft 5
Yarn uniformity	25% Arnel bright-75% cotton	Draft 5

Arnel bright sliver uniformity favors the highest draft more than did the dull. Yarn uniformity had somewhat a more uniform trend than the dull.

Per cent elongation of the yarns was closely related to the count strength products. A summary of the elongation tests are shown in tables 17 and 18. There were some cases where the strength and elongation did not completely agree but they are small in comparison to the yarn uniformity discrepancies.

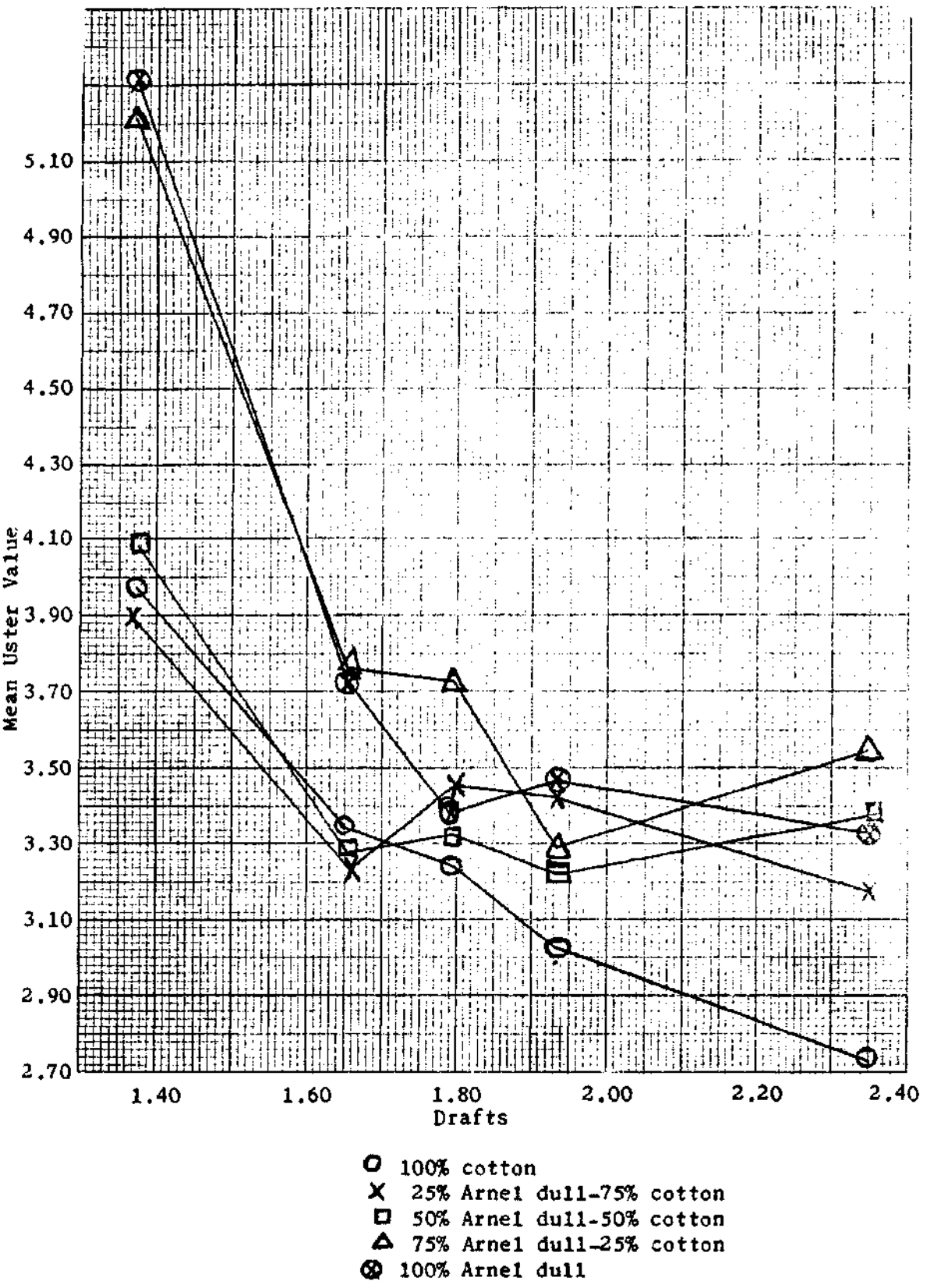

Figure 1. Comparison of Drafts and Mean Uster Values for Arnel Dull Drawing Sliver Uniformity

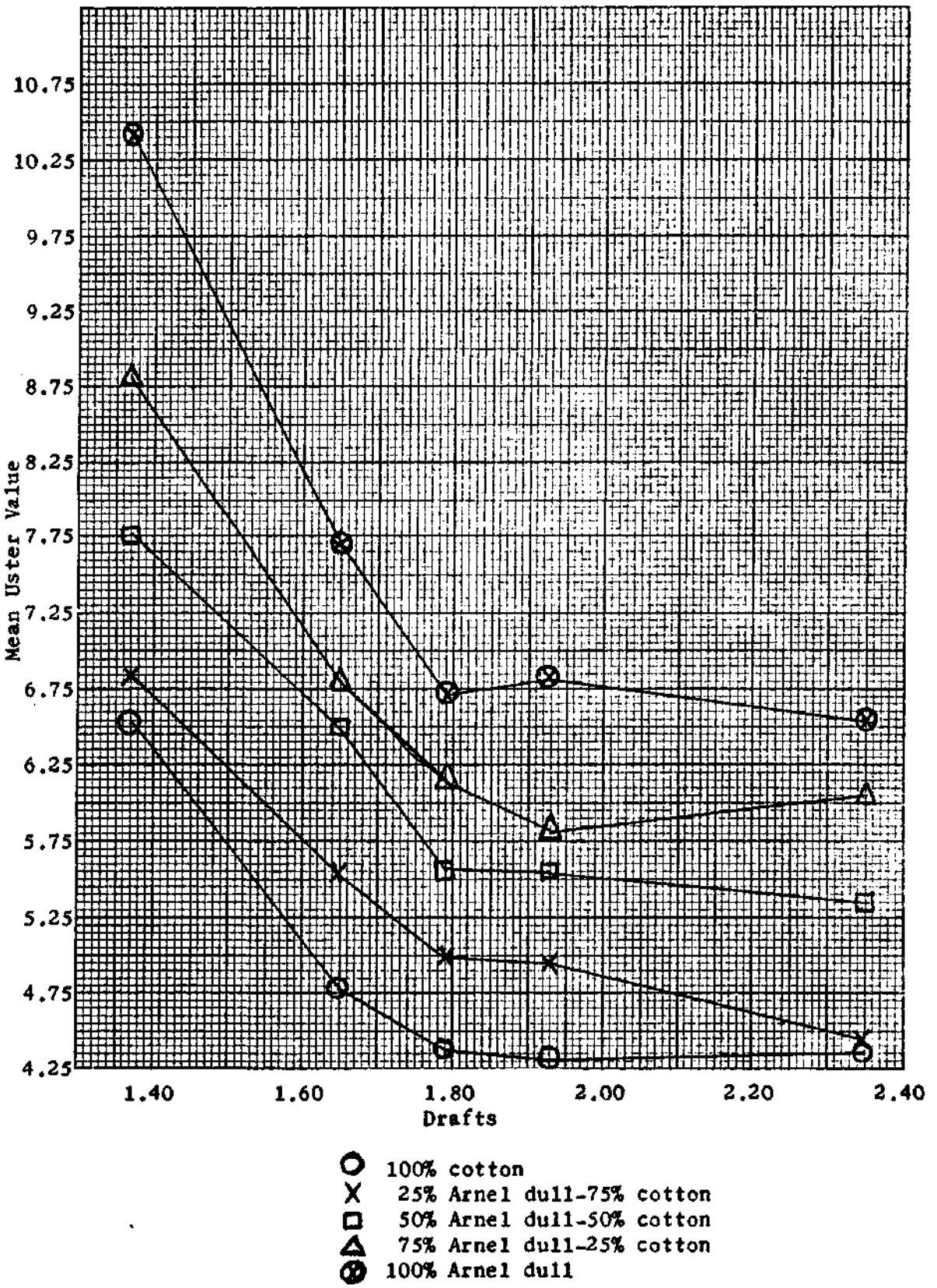

Figure 2. Comparison of Drafts and Mean Uster Values for Arnel Dull Roving Uniformity

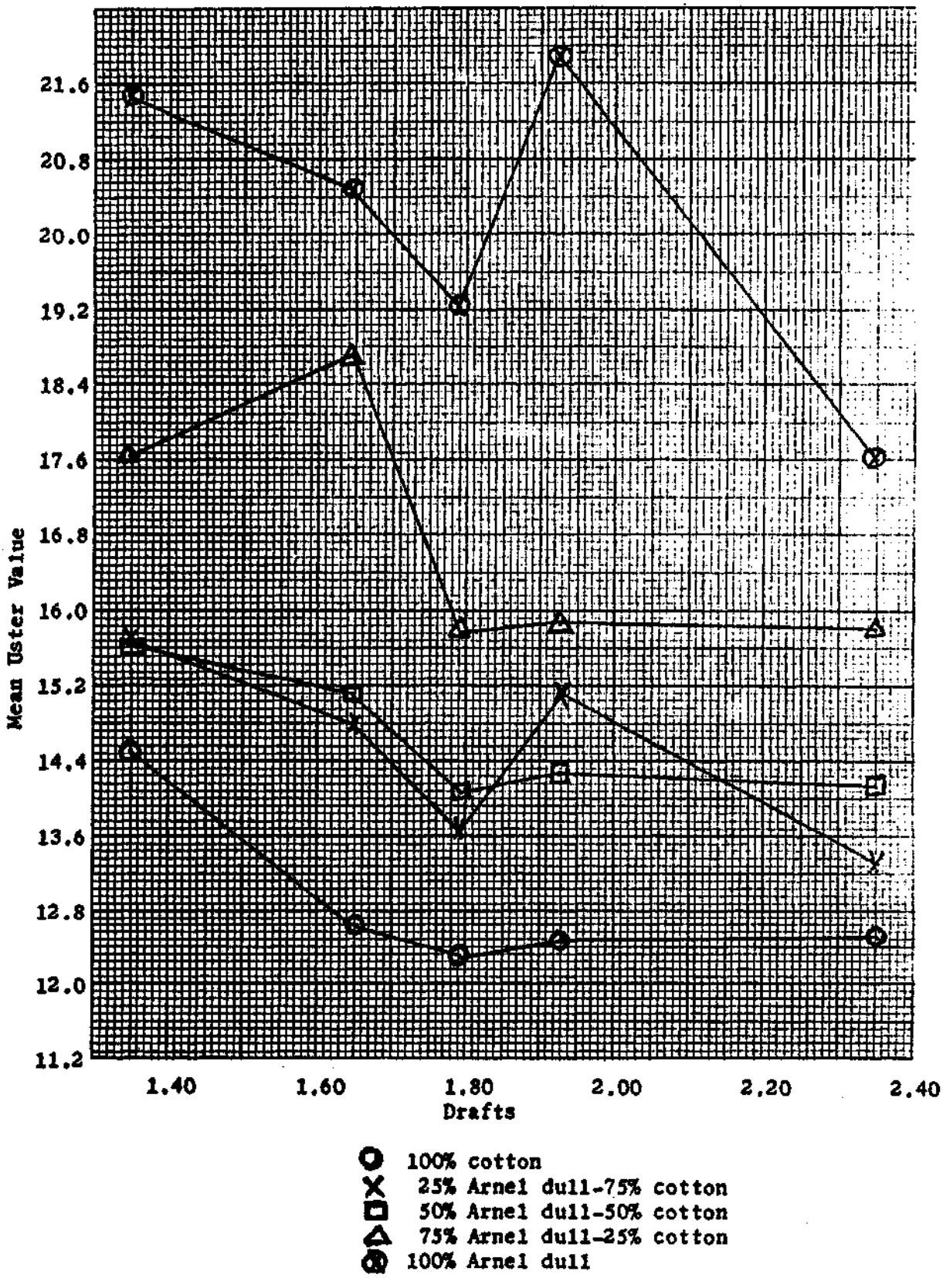

Figure 3. Comparison of Drafts and Mean Uster Values for Arnel Dull Yarn Uniformity

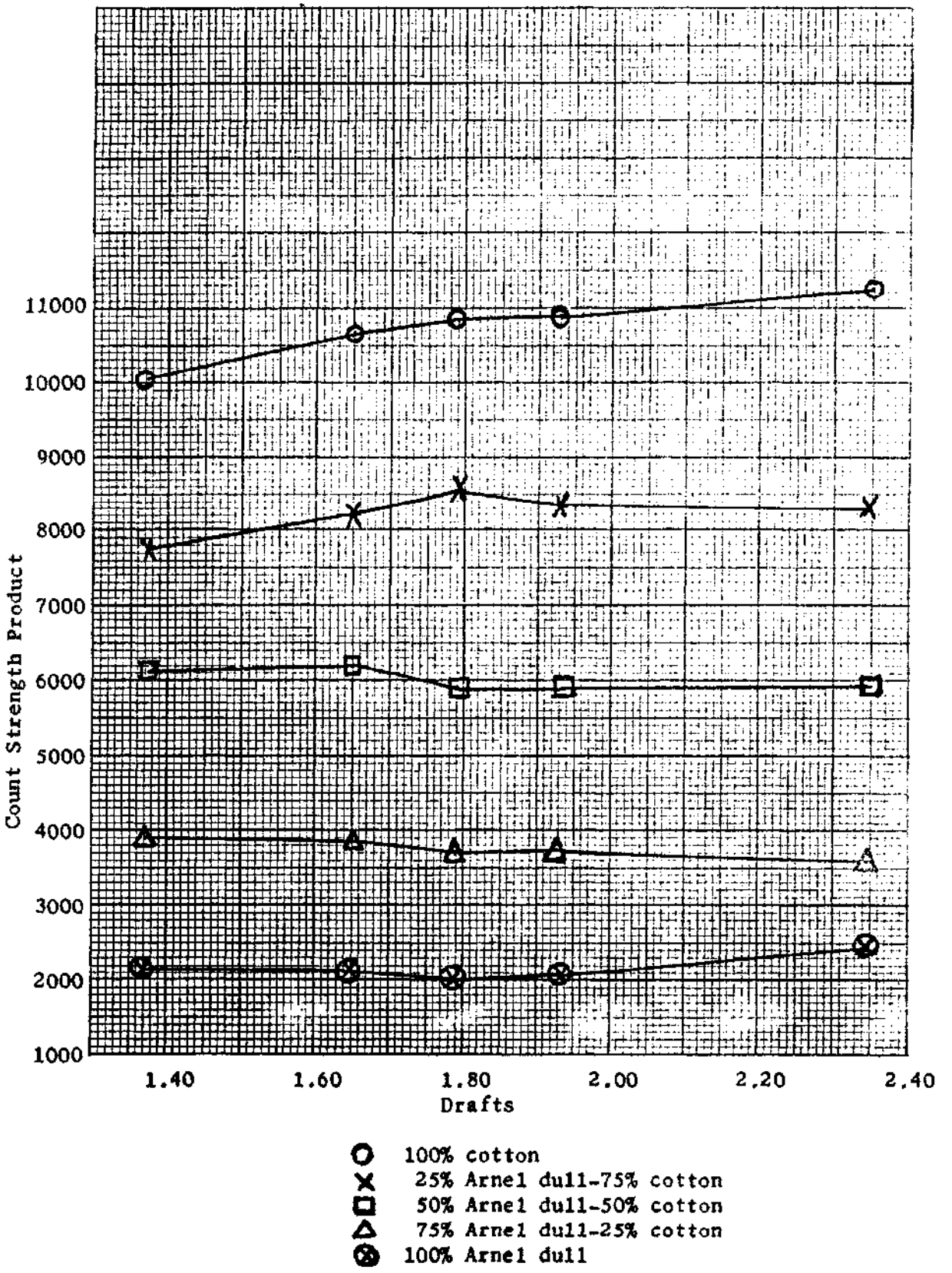

Figure 4. Comparison of Drafts and Count Strength Products for Arnel Dull

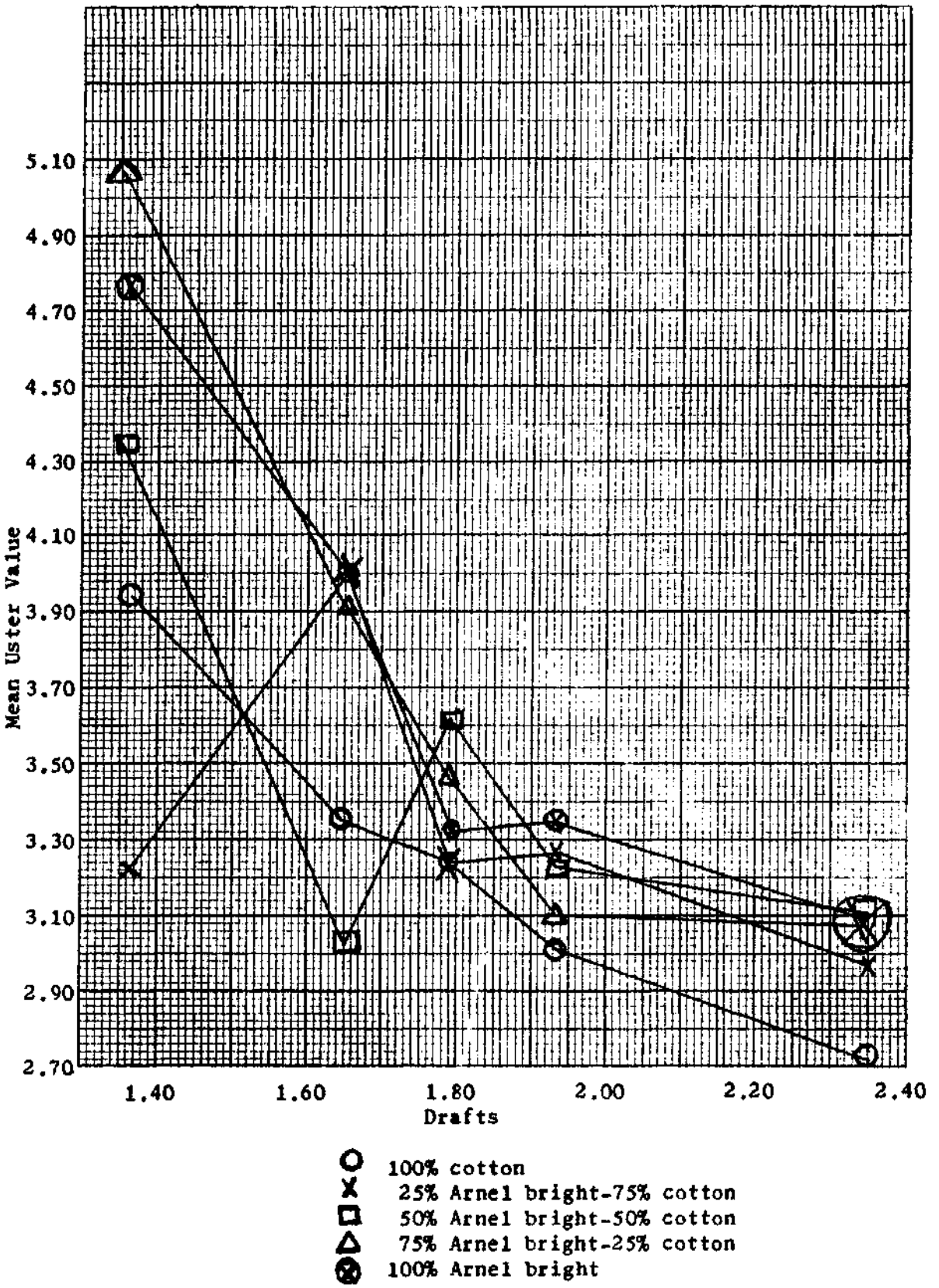

Figure 5. Comparison of Drafts and Mean Uster Values for Arnel Bright Drawing Sliver Uniformity

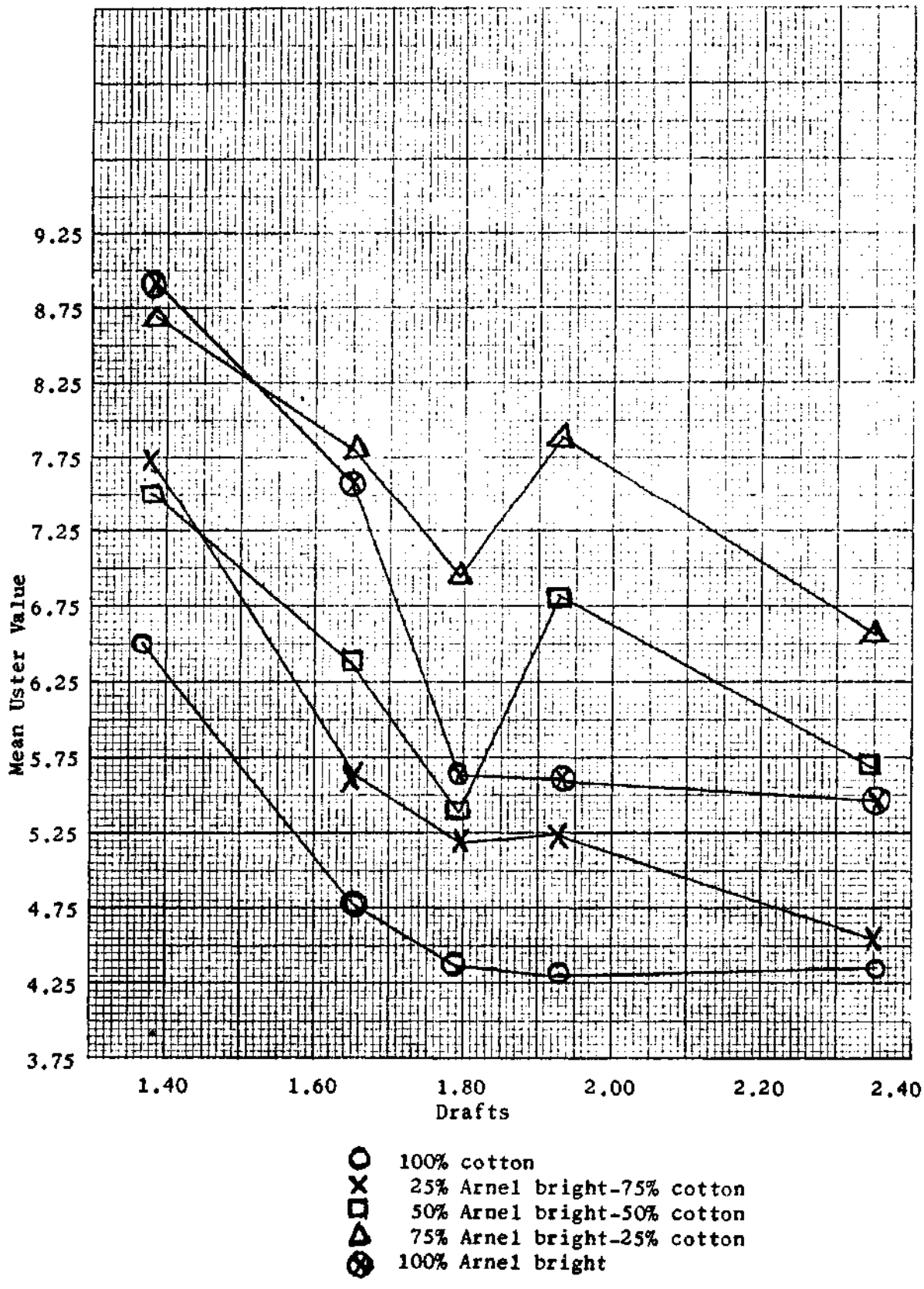

Figure 6. Comparison of Drafts and Mean Uster Values for Arnel Bright Roving Uniformity

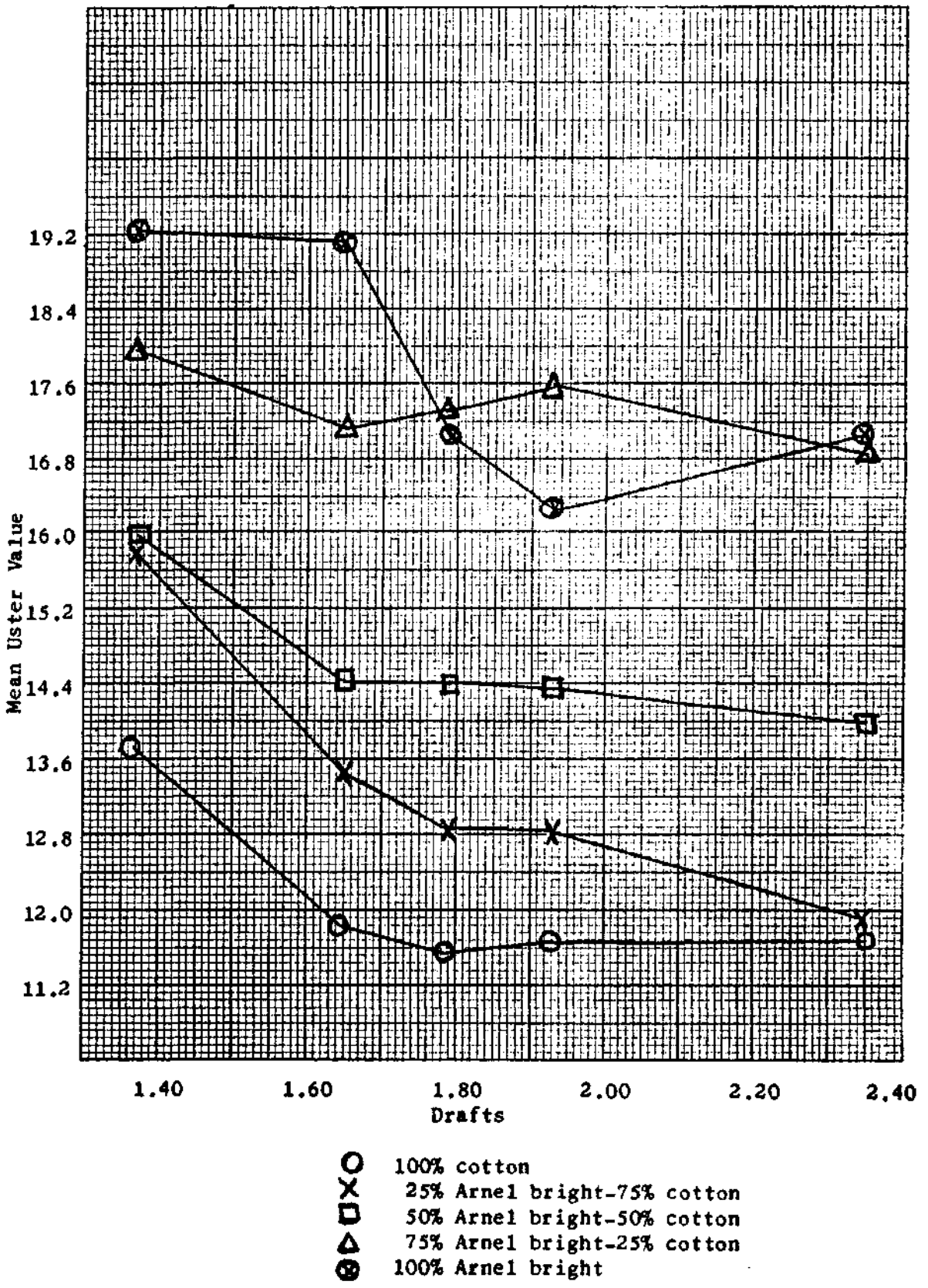

Figure 7. Comparison of Drafts and Mean Uster Values for Arnel Bright Yarn Uniformity

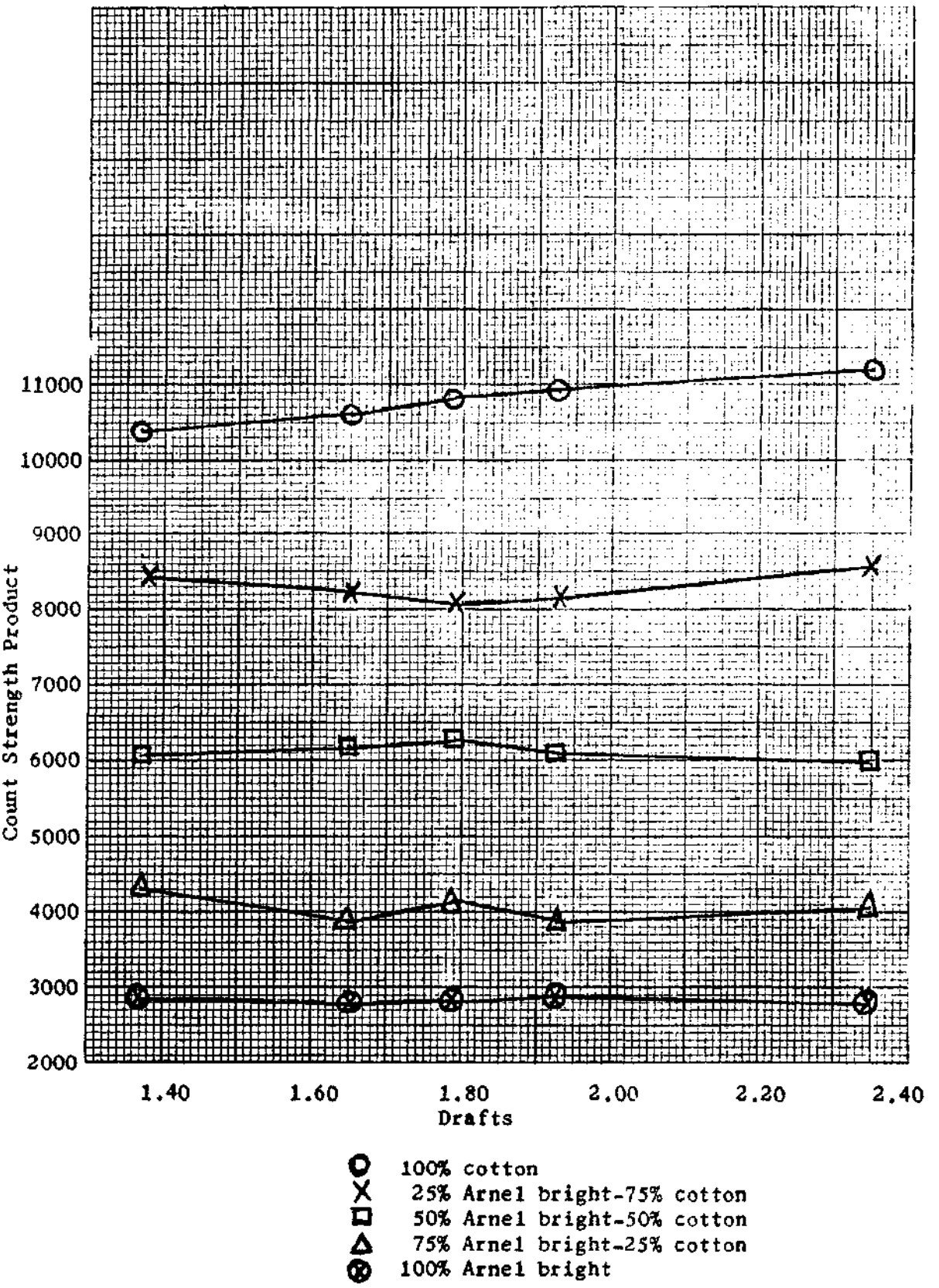

Figure 8. Comparison of Drafts and Count Strength Products for Arnel Bright

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

Regardless of the difficulty encountered in the experimentation and analysis due to the detrimental lap uniformity, it is apparent that the third draft is more suitable of the three drafts that were better for each of the three processes. The statistical analysis of the yarn physical properties as revealed in the fourth chapter casts less doubt upon the 1.79 drawing frame break draft.

The 1.93 and 2.35 break drafts cannot be overlooked since they are in close agreement with the 1.79 draft. An evaluation of each statistic used in the preceding chapter for a comparison of the mean linear unevenness and yarn strength did not define the patterns for a complete acceptance of any one of the three highest drafts.

There are further studies that could add a great deal toward a better understanding of the effects of break drafts on the physical properties of the yarns. A careful processing of the staple fiber in large enough quantities to obtain the best possible initial package could add greatly to the future work. The picker laps may be obtained from a mill that is on everyday production of Arnel staple fiber. A selection of the card slivers from several mills would be an ideal method of having better representation of the fiber universe.

Additional drafts beginning lower than the largest used in this study and going up much higher is another recommendation. Further research may be carried out by varying the drafts on other drafting systems and also by using other staple lengths.

APPENDIX

Table 9. Comparison of Sliver Uniformity for Cotton and Arnel Dull

Blend of Arnel-cotton per cent	Draft number	Mean uster value	t value	Standard deviation	Coefficient of variation per cent
0-100	1	3.97	-	0.419	10.6
	2	3.34	-	0.376	11.3
	3	3.24	-	0.277	8.5
	4	3.01	-	0.141	4.7
	5	2.71	-	0.239	8.8
25-75	1	3.88	0.90*	0.338	8.7
	2	3.26	1.05*	0.147	4.5
	3	3.47	-3.51	0.226	6.5
	4	3.47	-9.56	0.225	6.5
	5	3.15	-8.08	0.183	5.8
50-50	1	4.09	-1.06*	0.447	10.9
	2	3.27	8.67	0.248	7.6
	3	3.31	-7.08	0.447	13.5
	4	3.21	-3.94	0.248	7.7
	5	3.36	-11.30	0.208	6.2
75-25	1	5.23	-7.05	0.885	16.9
	2	3.75	-4.28	0.366	9.8
	3	3.71	-6.96	0.243	6.6
	4	3.29	-5.61	0.235	7.2
	5	3.54	-14.45	0.207	5.8
100-0	1	5.31	-7.15	0.936	17.6
	2	3.71	-3.46	0.441	11.9
	3	3.33	-1.16*	0.289	8.7
	4	3.46	-9.31	0.224	6.5
	5	3.34	-11.80	0.176	5.3

*Not significant

Table 10. Comparison of Roving Uniformity for Cotton and Arnel Dull

Blend of Arnel-cotton per cent	Draft number	Mean uster value	t value	Standard deviation	Coefficient of variation per cent
	1	6.53	-	1.26	19.3
	2	4.76	-	0.632	13.3
0-100	3	4.39	-	0.321	7.3
	4	4.30	-	0.313	7.3
	5	4.37	-	0.356	8.2
	1	6.86	-1.03*	1.26	18.4
	2	5.56	-5.76	0.430	7.7
25-75	3	4.99	-5.60	0.490	9.8
	4	4.96	-5.89	0.523	10.6
	5	4.45	-0.97*	0.267	6.0
	1	7.75	-5.03	0.454	5.9
	2	6.48	-9.36	0.782	12.1
50-50	3	5.51	-9.65	0.547	9.9
	4	5.54	-14.12	0.366	6.6
	5	5.37	-10.29	0.394	7.3
	1	8.82	-7.94	0.961	10.9
	2	6.80	-13.28	0.555	8.2
75-25	3	6.17	-13.08	0.674	10.9
	4	5.78	-13.83	0.495	8.6
	5	6.08	-15.28	0.500	8.2
	1	10.41	-15.53	0.586	5.6
	2	7.69	-19.90	0.500	6.5
100-0	3	6.73	-22.65	0.466	6.9
	4	6.77	-19.60	0.614	9.1
	5	6.54	-26.00	0.287	4.4

*Not significant

Table 11. Comparison of Yarn Uniformity for Cotton and Arnel Dull

Blend of Arnel-cotton per cent	Draft number	Mean uster value	t value	Standard deviation	Coefficient of variation per cent
	1	13.72	-	0.838	6.1
	2	11.80	-	0.618	5.2
0-100	3	11.48	-	0.711	6.2
	4	11.46	-	0.848	7.4
	5	11.69	-	0.651	5.6
	1	14.88	-4.37	1.184	8.0
	2	13.99	-12.79	0.703	5.0
25-75	3	12.83	-6.26	0.947	7.4
	4	14.28	-5.83	2.51	17.6
	5	12.48	-4.30	0.755	6.1
	1	14.84	-4.83	0.950	6.4
	2	14.33	-13.11	0.850	6.0
50-50	3	13.24	-9.05	0.731	5.5
	4	13.47	-11.71	0.409	3.0
	5	13.31	-10.95	0.483	3.6
	1	16.84	-11.14	1.282	7.6
	2	17.90	-10.59	3.090	17.3
75-25	3	14.97	-21.54	0.528	3.5
	4	15.07	-17.53	0.748	5.0
	5	14.97	-14.29	1.072	7.2
	1	20.67	-15.03	2.390	11.6
	2	19.66	-17.31	2.408	12.2
100-0	3	18.41	-18.37	1.94	10.5
	4	21.04	-20.21	2.46	11.7
	5	16.80	-26.82	0.815	4.8

Table 12. Comparison of Yarn Strength for Cotton and Arnel Dull

Blend of Arnel-cotton per cent	Draft number	Tensile strength pounds	t value	Tensile strength grams	Count strength product	Standard deviation pounds	Coefficient of variation per cent
	1	1.12	-	496	10401	1.27	11.3
	2	1.13	-	514	10758	0.107	9.5
0-100	3	1.11	-	502	10853	0.137	12.4
	4	1.12	-	511	10884	0.079	7.1
	5	1.14	-	521	10254	0.085	7.4
	1	0.83	9.10	377	7860	0.123	14.8
	2	0.85	10.30	386	8175	0.104	12.3
25-75	3	0.86	8.55	390	8533	0.075	18.7
	4	0.84	12.63	386	8311	0.087	10.2
	5	0.83	14.13	377	8249	0.090	10.8
	1	0.62	17.58	281	6112	0.089	14.4
	2	0.62	21.15	281	6140	0.076	12.1
50-50	3	0.59	18.32	268	5883	0.070	11.8
	4	0.59	28.26	268	5890	0.067	11.3
	5	0.61	28.00	277	5895	0.060	9.8
	1	0.39	15.78	175	3894	0.061	16.0
	2	0.39	34.63	176	3837	0.050	12.8
75-25	3	0.38	27.03	173	3676	0.052	13.7
	4	0.38	44.66	172	3715	0.046	12.1
	5	0.35	43.27	161	3560	0.044	12.3
	1	0.22	19.54	99	2136	0.057	26.1
	2	0.22	44.53	99	2096	0.036	16.4
100-0	3	0.20	34.69	92	1956	0.039	19.2
	4	0.21	55.01	94	2087	0.046	22.1
	5	0.24	47.68	110	2412	0.051	21.2

Table 13. Comparison of Sliver Uniformity for Cotton and Arnel Bright

Blend of Arnel-cotton per cent	Draft number	Mean uster value	t value	Standard deviation	Coefficient of variation per cent
	1	3.97		0.419	10.6
	2	3.34		0.376	11.3
0-100	3	3.24		0.277	8.5
	4	3.01		0.141	4.7
	5	2.71		0.239	8.8
	1	3.20	9.63	0.126	3.9
	2	3.99	-6.74	0.365	9.2
25-75	3	3.23	0.20*	0.149	4.6
	4	3.26	-4.26	0.299	9.2
	5	2.96	-5.11	0.133	4.5
	1	4.34	2.07*	0.874	20.2
	2	3.02	4.47	0.115	3.8
50-50	3	3.61	-4.39	0.370	10.2
	4	3.23	-3.89	0.289	8.9
	5	3.10	-6.31	0.238	7.7
	1	5.07	6.63	0.811	16.0
	2	3.91	-3.66	0.759	19.4
75-25	3	3.45	-2.74	0.303	8.8
	4	3.10	-3.03	0.105	3.4
	5	3.07	-6.04	0.225	7.3
	1	4.78	4.12	0.998	20.9
	2	3.98	-5.10	0.571	14.4
100-0	3	3.32	-0.83*	0.445	13.4
	4	3.34	-7.44	0.205	6.1
	5	3.08	-5.04	0.322	10.4

*Not significant

Table 14. Comparison of Roving Uniformity for Cotton and Arnel Bright

Blend of Arnel-cotton per cent	Draft number	Mean uster value	t value	Standard deviation	Coefficient of variation per cent
	1	6.53		1.26	19.3
	2	4.76		0.632	13.3
0-100	3	4.39		0.321	7.3
	4	4.30		0.313	7.3
	5	4.37		0.356	8.2
	1	7.74	-3.74	1.26	16.3
	2	5.64	-5.80	0.536	9.5
25-75	3	5.19	-8.30	0.422	8.1
	4	5.24	-9.81	0.416	8.0
	5	4.55	-1.92*	0.384	8.4
	1	7.55	-3.76	0.804	10.6
	2	6.37	-9.71	0.654	10.3
50-50	3	5.38	-5.86	0.870	16.2
	4	6.83	-12.37	1.07	15.7
	5	5.72	-13.82	0.400	7.0
	1	9.69	-9.21	1.40	14.5
	2	7.79	-12.16	1.21	15.5
75-25	3	6.95	-9.68	1.41	20.3
	4	7.88	-18.76	0.996	12.6
	5	6.55	-19.32	0.505	7.7
	1	9.13	-5.78	2.12	23.3
	2	7.56	-10.03	1.39	18.4
100-0	3	5.62	-14.32	0.346	6.2
	4	5.60	-11.77	0.517	9.2
	5	5.45	-4.51	0.360	6.6

*Not significant

Table 15. Comparison of Yarn Uniformity for Cotton and Arnel Bright

Blend of Arnel-cotton per cent	Draft number	Mean uster value	t value	Standard deviation	Coefficient of variation per cent
	1	13.72		0.838	6.1
	2	11.80		0.618	5.2
0-100	3	11.48		0.711	6.2
	4	11.46		0.848	7.4
	5	11.69		0.651	5.6
	1	15.82	-9.32	0.902	5.7
	2	13.46	-12.16	0.418	3.1
25-75	3	12.86	-9.45	0.358	2.8
	4	12.85	-5.67	1.043	8.1
	5	11.90	-1.40*	0.501	4.2
	1	15.97	-11.21	0.709	4.4
	2	14.44	-14.82	0.752	5.2
50-50	3	14.40	-17.43	0.578	4.0
	4	14.37	-15.10	0.630	4.4
	5	13.97	-14.04	0.606	4.3
	1	17.96	-15.65	1.225	6.8
	2	17.12	-21.92	1.175	6.9
75-25	3	17.32	-27.15	0.939	5.4
	4	17.57	-32.46	0.586	3.3
	5	16.84	-28.28	0.754	4.5
	1	19.24	-16.38	1.643	8.5
	2	19.10	-37.54	0.867	4.5
100-0	3	17.06	-32.62	0.609	3.6
	4	16.25	-22.83	0.777	4.8
	5	17.03	-19.46	1.35	7.9

*Not significant

Table 16. Comparison of Yarn Strength for Cotton and Arnel Bright

Blend of Arnel-cotton per cent	Draft number	Tensile strength pounds	t value	Tensile strength grams	Count strength product	Standard deviation pounds	Coefficient of variation per cent
0-100	1	1.12	-	496	10401	1.27	11.3
	2	1.13	-	514	10758	0.107	9.5
	3	1.11	-	502	10853	0.137	12.4
	4	1.24	-	511	10884	0.079	7.1
	5	1.14	-	521	10254	0.085	7.4
25-75	1	0.85	10.17	386	8426	0.078	9.3
	2	0.85	10.89	386	8233	0.092	10.8
	3	0.80	9.35	363	8088	0.117	14.6
	4	0.84	14.15	381	8184	0.077	9.2
	5	0.89	11.22	404	8577	0.089	10.0
50-50	1	0.62	19.04	281	6089	0.068	10.9
	2	0.63	20.71	286	6155	0.078	12.3
	3	0.63	16.50	286	6283	0.080	12.7
	4	0.60	27.72	272	6060	0.068	11.3
	5	0.59	27.39	268	5936	0.073	12.4
75-25	1	0.43	14.57	196	4306	0.070	16.3
	2	0.39	35.05	177	3894	0.068	17.4
	3	0.43	24.60	194	4136	0.063	14.8
	4	0.38	41.66	174	3854	0.057	14.8
	5	0.41	36.29	186	4060	0.065	15.9
100-0	1	0.29	17.97	132	2868	0.054	18.6
	2	0.28	38.51	127	2758	0.058	20.6
	3	0.29	29.86	132	2816	0.059	20.3
	4	0.30	47.03	134	2872	0.060	20.2
	5	0.28	46.68	127	2743	0.049	17.4

Table 17. Comparison of Yarn Elongation for Cotton and Arnel Dull

Blend of Arnel-cotton per cent	Draft number	Yarn count	Elongation per cent
	1	20.97	8.48
	2	20.93	9.02
0-100	3	21.62	7.92
	4	21.30	8.00
	5	21.60	8.39
	1	20.85	6.93
	2	21.18	7.38
25-75	3	21.88	7.42
	4	21.53	7.61
	5	21.88	7.59
	1	21.75	6.66
	2	21.85	6.45
50-50	3	21.95	6.42
	4	21.60	6.43
	5	21.28	6.62
	1	22.25	6.53
	2	21.80	6.39
75-25	3	21.25	6.66
	4	21.60	6.92
	5	22.30	6.18
	1	21.58	7.70
	2	21.17	7.05
100-0	3	21.26	6.88
	4	22.20	7.08
	5	21.93	7.93

Table 18. Comparison of Yarn Elongation for Cotton and Arnel Bright

Blend of Arnel-cotton per cent	Draft number	Yarn count	Elongation per cent
	1	20.97	8.48
	2	20.93	9.02
0-100	3	21.62	7.92
	4	21.30	8.00
	5	21.60	8.39
	1	21.83	7.91
	2	21.33	8.16
25-75	3	22.28	7.74
	4	21.48	7.73
	5	21.23	8.24
	1	21.69	7.03
	2	21.52	7.46
50-50	3	21.97	7.40
	4	22.28	7.16
	5	22.15	7.06
	1	21.97	6.92
	2	22.00	6.31
75-25	3	21.32	6.80
	4	22.15	6.58
	5	21.83	6.58
	1	21.73	10.6
	2	21.72	9.91
100-0	3	21.33	9.60
	4	21.43	10.10
	5	21.60	9.71

BIBLIOGRAPHY

LITERATURE CITED

1. Stoll, R. G., "Textiles with New Properties from Cellulose Triacetate," Textile Research Journal, 1955, pp. 650-651.

2. Grishin, P. F., "Theory of Drafting and its Practical Application," Journal of the Textile Institute, Vol. 45, March 1954, p. T168.

3. Ibid., p. T169.

4. Speakman, J.B., "Fibre Blends" Journal of the Textile Institute, Vol. 49, 1958, p. 580.

5. Technical Bulletin, Celanese Corporation of America, T D-14A, p. 4.

6. Brandt, C., "Some Details of Drafting" Textile Bulletin, May 1958, pp. 138-141.

7. Uster Corporation, Operating Instructions for the Uster Integrator, Switzerland, December 1949, pp. 32-33.

8. American Society of Testing Materials, Methods ofTesting, 1957, p. 459.

9. Uster Corporation, Instruction Book for the Uster Evenness Tester, Charlotte, North Carolina.

10. Neiswanger, W. A., "Sampling Error and Statistical Inference," Elementary Statistical Methods, 1956, p. 391.

11. Statistical Interpretive System, Rich Electronic Computer Center, Georgia Institute of Techology, 1959.