Equations for Predicting Single-Strand Yarn Strength and Elongation Based on Measures of Raw-Cotton Quality

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SUMMARY AND CONCLUSIONS

This is the first report in a series of relationship studies on cotton fiber properties which deals with single-strand yarn strength. All previous studies of this series dealing with yarn-strength have involved the measure of skein strength. The two tests of yarn strength, however, differ radically in a number of particulars.

Predicting equations and related information are helpful to the cotton trade and textile industry in choosing cottons best suited to the manufacture of specific products, in selecting blends of cotton for processing, and for meeting different levels of product quality. Such equations and knowledge also give assistance to cotton breeders by informing them of the fiber properties which are important to their programs.

This publication gives 13 equations, based on various measures of raw-cotton quality, for predicting single-strand strength and elongation of any size of carded yarn within a relatively wide range. Ten of the equations refer to yarn strength and three to yarn elongation. The precision of estimate expected with each equation is shown.

Varying numbers and combinations of cotton-quality factors, including alternative measures of fiber strength (1/8" and 0 gauge) and of fiber fineness and maturity (Micronaire and Causticaire), were used in the analyses. The other cotton quality measures used were upper half mean length, length uniformity ratio, and grade of cotton.

Calculations necessary for predicting single-strand yarn strength and elongation are illustrated by application of two equations. A supplemental procedure is suggested for making the prediction values flexible and more meaningful in terms of diverse processing and testing conditions.

The new equations were developed from data representing a total of 328 commercial cottons, grown in 111 selected cotton improvement areas across the U. S. Cotton Belt, during the crop year of 1954. The principal varieties in current commercial production were included. All cottons were grown, harvested, and ginned under commercial conditions identified with their respective growth areas. Early, midseason, and late-season samples were obtained from each growth locality, except in a few instances where test material representing all harvestings was not available.

A total of 678 lots of carded long-draft singles yarn, representing yarn sizes of 8s, 14s, 22s, and 50s, was used in the analyses. All yarns conformed to a warp type of construction and possessed a semihard twist.

The coefficients of multiple correlation ($\bar{R}$) obtained by use of yarn size and various measures of raw-cotton quality with single-strand count x strength product ranged from 0.873 to 0.830, and those with single-strand yarn elongation ranged from 0.851 to 0.722.

The factors included in the respective analyses explained from 76 to 69 percent of the variance in single-strand count x strength product, and from 72 to 52 percent of the variance in single-strand yarn elongation.

The measure of fiber strength at the 1/8" gauge was more important to single-strand count x strength product than fiber strength at the 0 gauge.

The rank of importance of upper half mean length toward single-strand count x strength product varied, depending on which fiber-strength measure was used in the correlation analysis.

Grade index generally ranked as the cotton-quality factor of third importance to count x strength product.

Micronaire fiber fineness in combination with maturity was more important to single-strand count x strength product than Causticaire fiber fineness.

Causticaire fiber maturity ranked fourth in importance to single-strand count x strength product. This finding suggests that it was the element of fiber maturity included in the Micronaire fineness measure which made it more important to c x s product than was the Causticaire fineness measure.

Length uniformity index made only a negligible effect on single-strand count x strength product.

With single-strand yarn elongation, fiber strength at the 0 gauge was more important than fiber strength at the 1/8" gauge.

When fiber strength at the 0 gauge was used in the analysis, Causticaire fiber fineness was more important to yarn elongation than Micronaire fiber fineness in combination with maturity. However, when fiber strength at the 1/8" gauge was included, the Causticaire fineness and Micronaire measures showed approximately equal contributions to yarn elongation.

Length uniformity ratio ranked higher in importance toward yarn elongation when fiber strength at the 1/8" gauge was included in the analysis than when fiber strength at the 0 gauge was used.

Grade, upper half mean length, and Causticaire fiber maturity made relatively small and somewhat variable contributions to yarn elongation.

Such variations in results, as reported herein, emphasize the interrelationships that commonly occur between cotton fiber properties. The findings demonstrate, moreover, the extent to which the evaluated importance of certain cotton fiber properties toward yarn strength, yarn elongation, and other yarn-quality properties may vary, depending upon which combination of factors and which alternative measures are used in the correlation analysis.

EQUATIONS FOR PREDICTING SINGLE-STRAND YARN STRENGTH AND ELONGATION BASED ON MEASURES OF RAW-COTTON QUALITY

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INTRODUCTION

Equations for predicting processing performance and product quality on the basis of measurable fiber properties and other factors of quality, identified with various kinds of cotton, are the subject of continuing studies by the Cotton Division of the Agricultural Marketing Service. From this series of relationship studies on cotton fiber properties, 21 reports (14 through 34) 1/ have been published to date. The basic problems and objectives underlying these studies, as well as the benefits expected from the development and application of such information and equations, were discussed in a report issued by the Department of Agriculture in 1947 (13).

All predicting equations heretofore published in this series of reports with respect to yarn strength and count-strength product have been identified with the skein measure of yarn strength. No reports have been issued thus far in reference to yarn elongation. This study and report, therefore, constitutes the first of this series dealing with single-strand yarn strength and elongation. As the two yarn-strength tests and measures are so radically different in principle, nature, and representativeness, the predicting equations and relationship findings here reported in connection with single-strand yarn strength possess particular interest by comparison with parallel values obtained with skein yarn strength, as reported for the same series of cottons and yarns in publication (17).

Moreover, during recent years, there has been a marked increase in interest and use of the single-strand test for yarn strength on the part of the textile industry, as well as of various laboratories for research and testing purposes. At the same time, further interest has been developing in the cotton world and textile industry on the subjects of yarn elongation and fiber elongation, due largely to recent publications of limited data from various research and testing laboratories. Therefore, more comprehensive information and equations bearing on the relations of cotton fiber properties to single-strand yarn strength and elongation are needed by many people who are working with various practical problems of cotton marketing and processing, as well as of cotton breeding, production, and improvement.

In the light of the foregoing and because many cotton technologists are using the alternative measures of fiber strength (1/8" and 0 gauge) and the alternative measures of fiber fineness (Micronaire and Causticaire), it was considered timely to conduct a series of multiple correlation analyses with those factors, among other fiber properties, on a large block of single-strand data for yarn strength and elongation. The data used in these analyses represented selected upland cottons from across the American cotton

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1/ Underscored numbers in parentheses refer to Literature Cited, p.31.

belt throughout the crop season of 1954. The resulting findings and equations, therefore, are applicable to American cotton in current commercial production.

This report presents the new equations developed for predicting single-strand yarn strength and elongation of any size of carded yarn on the basis of varying numbers and combinations of cotton fiber properties, including the alternative measures of fiber strength and the alternative measures of fiber fineness. The precision of estimate is given in every case. This report also presents statistical values which reveal the degree of relationship occuring between the collective factors used in each analysis, as well as the relative importance of yarn size and each cotton-quality measure toward single-strand yarn strength and elongation.

SAMPLES, TESTS, AND DATA

The fiber and spinning tests on the cottons used in these analyses were made in the laboratories of the Cotton Division, Agricultural Marketing Service, at Clemson, S. C. and at College Station, Tex. Causticaire fiber fineness and maturity tests, as well as single-strand yarn strength and elongation tests, were made in the Washington laboratory.

The fiber, processing, and product-quality data which served as the basis of this study are contained in Summary publication (10), except for the following:

(1) Values for fiber strength at the 0 gauge spacing were published in preliminary reports (4) through (9) and they are complete, except for 6 late-season samples.
(2) Micronaire values - unpublished data.
(3) Single-strand yarn strength - unpublished data.
(4) Single-strand yarn elongation - unpublished data.

Cottons. All cottons were of the American upland type and they were grown commercially in selected cotton improvement groups across the U. S. Cotton Belt, within their general area of growth adaptation, during the crop year of 1954. The cottons were ginned on commercial saw gins serving the respective cotton improvement groups. Each variety and location of growth was represented by early-season, midseason, and late-season samples, except in 5 cases.

The total number of localities from which samples were obtained was 111 and, on the basis of 3 samples per locality, the total number of cottons theoretically should be 333. The actual number of cottons that became available for testing, however, was 328.

The nature and scope of the cottons included in the reported analyses are shown by tabulation of the 19 varieties used, listed in order of descending number of lots of cotton per variety, as follows:

Variety	Lots of Cotton	
	Number	Percent
Deltapine 15	107	32.6
Coker 100 W	58	17.8
Acala 1517 C	27	8.2
Acala 4-42	24	7.3
Arizona 44	18	5.5
Lankhart 57	18	5.5
Deltapine TPSA	12	3.7
Empire	12	3.7
Rowden	12	3.7
Delfos 9169	6	1.8
Deltapine Fox	6	1.8
Northern Star	6	1.8
Stoneville 2B	6	1.8
Bobshaw 1-A	3	.9
Earlistaple	3	.9
Hibred	3	.9
Lockett SF-1	3	.9
Paymaster 54	3	.9
Macha	1	.3
Total	328	100.0

The distribution of the lots of cotton used in this study, by each of the 14 states involved, is shown in order of descending number of lots of cotton per state, as follows:

State	Lots of Cotton	
	Number	Percent
Texas	82	25.0
Mississippi	42	12.8
Arkansas	27	8.2
California	24	7.3
Georgia	24	7.3
Arizona	21	6.4
Louisiana	21	6.4
Alabama	18	5.5
New Mexico	15	4.6
North Carolina	12	3.7
South Carolina	12	3.7
Tennessee	12	3.7
Missouri	9	2.7
Oklahoma	9	2.7
Total	328	100.0

Sampling. Classing samples weighing 4 to 6 ounces were assembled for the most frequently occurring grade and staple-length groups of each selected cotton improvement area for each season of harvesting, until 8 to 10 pounds of raw cotton had been accumulated.

The original grade and staple length designations, which served as the basis for selecting and compositing the comparable lots of cotton for test purposes, were those assigned to the individual samples of raw cotton by cotton specialists of the U. S. Department of Agriculture. Classification of the samples was made in accordance with official standards for staple length and grade, as described for American upland cotton in the publication entitled "The Classification of Cotton" (12)

As a result of the method used for selecting the samples, not every grade and staple length in the range appearing in each cotton improvement area was represented by the test cottons.

Processing. Details of the processing procedure by which the cottons were converted into yarns may be found in the report setting forth the fiber and spinning test results (10). Report (11) described the cotton testing services of the Cotton Division, including not only processing procedures and waste analyses but also fiber, yarn and fabric tests.

All cottons used in this study were processed through the picker and card by the same standard procedure. On the basis of past performance, the varieties were grouped according to the staple length expected in their specified areas of growth. In general, the rates of carding were as follows: Cottons of 15/16 inch and shorter in staple length, 12-1/2 pounds per hour; those from 31/32 inch through 1-1/16 inches, 9-1/2 pounds per hour; and those from 1-3/32 inches through 1-1/4 inches, 6-1/2 pounds per hour.

The number of lots of cotton processed at each of the three rates of card production is indicated by the following tabulation:

Rate of card production (Lbs. per hr.)		Lots of cotton (Number)	Lots of cotton (Percent)
12-1/2		22	6.7
9-1/2		263	80.2
6-1/2		43	13.1
	Total	328	100.0

All yarns from all cottons were processed from long-draft roving by long-draft spinning equipment; they represented a warp-type of construction; and they possessed a semihard twist. The twist multiplier varied with the upper half mean length of the cottons, the one selected for each cotton being that which gave approximately the maximum yarn strength for an average or typical cotton of the particular classified length. The twist multiplier used in each case, therefore, was not selected to compenstate for the influence of other fiber properties involved but represented an empirical selection.

Fiber properties. Six factors of raw-cotton quality, including alternative measures of fiber fineness (Causticaire and Micronaire) and of fiber strength (1/8" gauge and 0 gauge), were used as independent variables in the correlation analyses of this study, as follows:

Upper half mean length, in inches, as determined by the Fibrograph method.

Length uniformity ratio, index, as determined by the Fibrograph.

Fiber fineness and maturity in combination, as evaluated for untreated samples by the Micronaire method and expressed in Micronaire scale units.

Fiber fineness, in micrograms per inch, as evaluated by the Causticaire method, using the Micronaire instrument.

Fiber maturity, index, as evaluated by the Causticaire method, using the Micronaire instrument.

Fiber strength, expressed in terms of an index, as determined by the Pressley tester with 1/8" gauge spacing between the gripping jaws.

Fiber strength, in terms of 1,000 lbs. per sq. in., as determined by the Pressley tester with a zero (0) gauge spacing.

Grade of cotton, expressed as an index.

The fiber tests and measures used in collecting the data for these analyses are those described in publications entitled "Cotton Testing Service" (11), "ASTM Standards on Textile Materials" (1), and "Summary of Fiber and Spinning Test Results for Some Varieties of Cotton Grown by Selected Cotton Improvement Groups, Crop of 1954" (10). A more detalied description of the improved Causticaire method for evaluating cotton fiber fineness and maturity, in conjunction with the Micronaire instrument, is contained in report (18).

Grade index as used in this study was explained in the report of this series having to do with the strength of 22s yarn, regular draft (25). The conversion chart for obtaining grade index values of samples of raw cotton, corresponding to various grade designations originally assigned by cotton specialists, is shown in table 1. 2/

In calculating the test results for fiber strength at the 1/8" gauge, the Pressley ratio is obtained by dividing the weight of the test specimen in milligrams into the strength of the specimen in pounds, and

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2/ All tables are grouped in the Appendix at the end of this report and hereafter they will be referred to by table number only.

then adjusting the quotient to a standard level on the basis of results obtained from check-test cottons. This ratio for an individual cotton, when divided by an average ratio of 3.19 and multiplied by 100, is converted to a fiber-strength index which indicates higher than average fiber strength by index values larger than 100 and lower than average strength by values smaller than 100.

A conversion chart for quickly obtaining index values of fiber strength at the 1/8" gauge spacing from Pressley-ratio values is shown in table 2. A Pressley strength index of 100 equals average fiber strength for 1954 crop of commercial American upland cottons tested, representing a beam-reading to weight-specimen ratio of 3.19 for the 1/8" gauge spacing, and corresponding to a fiber strength of 84,000 pounds per sq. in. for the 0 gauge spacing.

In calculating the test results for fiber strength at the 0 gauge spacing, the Pressley ratio is obtained as described for the 1/8" gauge spacing. The formula for converting the Pressley strength-weight ratio value at the 0 gauge spacing into terms of 1,000 lbs. per sq. in. is as follows:

$$X_{33} = 10.8116\ X_{22} - 0.12$$

Where X_{33} = Estimated fiber strength, in 1,000 lbs. psi.
X_{22} = Pressley strength-weight ratio at 0 gauge

For convenience in obtaining values of fiber strength at the 0 gauge in terms of 1,000 lbs. per sq. in., without actually making the necessary calculations, reference may be made to publication (3). That report contains tables of calculated data, representing small increments over a comparatively wide range of fiber bundle weights and beam readings, for use in connection with making Pressley strength tests on cotton fibers.

Atmospheric conditions for fiber testing. All fiber tests were made under controlled atmospheric conditions with a temperature of 70° F. ± 2° and a relative humidity of 65 percent ± 2 percent, according to ASTM specifications (1).

Yarn size. Yarn size, expressed in terms of the generally used or so-called English yarn numbers for cotton, was included as an independent variable in the multiple correlation analyses, when count-strength product or elongation of various yarn sizes was used as the dependent variable in the respective analyses. Data representing all yarn sizes processed from all cottons were used in the analyses, the breakdown of yarn sizes by cottons being as follows:

Cottons (Number)	Yarn size (Number)
22	8s, 14s, and 22s
306	22s and 50s

<u>Yarn strength</u>. Single-strand strength tests of all yarns were made by an automatic instrument known as the "Autodinamographo". 3/ The single-strand strength values were expressed in terms of grams and represented test specimens of 20 inches in length. A total of 70 yarn breaks was made for each yarn number for each cotton, representing 10 breaks on each of 7 bobbins of yarn per cotton.

Values for count x strength product were obtained by multiplying the individual yarn strengths by their respective yarn numbers, and expressing the results in terms of count-strength-product units. Such values were used as the dependent variable in one set of the correlation analyses reported herein.

<u>Yarn elongation</u>. In connection with the single-strand strength tests made on the yarns by the "Autodinamographo", simultaneous evaluations also were obtained for single-strand yarn elongation at the time of yarn breakage. The elongation values were expressed in terms of percent, as based on the original length of the test specimens; namely, 20 inches. Such elongation values were used as the dependent variable in the other set of correlation analyses covered in this report.

<u>Atmospheric conditions for yarn testing</u>. All yarn-strength and yarn elongation tests were made under controlled atmospheric conditions, as specified by ASTM for yarn testing (1); namely, with a temperature of 70° F. ± 2° and a relative humidity of 65 percent ± 2 percent.

STATISTICAL ANALYSES

This report covers results obtained from 21 correlation analyses with data representing 328 selected commercial American upland cottons, crop of 1954, and 678 lots of carded yarn, ranging in size from 8s to 50s. Included in this study were 18 multiple correlation analyses and 3 simple correlation analyses.

Ten multiple correlation analyses were made with single-strand count x strength product, as the dependent variable, when using varying numbers and combinations of cotton fiber properties as independent variables, including the alternative Causticaire and Micronaire measures for fiber fineness, as well as Pressley fiber strength at the 1/8" and 0 gauge spacings. A similar set of 8 multiple correlation analyses was made with single-strand yarn elongation as the dependent variable.

The simple correlation analyses involved different pairs of dependent variables as follows: Single-strand yarn strength versus single-strand yarn elongation, single-strand yarn strength versus skein yarn strength, and skein yarn strength versus single-strand yarn elongation.

3/ Mention of names of firms or trade products does not imply that they are recommended or endorsed by the U. S. Department of Agriculture over other firms or similar trade products not mentioned.

The nature and scope of the data representing the independent and dependent variables used in these correlation analyses are indicated by the values shown in table 3.

The same general pattern of statistical analyses was followed in this instance as was used in all previous studies of this series. For more detailed information with regard to the statistical terms, measures, and techniques applied, see appendixes and literature citations in the first and third reports (19), (21).

Beta coefficients were used to evaluate the relative net contribution or importance of the fiber properties to the respective dependent variables, instead of partial correlation coefficients as was done in the early studies of this series. The reason for the change in method was explained in report (25).

All statistical values reported herein are so-called corrected ones, as obtained from multiple linear correlation analyses or from simple correlation analyses. No curvilinear analyses were made in connection with this study.

EQUATIONS RECOMMENDED FOR PREDICTING PURPOSES

The equations for predicting single-strand strength and elongation of cotton yarns on the basis of certain elements of raw-cotton quality, as covered in this report, refer to carded warp singles yarn, processed on long draft equipment, and possessing a semi-hard twist. No analyses have been made in this study with yarns processed on a regular-draft equipment.

The yarn-strength and yarn-elongation predictions obtained for other cottons by use of the equations and procedure recommended in this report should be relatively accurate, as expressed in terms of the fiber tests, textile processing and yarn structure used in the laboratories of the Cotton Division, Agricultural Marketing Service. For the same accuracy of sampling, fiber measurements and yarn tests, however, the level of the various predictions derived by use of the equations reported here may be expected to vary somewhat from the actual values obtained by others from other cottons, as influenced by the textile-processing organization used, by the amount of twist inserted in the yarns, and by other possible factors involved.

After several trial determinations, however, if one finds that the predictions obtained by use of the equations presented in this report consistently differ from his actual values, he can adjust his future predictions to his level of fiber tests, textile processing, yarn structure, and yarn twist by increasing or decreasing them by whatever percentage he finds to be necessary. Obviously, it would be impractical to try to develop equations for predicting purposes that would represent and apply equally well to each and every one of the many different processing organizations and yarn structures available in the textile industry.

But, by following the procedure of adjusting prediction values to different textile organizations and levels of testing, as suggested above, more flexibility is given to the available equations than otherwise would be possible, and the individual needs of different cotton spinners are better served in maintaining quality control and meeting specifications of manufactured products. Thus, the various equations reported here can be used satisfactorily, through supplemental procedure, for most practical problems and purposes connected with single-strand strength and elongation of carded warp yarn processed from American upland cotton.

Single-Strand Yarn Strength

Ten equations (No. 1 through No. 10 as listed in table 4) were developed in this study for predicting directly the single-strand strength of any size of carded warp singles yarn from 8s to 60s, on the basis of varying numbers and combinations of factors in raw-cotton quality. Alternative measures of fiber fineness (Causticaire and Micronaire) and of fiber strength (1/8" and 0 gauge) were included. Those equations are adapted to current commercial production of American upland cotton because they represent 328 selected commercial cottons covering a relatively wide range of quality, as well as 678 lots of yarn extending from 8s to 50s, crop year 1954.

As discussed in the previous section of this report, some of the factors of raw-cotton quality included in the equations influenced count x strength product to a relatively small amount. For practical purposes, therefore, such factors as affect count x strength product only to a comparatively minor or negligible degree may be eliminated from the equations without any appreciable loss or sacrifice in accuracy to the resulting predictions. Omission of all unimportant and nonessential factors or fiber measures from the equations obviously reduces, by that much, the number of fiber tests involved and the amount of both technical and clerical work required. Use of equations representing such eliminations and simplifications, therefore, permits a saving in terms of fiber-laboratory and clerical manpower. This is a matter of considerable importance because of the fact that it causes a reduction in the time and expense which otherwise would be needed to make the extra fiber tests and statistical calculations, some of which are rather slow, laborious, and expensive.

In the light of the foregoing, 5 equations including fiber strength at the 1/8" gauge and 5 equations including fiber strength at the 0 gauge are recommended for use in predicting single-strand yarn strength. Those equations identified by number, according to their listing in table 4, are as follows:

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(Including fiber strength at 1/8" gauge)

Equation (1), including 6 factors of cotton quality

$$X'_{177} = -471.26 - 51.27X_{41} + 34.81X_{88} + 3{,}870.76X_{17} + 12.96X_{19} - 4.79X_{134} - 32.85X_{135} + 47.68X_{173}$$

Where X'_{177} = Estimated single-strand c x s product, in csp units
X_{41} = Size of yarn, by yarn number
X_{88} = Grade of cotton, as an index
X_{17} = Upper half mean length, in inches
X_{19} = Length uniformity ratio, as an index
X_{134} = Causticaire fineness, in micrograms per inch
X_{135} = Causticaire maturity, as an index
X_{173} = Fiber strength (Pressley), 1/8" gauge, as an index

($\bar{R} = 0.873$; $\bar{R}^2 \times 100 = 76$ percent; and $S = \pm 494$ csp units)

Equation (2), including 4 factors of cotton quality

$$X'_{177} = -681.90 - 51.42X_{41} + 36.57X_{88} + 3{,}349.28X_{17} - 246.74X_{104} + 48.32X_{173}$$

Where X'_{177} = Estimated single-strand c x s product, in csp units
X_{41} = Size of yarn, by yarn number
X_{88} = Grade of cotton, as an index
X_{17} = Upper half mean length, in inches
X_{104} = Micronaire fineness and maturity in combination, as scale units
X_{173} = Fiber strength (Pressley), 1/8" gauge, as an index

($\bar{R} = 0.873$; $\bar{R}^2 \times 100 = 76$ percent; and $\bar{S} = \pm 494$ csp units)

Equation (3), including 3 factors of cotton quality

$$X'_{177} = -1{,}940.34 - 51.42X_{41} + 32.79X_{88} + 4{,}068.43X_{17} + 46.65X_{173}$$

Where X'_{177} = Estimated single-strand c x s product, in csp units
X_{41} = Yarn size, by yarn number
X_{88} = Grade of cotton, as an index
X_{17} = Upper half mean length, in inches
X_{173} = Fiber strength (Pressley), 1/8" gauge, as an index

($\bar{R} = 0.868$; $\bar{R}^2 \times 100 = 75$ percent; and $\bar{S} = \pm 503$ csp units)

Equation (4), including 3 factors of cotton quality

$$X'_{177} = + 2,338.12 - 51.64X_{41} + 2,866.13X_{17} - 191.63X_{104} + 57.07X_{173}$$

Where X'_{177} = Estimated single-strand c x s product, in csp units
X_{41} = Yarn size, by yarn number
X_{17} = Upper half mean length, in inches
X_{104} = Micronaire fineness and maturity in combination, as scale units
X_{173} = Fiber strength (Pressley), 1/8" gauge, as an index

($\bar{R}$ = 0.861; $\bar{R}^2$ x 100 = 74 percent; and $\bar{S}$ = $\pm$ 514 csp units)

Equation (7), including 2 factors of cotton quality

$$X'_{177} = + 1,089.94 - 51.62X_{41} + 3,477.48X_{17} + 55.02X_{173}$$

Where X'_{177} = Estimated single-strand c x s product, in csp units
X_{41} = Yarn size, by yarn number
X_{17} = Upper half mean length, in inches
X_{173} = Fiber strength (Pressley), 1/8" gauge, as an index

($\bar{R}$ = 0.858; $\bar{R}^2$ x 100 = 74 percent; $\bar{S}$ = $\pm$ 520 csp units)

(Including fiber strength at 0 gauge)

Equation (5), including 6 factors of cotton quality

$$X'_{177} = - 6,238.85 - 51.24X_{41} + 45.48X_{88} + 6,741.76X_{17} + 54.64X_{19}$$
$$- 88.34X_{134} - 37.16X_{135} + 45.94X_{33}$$

Where X'_{177} = Estimated single-strand c x s product, in csp units
X_{41} = Yarn size, by yarn number
X_{88} = Grade of cotton, as an index
X_{17} = Upper half mean length, in inches
X_{19} = Length uniformity ratio, as an index
X_{134} = Causticaire fineness, in micrograms per inch
X_{135} = Causticaire maturity, as an index
X_{33} = Fiber strength (Pressley), 0 gauge, in 1,000 lbs. psi.

($\bar{R}$ = 0.861; $\bar{R}^2$ x 100 = 74 percent; and $\bar{S}$ = $\pm$ 515 csp units)

Equation (6), including 4 factors of cotton quality

$$X'_{177} = - 3{,}748.44 - 51.43X_{41} + 49.18X_{88} + 6{,}464.66X_{17} - 311.10X_{104} + 43.97X_{33}$$

Where X'_{177} = Estimated single-strand c x s product, in csp units
X_{41} = Yarn size, by yarn number
X_{88} = Grade of cotton, as an index
X_{17} = Upper half mean length, in inches
X_{104} = Micronaire fineness and maturity in combination, as scale units
X_{33} = Fiber strength (Pressley), 0 gauge, in 1,000 lbs. psi.

($\bar{R}$ = 0.858; $\bar{R}^2 \times 100$ = 74 percent; and $\bar{S} = \pm$ 519 csp units)

Equation (8), including 3 factors of cotton qualtiy

$$X'_{177} = - 4{,}936.39 - 51.38X_{41} + 44.98X_{88} + 7{,}237.23X_{17} + 37.69X_{33}$$

Where X'_{177} = Estimated single-strand c x s product, in csp units
X_{41} = Yarn size, by yarn number
X_{88} = Grade of cotton, as an index
X_{17} = Upper half mean length, in inches
X_{33} = Fiber strength (Pressley), 0 gauge, in 1,000 lbs. psi.

($\bar{R}$ = 0.850; $\bar{R}^2 \times 100$ = 72 percent; and $\bar{S} = \pm$ 533 csp units)

Equation (9), including 3 factors of cotton quality

$$X'_{177} = + 18.62 - 51.70X_{41} + 6{,}618.24X_{17} - 236.53X_{104} + 51.54X_{33}$$

Where X'_{177} = Estimated single-strand c x s product, in csp units
X_{41} = Yarn size, by yarn number
X_{17} = Upper half mean length, in inches
X_{104} = Micronaire fineness and maturity in combination, as scale units
X_{33} = Fiber strength (Pressley), 0 gauge, in 1,000 lbs. psi.

($\bar{R}$ = 0.835; $\bar{R}^2 \times 100$ = 70 percent; and $\bar{S} = \pm$ 557 csp units)

Equation 10, including 2 factors of cotton quality

$$X'_{177} = -\ 1{,}153.40 - 51.65X_{41} + 7{,}207.72X_{17} + 46.16X_{33}$$

Where X'_{177} = Estimated single-strand c x s product, in csp units
X_{41} = Yarn size, by yarn number
X_{17} = Upper half mean length, in inches
X_{33} = Fiber strength (Pressley), 0 gauge, in 1,000 lbs. psi.

($\bar{R}$ = 0.830; $\bar{R}^2$ x 100 = 69 percent; $\bar{S}$ = $\pm$ 564 csp units)

Single-Strand Yarn Elongation

Eight equations (No. 11 through No. 18 as listed in table 5) were developed in this study for predicting directly the single-strand elongation of any size of carded warp singles yarn from 8s to 60s, on the basis of varying numbers and combinations of factors in raw-cotton quality. Alternative measures of fiber fineness (Causticaire and Micronaire) and of fiber strength (0 and 1/8" gauge) were included. Those equations, adapted to current commercial production of American upland cotton, represent 328 selected commercial cottons covering a relatively wide range of quality, as well as 678 lots of yarn ranging from 8s to 50s, crop year 1954.

As the measure of fiber strength at the 0 gauge was highly important to single-strand yarn elongation and the alternative measure of fiber strength at the 1/8" gauge made only a negligible contribution, the equations containing the former furnish more accurate predictions of yarn elongation than the equations with the latter. In the light of those facts, 3 equations including fiber strength at the 0 gauge are recommended for use in predicting single-strand yarn elongation. Those equations identified by number, according to their listing in table 5, are as follows:

Equation (11), including 6 factors of cotton quality

$$X'_{178} = +\ 8.319 - .036X_{41} + .023X_{88} + 1.427X_{17} + .056X_{19} - .279X_{134}$$
$$-\ .017X_{135} - .077X_{33}$$

Where X'_{178} = Estimated single-strand yarn elongation, in pct. units
X_{41} = Yarn size, by yarn number
X_{88} = Grade of cotton, as an index
X_{17} = Upper half mean length, in inches
X_{19} = Length uniformity ratio, as an index
X_{134} = Causticaire fineness, in micrograms
X_{135} = Causticaire maturity, as an index
X_{33} = Fiber strength (Pressley), 0 gauge, in 1,000 lbs. psi.

($\bar{R}$ = 0.851; $\bar{R}^2$ x 100 = 72 percent; and S = $\pm$ 0.42 pct. units)

Equation (13), including 4 factors of cotton quality

$$X'_{178} = +\ 11.279 - .036X_{41} + .025X_{88} + 1.802X_{17} - .293X_{104} - .081X_{33}$$

Where X'_{178} = Estimated single-strand yarn elongation, in pct. units
X_{41} = Yarn size, by yarn number
X_{88} = Grade of cotton, as an index
X_{17} = Upper half mean length, in inches
X_{104} = Micronaire fineness and maturity in combination, as scale values
X_{33} = Fiber strength (Pressley), 0 gauge, in 1,000 lbs. psi.

($\bar{R} = 0.845$; $\bar{R}^2 \times 100 = 71$ percent; and $\bar{S} = \pm\ 0.43$ pct. units)

Equation (15), including 3 factors of cotton quality

$$X'_{178} = +\ 13.162 - .036X_{41} + 1.879X_{17} - .256X_{104} - .077X_{33}$$

Where X'_{178} = Estimated single-strand yarn elongation, in pct. units
X_{41} = Yarn size, by yarn number
X_{17} = Upper half mean length, in inches
X_{104} = Micronaire fineness and maturity in combination, as scale units
X_{33} = Fiber strength (Pressley), 0 gauge, in 1,000 lbs. psi.

($\bar{R} = 0.835$; $\bar{R}^2 \times 100 = 70$ percent; and $\bar{S} = \pm\ 0.44$ pct. units)

ILLUSTRATION OF CALCULATIONS FOR MAKING PREDICTIONS

The calculations and procedures essential for practical use of any of the predicting equations presented in this report are relatively simple and easy to carry out, once that they are understood and have been applied in a few cases.

Single-strand yarn strength. The fiber data used in this example represent the first cotton listed in the 1954 series which was processed into 22s and 50s yarn. Calculations are illustrated in this instance for predicting the single-strand strength of 2 sizes of carded warp singles yarn, namely, 22s and 50s. Predictions of strength for any size of yarn ranging from 8s to 60s, however, may be obtained from the same fiber data by the same procedure, except care must be exercised each time to multiply the yarn size factor in the equation by the particular size of yarn in question.

In this connection, it should be noted that the estimate of single-strand yarn strength so obtained is in terms of count-strength-product units. This value, therefore, is divided by the yarn number in question in order to convert the csp value into grams of single-strand yarn strength.

Equation (2), as listed in table 4, is used in the example cited for single-strand yarn strength. That equation includes 5 factors, namely, yarn size and 4 factors of raw-cotton quality, as follows:

$$X'_{177} = -681.90 - 51.42X_{41} + 36.57X_{88} + 3,349.28X_{17} - 246.74X_{104} + 48.32X_{173}$$

Where X'_{177} = Predicted S.S. yarn strength, in csp units
X_{41} = Yarn size, by yarn number
X_{88} = Grade of cotton, as an index
X_{17} = Upper half mean length, in inches
X_{104} = Micronaire fineness and maturity in combination, as scale units
X_{173} = Fiber strength (Pressley), 1/8" gauge, as an index

Substitutions are made in the equation for the cotton in question, as follows:

X_{41} = 22 and 50, size of yarn
X_{88} = 104, grade of cotton, as an index
X_{17} = 1.12, upper half mean length, in inches
X_{104} = 4.6 Micronaire fineness and maturity in combination, as scale units
X_{173} = 108, fiber strength (Pressley), 1/8" gauge, as an index

Factors in equation	Calculations for predicting S.S. strength of-- 22s yarn	50s yarn
- Constant = --------------	- 681.90	- 681.90
- 51.42 x 22 = ------------	- 1,131.24	--
- 51.42 x 50 = ------------	--	- 2,571.00
+ 36.57 x 104 = ------------	+ 3,803.28	+ 3,803.28
+ 3,349.28 x 1.12 = --------	+ 3,751.19	+ 3,751.19
- 246.74 x 4.6 = -----------	- 1,135.00	- 1,135.00
+ 48.32 x 108 = ------------	+ 5,218.56	+ 5,218.56
Total	+ 9,824.89	+ 8,385.13
$+\frac{9,824.89}{22}$ = --------------	447.	--
$+\frac{8,385.13}{50}$ = --------------	--	168.
Actual S.S. yarn strength in grams	461.	169.
Difference, in grams	- 14.	- 1.
Difference, in percent	- 3.0	- .6

Single-strand yarn elongation. Using the fiber data for the same sample of cotton, as referred to above, calculations also are illustrated for predicting the single-strand yarn elongation of 2 sizes of carded warp singles yarn, namely, 22s and 50s. Predictions of elongation for any size of yarn ranging from 8s to 60s, however, may be obtained from the same fiber data by the same procedure, except care must be exercised each time to multiply the yarn size factor in the equation by the particular size of yarn in question.

Equation (13), as listed in table 5, is used in the example cited for single-strand yarn elongation. That equation includes 5 factors, namely, yarn size and 4 factors of raw-cotton quality, as follows:

$$X'_{178} = +11.279 - .036X_{41} + .025X_{88} + 1.802X_{17} - .293X_{104} - .081X_{33}$$

Where X'_{178} = Predicted S.S. yarn elongation, in pct. units
X_{41} = Yarn size, by yarn number
X_{88} = Grade of cotton, as an index
X_{17} = Upper half mean length, in inches
X_{104} = Micronaire fineness and maturity in combination, as scale units
X_{33} = Fiber strength (Pressley), 0 gauge, in 1,000 lbs. psi.

Substitutions are made in the equation, as follows:

Factors in equation	Calculations for predicting S.S. elongation of-- 22s yarn	50s yarn
+ Constant ----------------	+ 11.279	+ 11.279
- .036 x 22 ----------------	- .792	--
- .036 x 50 ----------------	--	- 1.800
+ .025 x 104 ---------------	+ 2.600	+ 2.600
+ 1.802 x 1.12 -------------	+ 2.018	+ 2.018
- .293 x 4.6 ---------------	- 1.348	- 1.348
- .081 x 87 ----------------	- 7.047	- 7.047
Total	+ 6.7	+ 5.7
Actual yarn elong., in pct.units	7.2	5.9
Difference, in pct. units	- .5	- .2
Difference, in percent	- 6.9	- 3.4

It should be noted that the prediction of single-strand elongation, as obtained by any of the equations reported herein, is expressed directly in terms of percent units or the original units of yarn-elongation measurement. It is not necessary, therefore, to divide the estimated values of single-strand elongation by the yarn number in question, as is the case in deriving a predicted value of single-strand yarn strength from an estimated value of count x strength product.

It also should be noted that, in the case of the reported equations for predicting single-strand yarn elongation, the regression coefficients are expressed to the third decimal place. This procedure is necessary because of the fact that the regression coefficients are so relatively small; that is, rounding off the regression coefficients to the second decimal place would cause comparatively large errors to be reflected in the predicted values of yarn elongation so obtained.

In the case of the equations for predicting single-strand yarn strength, however, where the regression coefficients are many times larger than those in the yarn-elongation equations, expression of the regression coefficients only to the second decimal place is sufficient for all practical purposes. Obviously, in the interest of eliminating unnecessary work and of saving time, regression coefficients in such predicting equations never should be carried to a decimal point further than that necessary to meet the essential requirements.

Basic data needed for use in equations. The data, representing the independent and dependent variables included in the various predicting equations, were obtained by laboratory test methods, as described in the publication entitled "Cotton Testing Service" (11) in "ASTM Standards on Textile Materials" (1), and in "Summary of Fiber and Spinning Test Results for Crop of 1954" (10). Therefore, when one attempts to obtain a prediction value for a cotton by use of any of the equations presented in this report, data of similar nature and tests should be used for the factors included. Further specialized procedures are needed in the case of several of the factors involved and brief descriptions of such supplementary steps are given below.

Grade index. This factor is used as an independent variable in some of the equations. A conversion chart for obtaining grade index values of samples of raw cotton, corresponding to various grade designations originally assigned by cotton specialists, is shown in table 1.

Fiber strength at the 1/8" gauge. This measure is an independent variable used in a number of the predicting equations. In calculating the test results for this fiber property, the Pressley ratio (1/8-inch gauge) is obtained by dividing the weight of the specimen in milligrams into the strength of the specimen in pounds and then adjusting the quotient to a standard level from results of tests on check cottons. This ratio for an individual cotton, when divided by an average ratio of 3.19 and multiplied by 100, is converted to an index which indicates higher than average strength by values larger than 100 and lower than average strength by values smaller than 100.

Such index values for fiber strength at the 1/8" gauge, as described above, should be used when applying any of the predicting equations containing that measure of fiber strength as an independent variable. A conversion chart for obtaining index values of fiber strength at the 1/8" gauge, corresponding to various laboratory values of Pressley strength-weight ratios, is shown in table 2.

Fiber strength at the 0 gauge. This alternative measure of fiber strength is an independent variable used in a number of the predicting equations. In calculating the test results for this fiber property, the

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Pressley ratio (0 gauge) is obtained by dividing the weight of the specimen in milligrams into the strength of the specimen in pounds and then adjusting the quotient to a standard level from results of tests on check cottons.

The formula for converting the Pressley strength-weight ratio identified with the 0 gauge spacing between the testing jaws into terms of 1,000 lbs. per sq. in. is, as follows:

$$X_{33} = 10.8116X_{22} - 0.12$$

Where X_{33} = Estimated fiber strength, in 1,000 lbs. psi.
X_{22} = Pressley strength-weight ratio at 0 gauge

Such values for fiber strength at the 0 gauge, as described above, should be used when applying any of the predicting equations containing that measure of fiber strength as an independent variable.

For convenience in obtaining values of fiber strength at the 0 gauge in terms of 1,000 lbs. per sq. in., without going through the laborious process of making countless calculations, reference may be had to publication (3). That report contains tables of calculated data, representing small increments over a comparatively wide range of fiber bundle weights and beam readings, for use in connection with making Pressley strength tests on cotton fibers at the 0 gauge.

EVALUATION OF THE RELATIONS OF THE FACTORS

With Single-Strand Count x Strength Product

As previously stated, ten multiple correlation analyses were made with single-strand count x strength product as the dependent variable, using varying numbers and combinations of cotton fiber properties as independent variables, and with alternative measures for fiber fineness (Causticaire and Micronaire) and of fiber strength (1/8" and 0 gauge) being included. The regression equations and corresponding correlation values for the respective multiple relationships are summarized in table 4. The equations are listed in descending order of amount of variance in single-strand count x strength product explained by the collective factors used, and each equation is identified by number in sequence.

Referring to the series of equations by order of listing in table 4, it will be seen that the coefficients of multiple correlation ($\bar{R}$) decreased from 0.873 to 0.830; that the amount of variance in single-strand count x strength product explained by the collective factors used in each analysis ($\bar{R}^2$ x 100) decreased from 76.17 to 68.91 percent; that the absolute standard of error ($\bar{S}$) increased from ± 494 to ± 564 csp units; and that the relative standard error of estimate ($\bar{S}$) increased from ± 5.8 to ± 6.7 percent.

The values of the beta coefficients showing the relative importance of the respective independent variables to single-strand count x strength product, when varying numbers and combinations of cotton-quality measures were used in the different analyses, are summarized in table 6. Each set of listed beta values is identified by its corresponding equation number, as shown in table 4, and the order in which the various sets of beta values are listed follows that for the equations in table 4. This parallel presentation of data in tables 4 and 6 affords easy comparison of the related results reported in the two tables.

The highest degree of correlation obtained with single-strand count x strength product was furnished by the collective factors included in equations (1) and (2). Equation (1) contained 7 independent variables listed in order of decreasing contribution to single-strand count x strength product, as follows: Yarn size, fiber strength at the 1/8" gauge, upper half mean length, grade index, Causticaire fiber maturity, length uniformity ratio, and Causticaire fineness. Equation (2), with 5 factors, included the same variables as equation (1) except that the Micronaire measure for fineness in combination with maturity was substituted for the Causticaire fineness and maturity measures, and that length uniformity ratio was omitted. The correlation values were identical with both equations (1) and (2), as indicated by the following:

Coefficient of correlation ($\overline{R}$)-----------------0.873
Variance explained in csp ($\overline{R}^2$ x 100)----------76.2 percent
Standard error of estimate ($\overline{S}$), absolute----$\pm$494. csp units
Standard error of estimate ($\overline{S}$), relative----- $\pm$5.8 percent

With equation (3), using the 4 most important factors listed in descending order of contribution (yarn size, fiber strength at the 1/8" gauge, upper half mean length, and grade index), almost as good correlation values were obtained with single-strand count x strength product as those cited previously. The correlation results with equation (3) were as follows:

Coefficient of correlation ($\overline{R}$)-----------------0.868
Variance explained in csp ($\overline{R}^2$ x 100)----------75.3 percent
Standard error of estimate ($\overline{S}$), absolute----$\pm$503. csp units
Standard error of estimate ($\overline{S}$), relative------$\pm$6.0 percent

With equation (4), including the 4 factors (yarn size, fiber strength at 1/8" gauge, upper half mean length, and Micronaire), almost as good correlation values were obtained with single-strand count x strength product as those previously cited. The correlation values with equation (4) were as follows:

Coefficient of correlation ($\overline{R}$)-----------------0.861
Variance explained in csp ($\overline{R}^2$ x 100)----------74.2 percent
Standard error of estimate ($\overline{S}$), absolute----$\pm$514. csp units
Standard error of estimate ($\overline{S}$), relative------$\pm$6.1 percent

All the foregoing equations included the factor of fiber strength at the 1/8" gauge. Upon substituting fiber strength at the 0 gauge for fiber strength at the 1/8" gauge, however, the equations with corresponding factors showed slightly smaller degrees of evaluated relationships. Moreover, when fiber strength at the 1/8" gauge was used in the multiple analyses, fiber strength ranked second and upper half mean length ranked third in importance to single-strand count x strength product. But, when fiber strength at the 0 gauge was used in the analyses, the ranks of importance of fiber strength and upper half mean length toward count x strength product were reversed.

For example, equation (5) contained 7 independent variables listed in order of decreasing contribution to single-strand count x strength product, as follows. Yarn size, upper half mean length, fiber strength at the 0 gauge, grade index, Causticaire fiber maturity, length uniformity ratio, and Causticaire fineness. The correlation results with equation (5) were as follows:

Coefficient of correlation ($\bar{R}$)-----------------0.861
Variance in csp explained ($\bar{R}^2$ x 100)----------74.1 percent
Standard error of estimate ($\bar{S}$), absolute----$\pm$515. csp units
Standard error of estimate ($\bar{S}$), relative------$\pm$6.1 percent

Equation (6), with 5 factors, included the same variables as equation (5) except that the Micronaire measure for fineness in combination with maturity was substituted for the Causticaire fineness and maturity measures, and that length uniformity ratio was omitted. The correlation results with equation (6) were as follows:

Coefficient of correlation ($\bar{R}$)-----------------0.858
Variance explained in csp ($\bar{R}^2$ x 100)----------73.7 percent
Standard error of estimate ($\bar{S}$), absolute----$\pm$519. csp units
Standard error of estimate ($\bar{S}$), relative------$\pm$6.2 percent

With equation (7), including the 3 factors of yarn size, fiber strength at the 1/8" gauge, and upper half mean length, the correlation values were as follows:

Coefficient of correlation ($\bar{R}$)-----------------0.858
Variance explained in csp ($\bar{R}^2$ x 100)----------73.6 percent
Standard error of estimate ($\bar{S}$), absolute----$\pm$520. csp units
Standard error of estimate ($\bar{S}$), relative------$\pm$6.2 percent

With equation (8), containing the 4 factors of yarn size, upper half mean length, grade index, and fiber strength at the 0 gauge, the correlation results were as follows:

Coefficient of correlation ($\bar{R}$)-----------------0.850
Variance in csp explained ($\bar{R}^2$ x 100)----------72.3 percent
Standard error of estimate ($\bar{S}$), absolute----$\pm$533. csp units
Standard error of estimate ($\bar{S}$), relative------$\pm$6.3 percent

With equation (9), including the 4 variables of yarn size, upper half mean length, fiber strength at the 0 gauge, and Micronaire fineness in combination with maturity, the correlation values were as follows:

Coefficient of correlation ($\bar{R}$)-----------------0.835
Variance explained in csp ($\bar{R}^2$ x 100)----------69.7 percent
Standard error of estimate ($\bar{S}$), absolute----$\pm$557. csp units
Standard error of estimate ($\bar{S}$), relative------$\pm$6.6 percent

And, with equation (10), involving the 3 factors of yarn size, upper half mean length, and fiber strength at the 0 gauge, the correlation results were as follows:

Coefficient of correlation ($\bar{R}$)-----------------0.830
Variance explained in csp ($\bar{R}^2$ x 100)----------68.9 percent
Standard error of estimate ($\bar{S}$), absolute----±564. csp units
Standard error of estimate ($\bar{S}$), relative------±6.7 percent

With Single-Strand Yarn Elongation

Eight multiple correlation analyses were made with single-strand yarn elongation as the dependent variable, using varying numbers and combinations of cotton fiber properties as independent variables, and with alternative measures for fiber fineness (Causticaire and Micronaire) and of fiber strength (0 and 1/8" gauge) being included. The regression equations and corresponding correlation values for the respective multiple relationships are summarized in table 5. The equations are listed in descending order of amount of variance in single-strand yarn elongation explained by the collective factors used, and each equation is identified by number in sequence (following the last equation number shown in table 4 for count x strength product).

Examining the series of equations by order of listing in table 5, it will be seen that the coefficients of multiple correlation ($\bar{R}$) decreased from 0.851 to 0.722; that the amount of variance in single-strand yarn elongation explained by the collective factors used in each analysis ($\bar{R}^2$ x 100) decreased from 72.46 to 52.11 percent; that the absolute standard error of estimate ($\bar{S}$) increased from ± 0.42 to ± 0.55 percent units; and that the relative standard error of estimate ($\bar{S}$) increased from ± 6.6 to ± 8.7 percent.

The values of the beta coefficients showing the relative importance of the respective independent variables to single-strand yarn elongation, when varying numbers and combinations of cotton-quality measures were used in the different analyses, are summarized in table 7. Each set of listed beta values is identified by its corresponding equation number, as shown in table 5, and the order of listing the various sets of beta values follows that for the equations in table 5.

The highest degree of correlation obtained with single-strand yarn elongation was furnished by the 7 collective factors included in equation (11), which were yarn size, fiber strength at the 0 gauge, Causticaire fineness, upper half mean length, grade index, length uniformity ratio, and Causticaire maturity. The correlation values with equation (11) were as follows:

Coefficient of correlation ($\bar{R}$)-----------------0.851
Variance explained in yarn elong. ($\bar{R}^2$ x 100)--72.5 percent
Standard error of estimage ($\bar{S}$), absolute-------±.42 pct. units
Standard error of estimate ($\bar{S}$), relative------±6.6 percent

Equation (12), containing the 5 most important factors of equation (11), omitting Causticaire maturity and length uniformity ratio, gave correlation results as follows:

Coefficient of correlation ($\bar{R}$)----------------0.847
Variance explained in yarn elong. ($\bar{R}^2$ x 100)--71.7 percent
Standard error of estimate ($\bar{S}$), absolute-------+.43 pct. units
Standard error of estimate ($\bar{S}$), relative------$\pm$6.7 percent

With equation (13), including the 5 factors of yarn size, fiber strength at the 0 gauge, upper half mean length, Micronaire fineness in combination with maturity, and grade index, the correlation values were as follows:

Coefficient of correlation ($\bar{R}$)----------------0.845
Variance explained in yarn elong. ($\bar{R}^2$ x 100)--71.3 percent
Standard error of estimate ($\bar{S}$), absolute-------+.43 pct. units
Standard error of estimate ($\bar{S}$), relative------$\pm$6.8 percent

With equation (14), containing the 4 factors of yarn size, fiber strength at the 0 gauge, Causticaire fineness, and upper half mean length, the correlation results were as follows:

Correlation coefficient ($\bar{R}$)-------------------0.836
Variance explained in yarn elong. ($\bar{R}^2$ x 100)--70.0 percent
Standard error of estimate ($\bar{S}$), absolute-------+.44 pct. units
Standard error of estimate ($\bar{S}$), relative------$\pm$6.9 percent

With equation (15), including the 4 factors of yarn size, fiber strength at the 0 gauge, upper half mean length, and Micronaire fineness in combination with maturity, the correlation values were as follows:

Correlation coefficient ($\bar{R}$)-------------------0.835
Variance explained in yarn elong. ($\bar{R}^2$ x 100)--69.8 percent
Standard error of estimate ($\bar{S}$), absolute-------+.44 pct. units
Standard error of estimate ($\bar{S}$), relative------$\pm$7.0 percent

All equations cited previously in connection with yarn elongation included the factor of fiber strength at the 0 gauge. Upon substituting fiber strength at the 1/8" gauge for fiber strength at the 0 gauge, however, the equations with corresponding factors showed noticeably smaller degrees of evaluated relationships. Fiber strength as measured at the 0 gauge, therefore, appears to be considerably more important toward single-strand yarn elongation than does fiber strength as measured at the 1/8" gauge. Those differences may be better visualized and compared by reference to table 7.

Equation (16), contained 7 factors listed in descending order of importance to yarn elongation as follows: Yarn size, Causticaire fineness, length uniformity ratio, upper half mean length, fiber strength at the 1/8" gauge, Causticaire fiber maturity, and grade index. The correlation results with equation (16) were as follows:

Correlation coefficient ($\bar{R}$)--------------------0.736
Variance explained in yarn elong. ($\bar{R}^2$ x 100)--54.2 percent
Standard error of estimate ($\bar{S}$), absolute-------+.54 pct. units
Standard error of estimate ($\bar{S}$), relative------$\pm$8.6 percent

With equation (17), including the first 6 factors of equation (16) but omitting grade index, the correlation values were as follows:

Correlation coefficient ($\bar{R}$)--------------------0.734
Variance explained in yarn elong. ($\bar{R}^2$ x 100)--53.9 percent
Standard error of estimate ($\bar{S}$), absolute-------+.54 pct. units
Standard error of estimate ($\bar{S}$), relative------$\pm$8.6 percent

And, with equation (18), containing the 5 factors of yarn size, Micronaire fineness in combination with maturity, upper half mean length, length uniformity ratio, and fiber strength at the 1/8" gauge, the correlation results were as follows:

Correlation coefficient ($\bar{R}$)--------------------0.722
Variance explained in yarn elong. ($\bar{R}^2$ x 100)--52.1 percent
Standard error of estimate ($\bar{S}$), absolute-------+.55 pct. units
Standard error of estimate ($\bar{S}$), relative------$\pm$8.7 percent

DISCUSSION

Consideration has been given in this study and report to two cotton fiber measures which represent comparatively recent developments; namely, fiber strength at the 1/8" gauge and Causticaire fiber fineness (wt./in.). If further information is desired on those fiber tests and measures than that contained in this report, it may be obtained by referring to publications (2) and (18).

Meaning of Values in Predicting Equations

The equations reveal the mathematical evaluation of the multiple relationships existing, on the average, between the measures of various factors used in the respective analyses. The values that go to make up an equation are relative throughout and comparative within themselves. The values for the respective regression coefficients, however, are not strictly comparable from equation to equation because of the fact that the level of the regression values in each equation is identified with the value shown for the constant factor of each equation and the latter differs appreciably in various equations.

Pertinent information bearing on the multiple relationships occurring between the variables considered in the respective analyses may be obtained from the regression equations. This is possible because the respective regression coefficients in such equations serve to indicate directly the amount of change in a particular dependent variable caused, on the average, by one unit increase in each independent variable. The sign attached to a regression coefficient signifies whether a unit increase in the value of an independent variable produces an increase or decrease in the scale of values for the dependent variable.

In examining and comparing the values of the regression coefficients listed in the equations presented, it should be remembered that different units of measurement necessarily had to be used for the various independent variables included in the statistical analyses, as shown in the following tabulation:

Independent variables	Unit of measurement
Upper half mean length----------------------------	1 inch
Length uniformity ratio---------------------------	1 index unit
Fiber fineness and maturity in combination (Micronaire)------------------------------------	1 scale unit
Fiber fineness (Causticaire)----------------------	1 microgram per inch
Fiber maturity (Causticaire)----------------------	1 index unit
Fiber strength (Pressley), 1/8" gauge-------------	1 index unit
Fiber strength (Pressley), 0 gauge----------------	1,000 lb. per sq. in.
Grade of cotton-----------------------------------	1 index unit
Yarn size---	1 yarn number

As shown above, the unit of measurement for upper half mean length is 1 inch. Therefore, if the effect of upper half mean length on single-strand count x strength product or on single-strand yarn elongation is desired in terms of the more conventional units of 1/32-inch, as generally used in the cotton trade and textile industry, the regression coefficients shown in the equations for the length factor should be divided by 32. No further calculations or adjustments, however, are needed in connection with any of the other regression coefficients.

In this connection, it should be emphasized that, when a predicting equation is said to represent the average relations of cotton fiber properties to single-strand count x strength product, yarn strength or yarn elongation, it does not precisely denote that meaning. Rather, such an equation represents the average relations of the measures used for the respective fiber properties to the measure used for the dependent variable. There is an important distinction between those two concepts.

Thus, when varying numbers and combinations of factors are used in correlation analyses, when different or alternative measures are included as respective independent and dependent variables, and when different series of cottons vary appreciably in their ranges and distributions of fiber properties, fluctuations in predicting equations and associated statistical values occur and never can be avoided. Inconsistency in such findings under those conditions, therefore, is readily understandable.

Meaning of Standard Error of Estimate

The standard error of estimate ($\overline{S}$) identified with each predicting equation reported indicates the range within which 67 percent of the actual values for a particular dependent variable, representing a series of cottons, would be expected to occur in relation to the corresponding estimated values obtained on the basis of the factors included in the equation. Thus, 33 percent of the actual values would be expected to occur beyond the ± limits, or range, indicated by the standard error of estimate for a particular dependent variable.

In the light of the foregoing and according to conventional statistical concepts, if the ± value for the standard error of estimate of a dependent variable be multiplied by 2, this range would be expected to include 95 percent of the actual values involved. Likewise, if the ± value for the standard error of estimate for a dependent variable be multiplied by 3, this range would be expected to include 99 percent of the actual values under consideration.

Comparison of Relations with Single-Strand and Skein Yarn Strength

As reported in the previous publication of this series (17), when varying numbers and combinations of cotton-quality factors were related to count x strength product as determined by the skein test for the same 678 lots of yarn, 328 cottons, and fiber data as used in the present study, the coefficients of multiple correlation ($\bar{R}$) ranged from 0.930 to 0.917. And, the amount of variance ($\bar{R}^2$ x 100) explained in count x strength product by the factors used in the respective analyses ranged from 86.53 to 84.14 percent. Obviously, those correlation values are relatively high insofar as relationships between cotton fiber properties and yarn strength are concerned.

But, when varying numbers and combinations of cotton-quality factors for the same series of yarns and cottons were related to count x strength product as determined by the single-strand test, as summarized in table 4 of this report, the coefficients of multiple correlation ($\bar{R}$) ranged from 0.873 to 0.830. And, the amount of variance ($\bar{R}^2$ x 100) explained in single-strand count x strength product by the factors used in the respective analyses ranged from 76.17 to 68.91 percent.

Thus, the degree of relationship existing between the cotton-quality factors and count x strength product as determined by the single-strand test was somewhat less than that occurring between the corresponding factors and count x strength product as determined by the skein method. With single-strand count x strength product, for example, the $\bar{R}$ values were 0.057 to 0.087 smaller than the $\bar{R}$ values with skein count x strength product. Or, expressed in another manner, the factors used in each analysis explained 10 to 15 percent less variance in single-strand count x strength product than in skein count x strength product.

The explanation for the differences in degree of evaluated relationships obtained for corresponding factors of cotton quality with count x strength product as determined by the skein method and with count x strength product as determined by the single-strand method apparently lies in disparities of nature and representativeness possessed by the two radically different measures of yarn strength. The skein yarn strength test, as here used, involved a yarn specimen of 120 yards in length (80 turns @ 1-1/2 yards) or a total of 160 strands carefully distributed on the opposite spools of the testing instrument, and the strands were simultaneously subjected to increasing tension until the bulk of the yarn strands broke through rupture. In a sense, therefore, a value of skein yarn strength (expressed in pounds) represents a sort of multifarious averaging between the 160-strand specimen and constitutes a more or less aggregate of the several weakest placed within the 120-yard sample of yarn.

The single-strand yarn strength test used in this instance, by contrast, involved a yarn specimen of only 20 inches in length, each strand of yarn was subjected to regulated and increasing tension, and each strand of yarn was broken individually by the tester. A value of single-strand yarn strength (expressed in grams), therefore, constitutes the minimum strength or approximate weakest place within an individual strand of yarn representing a 20-inch length interval. Thus, the very nature and representativeness of the two yarn-strength tests and of the alternative yarn-strength measures are radically different in a number of particulars. Moreover, the respective values of skein yarn strength and single-strand yarn strength, representing a series of cottons, differ appreciably in relative level, variability, and range.

A comparison of the statistical values, representing the data identified with skein count x strength product and with single-strand count x strength product, for the 678 lots of carded yarn (8s, 14s, 22s, and 50s) and 328 cottons used in this study, is shown in the following tabulation:

Statistical item	Yarn strength values identified with--	
	Skein test (lbs.) 1/	Single-strand test (grams)
	csp	csp
Observations	678.	678.
Mean	2,272.85	8,442.15
Standard deviation	± 353.69	± 1,011.11
Maximum	3,366.	11,440.
Minimum	1,452.	5,950.
Range	1,914.	5,490

1/ Values were reported in table 3 of publication (17).

Notwithstanding the differences existing in principle, nature and representativeness between the skein and single-strand strength tests, there is a relatively high degree of positive correlation between the alternative yarn-strength measures. Using the data for single-strand count x strength product as the independent variable and those for skein count x strength product as the dependent variable, representing the 678 lots of carded yarn and 328 cottons involved in this study, the results obtained from simple correlation analysis were as follows:

Coefficient of correlation ($\bar{r}$)---------------+ 0.943
Variance explained in skein csp ($\bar{r}^2$ x 100)----88.96 percent
Standard error of estimate ($\bar{s}$)-------------± 117. csp (skein)

Comparison of Relations with Single Strand Yarn Strength and Elongation

As previously stated, when varying numbers and combinations of cotton quality factors were related to single-strand count x strength product, the coefficients of multiple correlation ($\overline{R}$) ranged from 0.873 to 0.830 and the amount of variance ($\overline{R}^2$ x 100) in single-strand count x strength product explained by the factors used in the respective analyses ranged from 76.17 to 68.91 percent.

For the same series of yarns, cottons and fiber data, when varying numbers and combinations of cotton-quality factors were related to single-strand yarn elongation, the coefficients of multiple correlation ($\overline{R}$) ranged from 0.851 to 0.722 and the amount of variance in single-strand yarn elongation explained by the factors used in the respective analyses ($\overline{R}^2$ x 100) ranged from 72.46 to 52.11 percent.

By comparison, therefore, the degree of relationship occurring between the factors and single-strand yarn elongation was somewhat less than that with single-strand count x strength product. The coefficients of multiple correlation ($\overline{R}$) were 0.022 to 0.108 smaller with single-strand yarn elongation than with single-strand count x strength product. Or expressed in another manner, the factors used in each analysis explained 3.71 to 16.80 percent less variance in single-strand yarn elongation than in single-strand count x strength product.

A relatively low degree of positive relationship was found to exist between single-strand yarn elongation and single-strand count x strength product, as evaluated by simple correlation analysis. For the 678 lots of yarn under study, the correlation values were as follows:

Coefficient of correlation ($\overline{r}$)------------------+ 0.514
Variance explained in s.s. csp ($\overline{r}^2$ x 100)--------26.40 percent
Standard error of estimate ($\overline{s}$)---------------$\pm$ 868. csp (s.s.)

In this connection, it is of interest to note that a slightly higher degree of positive relationship was observed to occur between single-strand yarn elongation and skein count x strength product for the same series of yarns than between single-strand yarn elongation and single-strand count x strength product, as revealed by the following values obtained from simple correlation analysis:

Coefficient of correlation ($\overline{r}$)------------------+ 0.575
Variance explained in skein csp ($\overline{r}^2$ x 100)-------33.02 percent
Standard error of estimate ($\overline{s}$)----------------$\pm$ 290. csp (skein)

Comparative Significance of Alternative Fiber Strength Measures to Yarn Strength and Elongation

As shown by the beta values listed in table 6, the measure of fiber strength at the 1/8" gauge was more important to single-strand count x strength product than was the measure of fiber strength at the 0 gauge. In all cases, fiber strength at the 1/8" gauge ranked first in importance of the fiber properties included in the respective analyses, being exceeded in contribution to single-strand count x strength product only by the factor of yarn size. Of the fiber properties included in the respective analyses, however, fiber strength at the 0 gauge ranked only second or third in importance to single-strand count x strength product.

In this connection, it is of interest to observe that, whenever fiber strength at the 1/8" gauge was included in the correlation analysis, upper half mean length ranked next below fiber strength in importance toward single-strand count x strength product. However, when fiber strength at the 0 gauge was included in the analysis, upper half mean length ranked next above fiber strength in importance to single-strand count x strength product.

There is an explanation for the disparity in evaluations of the relative importance of upper half mean length to single-strand count x strength product, as influenced by the use of alternative measures of fiber strength in the respective analyses, and for the associated reversal in ranks of evaluated importance of fiber length and fiber strength toward count x strength product under such parallel conditions. Those considerations in conjunction with other relationships existing among various pairs of fiber properties, however, will be discussed in a later report of this series.

Whereas the measure of fiber strength at the 1/8" gauge proved to be more important to single-strand count x strength product than did fiber strength at the 0 gauge, the reverse was true for those alternative measures in the case of single-strand yarn elongation, as shown by the beta values listed in table 7. That is, of the fiber properties included in the respective analyses, the measure of fiber strength at the 0 gauge always ranked first in importance toward single-strand yarn elongation, being exceeded only by the factor of yarn size. The measure of fiber strength at the 1/8" gauge, however, was found to rank only fourth or fifth in importance toward yarn elongation, of the fiber properties included in the respective analyses.

In the case of single-strand yarn elongation, there was no apparent disparity caused in evaluations for the relative contribution of upper half mean length by use of alternative measures of fiber strength in correlation analysis. No reversal was observed in the ranks of evaluated importance of fiber length to yarn elongation under those conditions, as was noted in connection with single-strand count x strength product.

The relative importance of length uniformity ratio to single-strand yarn elongation, however, was influenced by the use of alternative measures of fiber strength. That is, length uniformity ratio was found to rank higher in importance toward yarn elongation when fiber strength at the 1/8" gauge was included in the analysis than when fiber strength at the 0 gauge was used. Apparently, this disparity was due in substantial part to the sizable difference in evaluated importance of the alternative fiber strength measures with respect to yarn elongation.

Comparative Significance of Alternative Fiber Fineness Measures to Yarn Strength and Elongation

Micronaire values, representing fiber fineness in combination with fiber maturity, proved to be more important to single-strand count x strength product than did the Causticaire measure for fiber fineness (wt./in.) alone, as shown by the beta values listed in table 6. Of the fiber properties included in the respective analyses, the Micronaire measure ranked either third or fourth in importance to single-strand c x s product whereas Causticaire fineness ranked sixth. The effect of Micronaire fineness and maturity in combination on c x s product equalled approximately the sum of the effects of Causticaire maturity and fineness.

It is of interest to observe in this connection that Causticaire fiber maturity ranked fourth in importance to single-strand count x strength product. This finding suggests that it was the element of fiber maturity contained in the Micronaire measure which caused it to possess more importance with respect to c x s product than did the measure of Causticaire fineness.

In the present study, the Causticaire fineness and Micronaire values were not sufficiently different in trends or relationships as to cause a shift in the evaluated rank of importance of any other fiber property toward single-strand count x strength product. This finding is in contrast to that associated with the use of alternative measures of fiber strength.

Referring to the beta values listed in table 7, it will be seen that, when fiber strength at the 0 gauge was included in the respective analyses, the measure of Causticaire fiber fineness proved to be more important to single-strand yarn elongation than did the Micronaire measure of fiber fineness in combination with fiber maturity. Under that set of conditions, of the fiber properties included in the respective analyses, Causticaire fiber fineness always ranked second in importance to single-strand yarn elongation, being exceeded in each case only by fiber strength at the 0 gauge. The Micronaire measure, on the other hand, ranked third in importance toward yarn elongation in every case.

When fiber strength at the 1/8" gauge was used in the respective analyses, however, the relative importance of the Causticaire fineness and Micronaire measures to single-strand yarn elongation was approximately equal. In the parallel cases, the Causticaire fineness and Micronaire measures each ranked first in importance toward yarn elongation, being exceeded only by the factor of yarn size.

In the present analyses, the Causticaire fineness and Micronaire values were not sufficiently different in trends or relationships as to cause a shift in the evaluated rank of importance of any other fiber property toward single-strand yarn elongation.

Direction of Factorial Contributions to Yarn Strength and Elongation

In connection with the evaluated relations and equations reported herein, the direction of the contribution of yarn size and of the various measures of raw-cotton quality to single-strand yarn strength and to yarn elongation are of interest. The signs attached to the beta coefficients for the respective independent variables, indicating the direction of their contributions to each of the two dependent variables, are shown in the following tabulation:

Factors	Direction of Contribution to S.S. Yarn	
	Strength	Elongation
Yarn size	-	-
Fiber strength, 1/8" gauge	+	-
Fiber strength, 0 gauge	+	-
U.H.M. length	+	+
L. uniformity ratio	+	+
Micronaire fineness in combination with maturity	-	-
Causticaire fineness	-	-
Causticaire maturity	-	-
Grade index	+	+

From the signs listed in the foregoing, it will be noted that, with respect to the factors of raw-cotton quality considered, the stronger the fibers (at the 1/8" gauge or the 0 gauge), the longer the fibers, the greater the length uniformity, the finer the fibers (as measured by either the Micronaire or the Causticaire method), the less the Causticaire maturity, and the higher the grade index,--the stronger was the resulting yarn. Naturally, of course, the larger the yarn size or the smaller the yarn number, the greater was the yarn strength.

The direction of the contribution of the respective cotton-quality measures and yarn size to yarn elongation was the same as that for yarn strength, except for one fiber property. That is, the stronger the fibers (at the 1/8" gauge or the 0 gauge) the less was the yarn elongation, whereas the stronger the fibers the greater was the yarn strength.

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APPENDIX

Table 1.--Conversion chart for obtaining the grade index value of raw cotton from its grade designation by classification

Grade designation	Grade index values for-- White and Extra White	Spotted	Tinged	Yellow Stained	Gray
SGM	106	--	--	--	--
GM	105	101	94	86	93
SM	104	99	91	81	91
M	100	93	82	73	84
SLM	94	83	75	--	75
LM	85	75	68	--	--
SGO	76	--	--	--	--
GO	70	--	--	--	--
Below Grade	60	--	--	--	--

Table 2.--Conversion chart for obtaining the index value of fiber strength at the 1/8" gauge from its Pressley strength-weight ratio 1/

Strength - wt. ratio	Index Value	Index Description	Strength - wt. ratio	Index Value	Index Description
3.96	124	Very strong	3.00	94	Fair
3.89	122	do	2.93	92	do
3.83	120	do	2.87	90	do
3.76	118	do	2.81	88	do
3.70	116	do	2.74	86	do
3.64	114	Strong	2.68	84	Weak
3.57	112	do	2.62	82	do
3.51	110	do	2.55	80	do
3.45	108	do	2.49	78	do
3.38	106	do	2.42	76	do
3.32	104	Average	--	--	--
3.25	102	do	--	--	--
3.19	100	do	--	--	--
3.13	98	do	--	--	--
3.06	96	do	--	--	--

1/ Intervening index values may be obtained by interpolation and those beyond the extremes, by extrapolation. The basis and method for calculating individual index values are described in the text (pages 5 and 6).

Table 3.--Comparison of statistical values, representing data identified with the factors of cotton quality used in multiple correlation analyses with single-strand count x strength product and elongation, for cottons from selected cotton improvement groups, crop year 1954

Factors used in analysis, as --	Value for --					
	Observations 1/	Mean	Standard deviation	Maximum	Minimum	Range
	Number					
Independent variables 2/:						
Grade of cotton..................index	328	98.98	± 4.27	105.	84.	21.
Upper half mean length...........inch	328	1.042	± .07	1.24	.79	.45
Length uniformity ratio.........index	328	79.96	± 1.14	85.	76.	9.
Causticaire fineness........microgram	328	4.17	± .44	5.5	2.7	2.8
Micronaire fineness...........reading	328	4.25	± .43	5.4	2.7	2.7
Fiber strength, 1/8" gauge......index	328	100.11	± 7.45	120.0	82.0	38.0
Fiber strength, 0 gauge..1,000 lb. psi	328	83.76	± 4.79	97.0	66.0	31.0
Causticaire fiber maturity......index	328	78.79	± 2.98	85.0	61.0	24.0
Yarn size.......................number	678	33.85	± 14.83	50.0	8.0	42.0
Dependent variables:						
Single-strand c x s product........csp	678	8,442.15	±1,011.11	11,440.	5,950.	5,490.
S. S. yarn elongation.........percent	678	6.34	± .80	10.0	4.5	5.5

1/ Number of observations used in each correlation analysis.
2/ Including alternative measures of fiber fineness (Causticaire and Micronaire) and of fiber strength (1/8" and 0 gauge).

Table 4--Summary of regression equations showing the relation of varying numbers and combinations of cotton-quality measures to single-strand count x strength product of a wide range of yarn sizes, as based on multiple linear correlation analyses, representing 328 American upland cottons and 678 lots of carded yarn from selected cotton improvement groups, crop year 1954

Equation 1/	Dependent variable	Factors used in analysis 2/	Estimate	Regression equations involving-- Coefficients for independent variables of-- X_{41} Yarn size, number	X_{88} Grade of cotton, index	X_{17} U. H. M. length, inches	X_{19} L. unif. ratio, index	X_{134} Causticaire fineness, micrograms	X_{104} Micronaire fineness, reading	X_{135} Causticaire maturity, index	X_{173} F. strength, 1/8" gauge, index	X_{33} F. strength, 0 gauge, 1,000 lbs.psi.	Constant	Statistical values ($\bar{R}$) Coef. of correlation	($\bar{R}^2$ x 100) Variance explained 3/	($\bar{S}$) Standard error of estimate: Absolute	($\bar{S}$) Standard error of estimate: Relative
		Number													Percent	Csp units	Percent 4/
(1)	c x s product---	7	X'_{177} =	-51.27	+34.81	+3,870.76	+12.96	-4.79	---	-32.85	+47.68	---	- 471.26	0.873	76.17	±494.	±5.8
(2)	do-------	5	X'_{177} =	-51.42	+36.57	+3,349.28	---	---	-246.74	---	+48.32	---	- 681.90	.873	76.17	±494.	±5.8
(3)	do-------	4	X'_{177} =	-51.42	+32.79	+4,068.43	---	---	---	---	+46.65	---	-1,940.34	.868	75.27	±503.	±6.0
(4)	do-------	4	X'_{177} =	-51.64	---	+2,866.13	---	---	-191.63	---	+57.07	---	+2,338.12	.861	74.17	±514.	±6.1
(5)	do-------	7	X'_{177} =	-51.24	+45.48	+6,741.76	+54.64	-88.34	---	-37.16	---	+45.94	-6,238.85	.861	74.08	±515.	±6.1
(6)	do-------	5	X'_{177} =	-51.43	+49.18	+6,464.66	---	---	-311.10	---	---	+43.97	-3,748.44	.858	73.70	±519.	±6.2
(7)	do-------	3	X'_{177} =	-51.62	---	+3,477.48	---	---	---	---	+55.02	---	+1,089.94	.858	73.63	±520.	±6.2
(8)	do-------	4	X'_{177} =	-51.38	+44.98	+7,237.23	---	---	---	---	---	+37.69	-4,936.39	.850	72.28	±533.	±6.3
(9)	do-------	4	X'_{177} =	-51.70	---	+6,618.24	---	---	-236.53	---	---	+51.54	+ 18.62	.835	69.71	±557.	±6.6
(10)	do-------	3	X'_{177} =	-51.65	---	+7,207.72	---	---	---	---	---	+46.16	-1,153.40	.830	68.91	±564.	±6.7

1/ Identification of equations, as listed in descending order of percentage of variance in single-strand count x strength product explained by the collective factors used in each correlation analysis.

2/ Including alternative measures of fiber fineness (Caueticaire and Micronaire) and of fiber strength (1/8" and 0 gauge).

3/ Amount of variance in single-strand count x strength product explained by the collective factors used in each correlation analysis.

4/ Absolute standard error of estimate ($\bar{S}$) divided by the mean value of the dependent variable, multiplied by 100.

Table 5.--Summary of regression equations showing the relation of varying numbers and combinations of cotton-quality measures to single-strand yarn elongation of a wide range of yarn sizes, as based on multiple linear correlation analyses, representing 328 American upland cottons and 678 lots of carded yarn from selected cotton improvement groups, crop year 1954

Equation 1/	Dependent variable	Factors used in analysis 2/	Estimate	X_{41} Yarn size, number	X_{88} Grade of cotton, index	X_{17} U. H. M. length, inches	X_{19} L. unif. ratio, index	X_{134} Causticaire fineness, micrograms	X_{104} Micronaire fineness, reading	X_{135} Causticaire maturity, index	X_{173} F. strength, 1/8" gauge, index	X_{33} F. strength, 0 gauge, 1,000 lbs.psi.	Constant	($\bar{R}$) Coef. of correlation	($\bar{R}^2$ x 100) Variance explained 3/	($\bar{S}$) Standard error of estimate: Absolute	($\bar{S}$) Standard error of estimate: Relative
Number		Number													Percent	Pct. units	Percent 4/
(11)	Elongation----	7	X'_{178} =	-0.036	+0.023	+1.427	+0.056	-0.279	---	-0.017	---	-0.077	+ 8.319	0.851	72.46	±0.42	±6.6
(12)	do--------	5	X'_{178} =	- .036	+ .026	+1.336	---	- .341	---	---	---	- .080	+11.722	.847	71.67	± .43	±6.7
(13)	do--------	5	X'_{178} =	- .036	+ .025	+1.802	---	---	-0.293	---	---	- .081	+11.279	.845	71.33	± .43	±6.8
(14)	do--------	4	X'_{178} =	- .036	---	+1.497	---	- .291	---	---	---	- .076	+13.597	.836	69.98	± .44	±6.9
(15)	do--------	4	X'_{178} =	- .036	---	+1.879	---	---	- .256	---	---	- .077	+13.162	.835	69.78	± .44	±7.0
(16)	do--------	7	X'_{178} =	- .036	+ .012	+1.351	+ .099	- .478	---	- .028	-0.012	---	+ 2.398	.736	54.24	± .54	±8.6
(17)	do--------	6	X'_{178} =	- .037	---	+1.229	+ .105	- .454	---	- .028	- .009	---	+ 2.954	.734	53.94	± .54	±8.6
(18)	do--------	5	X'_{178} =	- .037	---	+1.683	+ .101	---	- .511	---	- .010	---	+ .975	.722	52.11	± .55	±8.7

1/ Identification of equations, as listed in descending order of percentage of variance in single-strand elongation explained by the collective factors used in each correlation analysis.

2/ Including alternative measures of fiber fineness (Causticaire and Micronaire) and of fiber strength (0 and 1/8" gauge).

3/ Amount of variance in single-strand elongation explained by the collective factors used in each correlation analysis.

4/ Absolute standard error ($\bar{S}$) divided by the mean value of the dependent variable, multiplied by 100.

Table 6--Summary of beta coefficients showing the relative importance of the respective cotton-quality measures to single-strand count x strength product, when varying numbers and combinations of factors were used in the correlation analysis, representing American upland cottons from selected cotton improvement groups, crop year 1954

Equation 1/	Lots of cotton	Lots of yarn	Observations 2/	Independent variables 3/: Total	Independent variables 3/: Identification	Relative importance: Rank	Relative importance: Beta coefficient 4/
Number	Number	Number	Number	Number			
(1)	328	678	678	7	Yarn size	1	-0.752 ± 0.019
					Fiber strength, 1/8" gauge	2	+ .358 ± .027
					Upper half mean length	3	+ .279 ± .031
					Grade index	4	+ .146 ± .020
					Causticaire fiber maturity	5	- .100 ± .024
					Length uniformity ratio	6	+ .015* ± .019
					Causticaire wt./in.	7	- .002* ± .029
(2)	328	678	678	5	Yarn size	1	- .754 ± .019
					Fiber strength, 1/8" gauge	2	+ .363 ± .027
					Upper half mean length	3	+ .241 ± .028
					Grade index	4	+ .153 ± .020
					Micronaire reading	5	- .108 ± .021
(3)	328	678	678	4	Yarn size	1	- .754 ± .020
					Fiber strength, 1/8" gauge	2	+ .351 ± .027
					Upper half mean length	3	+ .293 ± .027
					Grade index	4	+ .137 ± .020
(4)	328	678	678	4	Yarn size	1	- .757 ± .020
					Fiber strength, 1/8" gauge	2	+ .429 ± .026
					Upper half mean length	3	+ .206 ± .029
					Micronaire reading	4	- .084 ± .022
(5)	328	678	678	7	Yarn size	1	- .751 ± .020
					Upper half mean length	2	+ .486 ± .026
					Fiber strength, 0 gauge	3	+ .218 ± .021
					Grade index	4	+ .190 ± .021
					Causticaire fiber maturity	5	- .113 ± .025
					Length uniformity ratio	6	+ .061 ± .020
					Causticaire wt./in.	7	- .040* ± .031
(6)	328	678	678	5	Yarn size	1	- .754 ± .020
					Upper half mean length	2	+ .466 ± .022
					Fiber strength, 0 gauge	3	+ .208 ± .021
					Grade index	4	+ .206 ± .020
					Micronaire reading	5	- .136 ± .023
(7)	328	678	678	3	Yarn size	1	- .757 ± .020
					Fiber strength, 1/8" gauge	2	+ .414 ± .027
					Upper half mean length	3	+ .251 ± .027
(8)	328	678	678	4	Yarn size	1	- .753 ± .020
					Upper half mean length	2	+ .521 ± .021
					Grade index	3	+ .188 ± .021
					Fiber strength, 0 gauge	4	+ .179 ± .021
(9)	328	678	678	4	Yarn size	1	- .758 ± .022
					Upper half mean length	2	+ .477 ± .024
					Fiber strength, 0 gauge	3	+ .244 ± .022
					Micronaire reading	4	- .104 ± .024
(10)	328	678	678	3	Yarn size	1	- .757 ± .021
					Upper half mean length	2	+ .519 ± .021
					Fiber strength, 0 gauge	3	+ .219 ± .021

1/ Equation identification, as shown in table 4.
2/ Number of observations used in each correlation analysis.
3/ Including alternative measures of fiber fineness (Causticaire and Micronaire) and of fiber strength (1/8" and 0 gauge).
4/ The sign indicates the direction of the contribution of the independent variable to single-strand count x strength product.
* Statistically insignificant, being less than 3 times its standard error.

Table 7.--Summary of beta coefficients showing the relative importance of the respective cotton-quality measures to single-strand yarn elongation, when varying numbers and combinations of factors were used in the correlation analysis, representing American upland cottons from selected cotton improvement groups, crop year 1954

Equation 1/	Lots of cotton	Lots of yarn	Observations 2/	Independent variables 3/: Total	Independent variables 3/: Identification	Relative importance: Rank	Relative importance: Beta coefficients 4/
Number	Number	Number	Number	Number			
(11)	328	678	678	7	Yarn size	1	-0.665 ± 0.021
					Fiber strength, 0 gauge	2	- .463 ± .022
					Causticaire wt./in.	3	- .159 ± .032
					Upper half mean length	4	+ .130 ± .027
					Grade index	5	+ .120 ± .021
					Length uniformity ratio	6	+ .080 ± .021
					Causticaire fiber maturity	7	- .066* ± .026
(12)	328	678	678	5	Yarn size	1	- .666 ± .021
					Fiber strength, 0 gauge	2	- .477 ± .022
					Causticaire wt./in.	3	- .195 ± .026
					Grade index	4	+ .136 ± .021
					Upper half mean length	5	+ .122 ± .026
(13)	328	678	678	5	Yarn size	1	- .668 ± .021
					Fiber strength, 0 gauge	2	- .484 ± .022
					Upper half mean length	3	+ .164 ± .023
					Micronaire reading	4	- .162 ± .024
					Grade index	5	+ .130 ± .021
(14)	328	678	678	4	Yarn size	1	- .669 ± .022
					Fiber strength, 0 gauge	2	- .455 ± .022
					Causticaire wt./in.	3	- .166 ± .026
					Upper half mean length	4	+ .136 ± .026
(15)	328	678	678	4	Yarn size	1	- .670 ± .022
					Fiber strength, 0 gauge	2	- .461 ± .022
					Upper half mean length	3	+ .171 ± .024
					Micronaire reading	4	- .142 ± .024
(16)	328	678	678	7	Yarn size	1	- .675 ± .027
					Causticaire wt./in.	2	- .273 ± .040
					Length uniformity ratio	3	+ .140 ± .027
					Upper half mean length	4	+ .123* ± .043
					Fiber strength, 1/8" gauge	5	- .115 ± .037
					Causticaire fiber maturity	6	- .106 ± .033
					Grade index	7	+ .066* ± .028
(17)	328	678	678	6	Yarn size	1	- .676 ± .027
					Causticaire wt./in.	2	- .259 ± .040
					Length uniformity ratio	3	+ .148 ± .027
					Upper half mean length	4	+ .112* ± .043
					Causticaire fiber maturity	5	- .108 ± .033
					Fiber strength, 1/8" gauge	6	- .089* ± .036
(18)	328	678	678	5	Yarn size	1	- .680 ± .027
					Micronaire reading	2	- .283 ± .030
					Upper half mean length	3	+ .153 ± .039
					Length uniformity ratio	4	+ .142 ± .027
					Fiber strength, 1/8" gauge	5	- .095* ± .036

1/ Equation identification, as shown in table 6.
2/ Number of observations used in each correlation analysis.
3/ Including alternative measures of fiber fineness (Causticaire and Micronaire) and of fiber strength (0 and 1/8" gauge).
4/ The sign indicates the direction of the contribution of the independent variable to single-strand yarn elongation.
* Statistically insignificant, being less than 3 times its standard error.

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