# Equations for Predicting Cotton Processing Performance and Product Quality by Improved Evaluations of Raw-Cotton Quality



By

**Robert W. Webb**

**Cotton Technologist**

**UNITED STATES DEPARTMENT OF AGRICULTURE**

**Agricultural Marketing Service**

**Washington, D. C., April 1956**

**Marketing Research Report No. 114**

CONTENTS



ooOoo

ACKNOWLEDGMENTS

The study reported in this publication was planned and conducted under the administrative direction of John W. Wright, Chief, Standards and Testing Branch, Cotton Division, AMS. Appreciation is expressed to staff members of the Branch's fiber and spinning laboratories at Clemson, S. C., and College Station, Tex., and of its fiber laboratory at Washington, D. C. for making the tests and providing the basic data. Appreciation also is expressed to Gordon L. Austin and associates in the Branch's Statistical Unit for making the correlation analyses, and to Mrs. Miriam M. Hallock for assistance in preparing the statistical tables and text.

For sale by the Superintendent of Documents, U. S. Government Printing Office
Washington 25, D. C. - Price 25 cents

## SUMMARY AND CONCLUSIONS

The equations and related information presented in this report are helpful to the cotton trade and textile industry in choosing cottons best suited to the manufacture of specific products, in selecting various blends of cotton for processing, and for meeting different levels of product quality. Such equations and knowledge, moreover, give assistance to cotton breeders by informing them of the fiber properties they should consider important in their programs.

This report presents a number of new equations for predicting the strength and appearance of any size of carded yarn over a wide range, number of neps per 100 sq. in. of card web, and percentage of total picker and card waste on the basis of improved methods for evaluating raw-cotton quality. Predicting equations including only the several most important factors to each of those dependent variables, however, are recommended. These equations are adapted to the general run of American upland cottons in current commercial production.

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

An illustration of the calculations necessary for predicting the strength of any size of yarn is shown by application of one equation. For the same accuracy of sampling, fiber measurements and yarn tests, however, the level of prediction values derived by use of the equations here reported may be expected to vary somewhat from the actual values obtained with different processing organizations and yarn constructions.

But, after several trial determinations, if prediction values obtained by use of one of the equations differ more or less consistently from actual values, the future prediction values can be adjusted to the combined level of fiber tests, textile processing, yarn structure and yarn twist involved, by increasing or decreasing them by whatever percentage that is found to be necessary. This procedure gives needed flexibility to the application of such prediction equations and, in turn, enables the prediction values so obtained to possess more practical meaning and significance--under diverse processing and testing conditions--than otherwise would be possible.

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, crop year of 1954. A total of 678 lots of singles yarn, ranging in size from 8s to 50s, was used in the analyses. All yarns were of a warp type of construction and possessed a semihard twist. The principal varieties of cotton grown in current commercial production were included in this study. All cottons were grown, harvested, and ginned under commercial conditions identified with their respective growth areas. Three lots of cotton representing early, midseason, and late-season samples were obtained from each growth locality, except in a few instances.

The coefficients of correlation obtained by use of various cotton-quality factors with count-strength product range from 0.930 to 0.910; those with yarn appearance from 0.750 to 0.738; those with percentage of picker and card waste, from 0.625 to 0.576; and those with number of neps per 100 sq. in. of card web, from 0.612 to 0.471.

The factors included in the analyses explain 86-84 percent of the variance in count-strength product; 56-54 percent of the variance in yarn appearance; 39-33 percent of the variance in percentage of picker and card waste; and 37-22 percent of the variance in number of neps per 100 sq. in. of card web.

The 3 principal fiber properties contributing to yarn strength listed in descending order of importance, are fiber strength at 1/8" gauge or upper half mean length, and fiber fineness (wt./in.). The 2 most important factors influencing yarn appearance are yarn size and fiber fineness. Grade index is, by far, the most important factor affecting percentage of picker and card waste. Causticaire fiber maturity ranks first in importance to nep count of card web.

Fiber strength at the 1/8" gauge spacing is more important to yarn strength than is fiber strength at the 0 gauge spacing. Micronaire fiber fineness is slightly more important to yarn strength, yarn appearance, nep count of card web, and percentage of picker and card waste than is Causticaire fiber fineness. In this connection, however, it should be remembered that Micronaire fiber fineness includes an element of fiber maturity, whereas Causticaire fiber fineness does not.

Such variations in results, as reported in this paper, emphasize the appreciable degree of interrelationships that exist between various cotton fiber properties, as well as between certain laboratory measures in current use for evaluating them. These results, moreover, demonstrate how evaluations of such relationships between cotton fiber properties and yarn strength, as well as other dependent variables, may be influenced by the number and combination of factors used in the respective analyses. These results further demonstrate how the evaluated relations for a given cotton fiber property with respect to cotton processing, yarn strength, or some other quality element of products processed from cotton may vary, depending upon which alternative measures are used for the fiber properties included in the analysis.

In a sense, therefore, the condition of interrelationships which always is prevalent among cotton fiber properties constitutes the very heart of the cotton-quality problem and offers one of the basic opportunities for future improvement in cotton-fiber-spinning quality. It is that condition of fiber-property interrelationships, however, which makes so difficult any attempt to evaluate, precisely and in a comprehensive manner, the relative importance of individual cotton fiber properties--or measures of them--to processing performance and quality of product.

# EQUATIONS FOR PREDICTING COTTON PROCESSING PERFORMANCE AND PRODUCT QUALITY BY IMPROVED EVALUATIONS OF RAW-COTTON QUALITY

By Robert W. Webb, Cotton Technologist,
Cotton Division, Agricultural Marketing Service

## INTRODUCTION

Equations for predicting processing performance and product quality on the basis of measurable fiber properties and other factors of quality, representing 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, 20 reports (7 through 26) 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 (6).

In report (8), two new count-strength-product equations were presented for predicting skein strength of carded warp singles yarn of any size over a wide range with special reference to current commercial production of American cotton. Those new equations are better adapted for predicting strength of yarn processed from American upland cottons in current commercial production, representing early-season, midseason, and late-season cottons, than are similar count-strength-product equations published previously by the Cotton Division of the U. S. Department of Agriculture.

The improved equations recently published for predicting yarn strength included fiber strength, as determined by the Pressley tester at the zero gauge spacing; fiber fineness, as determined by the Micronaire method; and percentage of mature fibers, as determined by the long-established standard method. None of the predicting equations heretofore published in this series of reports has included the new and improved measure of fiber strength, as determined by the Pressley tester at the 1/8-inch gauge spacing, and of fiber fineness and maturity, as evaluated by the Causticaire method in conjunction with the Micronaire instrument.

In the light of the foregoing and because of increasing interest being shown on the part of many cotton technologists to use those new

---

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

alternative fiber measures, it was considered timely to conduct a series of multiple correlation analyses with them, among others, on a large block of cotton fiber and spinning data representing current commercial production of American cotton. It also was considered desirable to provide to the public as soon as possible a set of predicting equations which would include those new and improved fiber measures.

This report presents the new equations developed from this study for predicting the strength and appearance of any size of carded yarn, number of neps per 100 sq. in. of card web, and percentage of total picker and card waste on the basis of varying numbers and combinations of cotton fiber properties. Predicting equations involving only the several most important factors to each of those dependent variables are recommended, and pertinent statistical values revealing the degree of relationship occurring between the various factors, are shown for every case.

## SAMPLES, TESTS AND DATA

The fiber, spinning, and yarn-strength 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 were made in the Washington fiber laboratory.

The fiber, processing, and product-quality data which served as the basis of this study are contained in publication (5).

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, for 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 were represented by early-season, midseason, and late-season samples, except in 5 cases as noted below.

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. That is, 5 samples were missing from 3 of the localities.

The nature and scope of the cottons included in the analyses reported herein 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 | Lots of cotton Percent |
|---|---|---|
| Deltapine 15 | 107 | 32.6 |
| Coker 100 W | 58 | 17.8 |
| Acala 1517C | 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 |

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, 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" (3).

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

Processing. Details as to 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 (5). Report (4) describes the service testing of cotton by 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 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 compensate for the influence of other fiber properties involved but represented an empirical selection.

Fiber properties. Six elements of raw-cotton quality were used as independent variables in 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, in micrograms per inch, as evaluated by the Micronaire method.

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 2/, 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.

Grade index was used in this study, as explained in the report of this series having to do with the strength of 22s yarn, regular draft (17). 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. 3/

The fiber tests relating to the data used in these analyses were those described in the publications entitled "Cotton Testing Service" (4), "ASTM Standards on Textile Materials" (1), and "Summary of Fiber and

---

2/ 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 zero (0) gauge spacing.

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

Spinning Test Results for Some Varieties of Cotton Grown by Selected Cotton Improvement Groups, Crop of 1954" (5). A more detailed description of the improved Causticaire method for evaluating cotton fiber fineness and maturity, in conjunction with the Micronaire instrument, is contained in report (10).

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 and appearance 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 those 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 |

Yarn strength. Conventional skein-strength tests of all yarns were made according to the generally adopted procedure described in ASTM Standards on Textile Materials (1) and referred to in Cotton Testing Service (4), and expressed in terms of pounds.

Values for count-strength product were obtained by multiplying the indivual yarn strengths by their respective yarn numbers, and expressing the results in terms of count-strength-product units.

All yarn-strength tests were made under the same controlled atmospheric conditions, as specified by ASTM for fiber and yarn testing.

Yarn appearance. The standards and procedure used in evaluating yarn appearance are those described in Cotton Testing Service (4) and by ASTM (1). Index values and adjective ratings for grades of yarn appearance are shown in table 2.

Neps in card web. The card webs used as a basis of the data used in this study were those obtained in the Cotton Division's spinning laboratories during the processing of the respective cottons into carded yarns. Details as to the procedure for determining the number of neps per 100 sq. in. of card web may be had by reference to Cotton Testing Service (4) and ASTM (1).

Picker and card waste. The values of total picker and card waste used in this study represent the sum of the weights of all kinds of waste removed by the picker and card machines, expressed as a percentage of the weight of raw stock fed to the picker or opening machines. The methods used in the Cotton Division's spinning laboratories for processing such cottons and for making such evaluations are described in Cotton Testing Service (4) and in the summary report (5) covering the fiber and spinning data used in this study.

## STATISTICAL ANALYSES

This report covers results obtained from a total of 28 correlation analyses, representing a total of 328 cottons, 328 lots of picker and card waste, 328 lots of card web, and 678 lots of yarn, ranging in size from 8s to 50s, crop year 1954. Included in this study were 24 multiple correlation analyses and 4 simple correlation analyses.

Seven correlation analyses were made with count-strength product, using varying numbers and combinations of cotton fiber properties and including the alternative Causticaire and Micronaire measures for fiber fineness (wt./in.), as well as Pressley fiber strength at the 1/8" and 0 gauge spacings. Similar sets of correlation analyses were made with the following: Yarn appearance, 10; number of neps per 100 sq. in. of card web, 6; and percentage of picker and card waste, 5.

The nature and scope of the data which served as the basis of these correlation analyses are indicated by the values shown in table 3.

The same general pattern of statistical analyses was followed in this study as that followed 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 (11), (13).

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 (17).

All statistical values reported herein are so-called corrected ones, as obtained from multiple linear correlation analyses, except in four cases which involved simple correlation analyses. No curvilinear correlation analyses were made in this instance because of the general ranges of cotton quality factors involved in this study and because previous curvilinear analyses in this series of studies have not given any appreciably better results with such dependent variables than did linear correlation analyses.

## EVALUATION OF THE RELATIONS OF THE FACTORS INCLUDED IN THE VARIOUS EQUATIONS

### With Count-Strength Product

Six multiple correlation analyses were made with count-strength product as the dependent variable, using varying numbers and combinations of cotton fiber properties with fiber strength at the 1/8" gauge spacing and including the alternative Causticaire and Micronaire measures for cotton fiber fineness (wt./in.). The 6 regression equations and corresponding statistical values, as obtained from those correlation analyses, are summarized in the upper part of table 4.

Causticaire fiber fineness included. Using 7 independent variables (yarn size, upper half mean length, fiber strength 1/8" gauge spacing between the jaws of the testing instrument, grade index, Causticaire fiber maturity, Causticaire fineness, and length uniformity ratio), the statistical values obtained from the correlation analysis with count-strength product were as follows:

Coefficient of correlation ($\bar{R}$) ----------------0.930
Variance explained in csp ($\bar{R}^2$ x 100) ---------86 percent
Standard error of estimate ($\bar{S}$), absolute ---±130 csp units
Standard error of estimate ($\bar{S}$), relative -----±5.7 percent

On the basis of the beta values obtained from the analysis referred to above, the four most important factors with respect to count-strength product were found to rank in descending order, as follows: Yarn size, upper half mean length, fiber strength at the 1/8" gauge, and grade index. Thus, in this instance, Causticaire fiber maturity, Causticaire fiber fineness, and length uniformity ratio influenced the variance in count-strength product only to a minor or negligible degree.

Using the 4 most important factors (yarn size, upper half mean length, fiber strength at the 1/8" gauge, and grade index) the correlation values obtained with count-strength product were almost as good as those shown previously with all 7 factors. The findings in this case were, as follows:

Coefficient of correlation ($\bar{R}$) ----------------0.924
Variance explained in csp ($\bar{R}^2$ x 100) ---------85 percent
Standard error of estimate ($\bar{S}$), absolute ---±136 csp units
Standard error of estimate ($\bar{S}$), relative -----±6.0 percent

Omitting the grade factor and including only the 3 most important independent variables (yarn size, fiber strength at 1/8" gauge, and upper half mean length), the correlation values obtained with count-strength product were nearly as good as those shown previously with all 7 factors. The findings from this analysis were, as follows:

Coefficient of correlation ($\bar{R}$) -----------------0.917
Variance explained in csp ($\bar{R}^2$ x 100) ----------84 percent
Standard error of estimate ($\bar{S}$), absolute ----±141 csp units
Standard error of estimate ($\bar{S}$), relative ------±6.2 percent

Micronaire fiber fineness included. Using 6 independent variables (listed in descending order of importance to count-strength product: Yarn size, fiber strength at 1/8" gauge, upper half mean length, grade index, Micronaire fineness and maturity in combination (wt./in.), and length uniformity ratio), the statistical values obtained from correlation analyses with count-strength product were, as follows:

Coefficient of correlation ($\bar{R}$) -----------------0.930
Variance explained in csp ($\bar{R}^2$ x 100) ----------86 percent
Standard error of estimate ($\bar{S}$), absolute ----±130 csp units
Standard error of estimate ($\bar{S}$), relative ------±5.7 percent

Omitting length uniformity ratio and including the first five factors listed above, the correlation values with count-strength product were the same as the foregoing.

Using four factors (yarn size, fiber strength at 1/8" gauge, upper half mean length, and Micronaire fineness and maturity in combination (wt./in.), the results obtained from the correlation analysis with count-strength product are nearly as good as those obtained with all six factors, as shown by the following:

Coefficient of correlation ($\bar{R}$)-----------------0.922
Variance explained in csp ($\bar{R}^2$ x 100) ---------85 percent
Standard error of estimate ($\bar{S}$), absolute ---±137 csp units
Standard error of estimate ($\bar{S}$), relative -----±6.0 percent

The beta coefficients showing the relative importance of the respective independent variables to count-strength product, when varying numbers and combinations of cotton-quality measures were used in the respective correlation analyses, are summarized in table 5.

In all of the foregoing analyses, the measure of fiber strength (Pressley) determined with the 1/8" gauge spacing between the jaws of the tester was included. However, because most previous studies in this series have included fiber strength (Pressley) evaluated at the 0 gauge spacing, and because this method of test and expression are used today in many laboratories of this country and abroad, a supplemental analysis has been made which included that factor among others.

Using four factors (yarn size, fiber strength at 0 gauge, upper half mean length, and Micronaire fineness and maturity in combination (wt./in.), the results obtained from the correlation analysis with count-strength product were, as follows:

Coefficient of correlation ($\bar{R}$) ----------------0.893
Variance explained in csp ($\bar{R}^2$ x 100) ----------80 percent
Standard error of estimate ($\bar{S}$), absolute ----±160 csp units
Standard error of estimate ($\bar{S}$), relative ------±7.0 percent

As the values for the beta coefficients obtained from this supplementary analysis are not included in table 5, they are listed in the tabulation below, for comparative purposes, as follows:

| Factors | Relative importance to csp: Rank | Relative importance to csp: Beta coefficients |
|---|---|---|
| Yarn size | (1) | -0.816 ± 0.018 |
| Upper half mean length | (2) | + .540 ± .020 |
| Fiber strength, 0 gauge | (3) | + .182 ± .018 |
| Micronaire (wt./in.) | (4) | - .107 ± .020 |

It is of interest to note from the above that upper half mean length ranks second in importance to count-strength product and that fiber strength determined by the 0 gauge spacing is the third factor of importance. When fiber strength at the 1/8" gauge was substituted for fiber strength at the 0 gauge, however, the analysis with the same group of factors shows a reversal in ranks of importance for fiber strength and upper half mean length toward count-strength product, as shown in the fifth grouping of table 5. Further consideration of this subject is given in the latter part of the Discussion section of this report.

It also is of interest to note from the results obtained in this and previous studies that Micronaire fiber fineness and maturity in combination (wt./in.) generally shows slightly more importance to yarn strength or count-strength product than does Causticaire fineness (wt./in.). The disparity, it may be pointed out, arises by virtue of the fact that the measure of Micronaire fiber fineness also includes an element of fiber maturity whereas the measure of Causticaire fiber fineness does not.

With Yarn Appearance

Ten multiple correlation analyses were made with yarn appearance as the dependent variable, using varying numbers and combinations of cotton fiber properties and including the alternative Causticaire and Micronaire measures for cotton fiber fineness (wt./in.). The 10 regression equations and associated statistical values, as derived from those correlation analyses, are summarized in the lower part of table 4.

In spite of the fact that the number of independent variables used in the respective analyses varied from a total of 7 to 2, that the alternative Causticaire and Micronaire measures of cotton fineness (wt./in.) were included, and that different combinations of fiber properties were represented, the statistical values obtained with yarn appearance were remarkably similar. Referring to the lower part of table 4; it will be seen that the coefficients of multiple correlation ($\bar{R}$) for the 10 analyses ranged only from 0.750 to 0.738 and that the amount of variance explained in yarn appearance by the different combinations of factors extended only from 56 percent to 54 percent. The absolute standard error of estimate ($\bar{S}$) ranged only from ± 7.1 to ± 7.2 index units of yarn appearance and the relative standard error of estimate ($\bar{S}$) extended only from ± 7.2 to 7.3 percent.

Even when only the two factors of yarn size and Micronaire fiber fineness (wt./in.) were used in the analysis, 55 percent of the yarn-appearance variance was explained. This compares with the total 56 percent of yarn-appearance variance explained by the 6 factors in the corresponding over-all analysis. Yarn size and Causticaire fiber fineness (wt./in.) explained 54 percent of yarn-appearance variance, as compared with 56 percent by the 7 factors in the corresponding over-all analysis. Thus, insofar as yarn appearance is concerned, the results obtained from this study with this series of cottons and yarns indicate that the measures of Micronaire fineness and Causticaire fineness compare favorably and that, on the basis of yarn appearance, there is little difference.

The beta coefficients showing the relative importance of the respective independent variables to yarn appearance, when varying numbers and combinations of factors were used in the correlation analyses, are summarized in table 6.

## With Neps in Card Web

Six correlation analyses were made with number of neps per 100 square inches of card web as the dependent variable, including varying numbers and combinations of cotton fiber properties, as well as the alternative Causticaire and Micronaire measures of cotton fiber fineness (wt./in.). The 6 regression equations and corresponding statistical values, as obtained from those correlation analyses, are summarized in the upper part of table 7.

Using 6 factors of raw cotton quality, namely Causticaire fiber maturity, Causticaire fiber fineness (wt./in.) fiber strength at 1/8" gauge, grade index, upper half mean length, and length uniformity ratio, the statistical values obtained with nep count of card web were, as follows:

Coefficient of correlation ($\bar{R}$) ------------------0.612
Variance in nep count of card web explained
($\bar{R}^2$ x 100) ---------37 percent
Standard error of estimate ($\bar{S}$) ----------------±6.8*
* Number of neps per 100 sq. in. of card web

With only Causticaire maturity and Causticaire fineness (wt./in.) used in the analysis, the corresponding statistical values obtained with nep count of card web were, as follows:

Coefficient of correlation ($\bar{R}$) ------------------0.606
Variance in nep count of card web explained
($\bar{R}^2$ x 100)----------37 percent
Standard error of estimate ($\bar{S}$) ----------------±6.8*
* Number of neps per 100 sq. in. of card web

Even when only Causticaire fiber maturity was considered in the analysis with nep count of card web, the coefficient of simple correlation ($\bar{r}$) was -0.572, followed by that of -0.544 for Micronaire fiber fineness (wt./in.), and by that of -0.471 for Causticaire fiber fineness (wt./in.). Thus, Causticaire fiber maturity alone explained 33 percent of the variance in number of neps per 100 sq. in. of card web; Micronaire fiber fineness (wt./in.), 30 percent; and Causticaire fiber fineness, 22 percent. (See upper part of table 7.)

The respective standard errors of estimate ($\bar{s}$) identified with each of the foregoing fiber measures were ± 7.0, ± 7.2, and ± 7.6, in terms of number of neps per 100 sq. in. of card web, as also shown in the upper section of table 7.

The beta coefficients showing the relative importance of the respective independent variables to number of neps per 100 sq. in. of card web, when varying numbers and combinations of factors were used in the correlation analyses, are summarized in table 8.

With Picker and Card Waste

Five correlation analyses were made with percentage of picker and card waste as the dependent variable, employing varying numbers and combinations of cotton fiber properties, and including the alternative

Causticaire and Micronaire measures for cotton fiber fineness (wt./in.). The 5 regression equations and associated statistical values, as obtained from those correlation analyses, are summarized in the lower part of table 7.

With 6 factors (grade index, upper half mean length, Causticaire fiber fineness (wt./in.), Causticaire fiber maturity, fiber strength at 1/8" gauge, and length uniformity ratio) used in the analysis, the statistical values obtained with percentage of picker and card waste were as follows:

Coefficient of correlation ($\bar{R}$) ----------------0.623
Variance in amount of waste explained
($\bar{R}^2$ x 100) --------39 percent
Standard error of estimate ($\bar{S}$) ---------------$\pm$ .9 percent

Omitting length uniformity ratio and fiber strength at 1/8" gauge from the analysis, the 4 remaining factors gave approximately the same statistical values with picker and card waste, as cited above. Essentially the same statistical values were obtained with waste by using 3 of those factors, with Micronaire fiber fineness (wt./in.) substituted for Causticaire fiber fineness (wt./in.).

Of the factors included in the respective analyses, grade index always ranked first in importance to percentage of picker and card waste, as shown by the beta coefficients summarized in table 9, and upper half mean length always ranked second. The other factors of cotton quality included in the analyses influenced percentage of picker and card waste only to a minor or negligible degree.

The foregoing conclusions are confirmed by the fact that grade index alone explained 33 percent of the variance in picker and card waste and that grade index, together with upper half mean length, accounted for 36 percent of the variance in such waste. Those values, as shown in the lower part of table 7, compare with 39 percent for the amount of variance in picker and card waste explained by all 6 factors of cotton quality used in the over-all analysis.

The beta coefficients showing the relative importance of the respective independent variables to percentage of picker and card waste, when varying numbers and combinations of factors were used in the correlation analyses, are summarized in table 9.

## EQUATIONS RECOMMENDED FOR PREDICTING PURPOSES

The equations for predicting skein strength and appearance 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 with single-strand strength of yarns and no analyses have been included for yarns processed on regular-draft equipment.

The yarn-strength, yarn appearance, nep count of card web, and percentage of picker and card waste 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, yarn structure used in the laboratories of the Cotton Division, Agricultural Marketing Service. For the same accuracy of sampling, fiber measurements, yarn tests, nep counts, and waste determinations, 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, yarn twist, nep counts of card web, and amounts of picker and card waste by increasing or decreasing them by what ever percentage he finds to be necessary. Obviously, it would be impractical to develop such 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 so used in a manner by supplemental procedure as to serve satisfactorily most practical problems and purposes connected with skein strength and appearance of carded warp cotton yarn, as well as with nep count of card web and percentage of picker and card waste.

## Yarn Strength

Six equations were developed in this study for predicting directly the skein strength of any size of carded warp singles yarn from 8s to 50s or 60s, on the basis of varying numbers and combinations of factors in raw-cotton quality (including fiber strength at the 1/8" gauge spacing and the alternative Causticaire and Micronaire measures of fiber fineness), as listed in the upper part of table 4. Those equations are adapted more particularly to current commercial production of American upland cotton and 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-strength product to a relatively small amount. For practical purposes, therefore, such factors as affect count-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 manpower and clerical personnel. 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, 3 equations for predicting yarn strength, as identified by equation number shown in the listing of table 4, are recommended, as follows:

<u>Equation (4), including 3 factors of cotton-quality.</u>

$$X'_{91} = -1,411.42 - 19.41X_{41} + 1,824.18X_{17} + 14.91X_{173} + 9.71X_{88}$$

Where $X'_{91}$ = estimated count-strength product, in csp units

$X_{41}$ = size of yarn, as yarn number

$X_{17}$ = upper half mean length, in inches

$X_{173}$ = fiber strength (Pressley), 1/8" gauge, as an index

$X_{88}$ = grade of cotton, as an index

($\bar{R} = 0.924$; $\bar{R}^2 \times 100 = 85$ percent; and $\bar{S} = \pm 136$ csp units)

Equation (5), including 3 factors of cotton quality.

$$X'_{91} = +10.28 - 19.48X_{41} + 18.25X_{173} + 1{,}392.25X_{17} - 80.56X_{104}$$

Where $X'_{91}$ = estimated count-strength product, in csp units

$X_{41}$ = size of yarn, as yarn number

$X_{173}$ = fiber strength (Pressley), 1/8" gauge, as an index

$X_{17}$ = upper half mean length, in inches

$X_{104}$ = fiber weight per inch (Micronaire), in micrograms

($\bar{R}$ = 0.922; $\bar{R}^2$ x 100 = 85 percent; and $\bar{S}$ = $\pm$ 137 csp units)

Equation (6), including 2 factors of cotton quality.

$$X'_{91} = -514.45 - 19.47X_{41} + 17.39X_{173} + 1{,}649.26X_{17}$$

Where $X'_{91}$ = estimated count-strength product, in csp units

$X_{41}$ = size of yarn, as yarn number

$X_{173}$ = fiber strength (Pressley), 1/8" gauge, as an index

$X_{17}$ = upper half mean length, in inches

($\bar{R}$ = 0.917; $\bar{R}^2$ x 100 = 84 percent; and $\bar{S}$ = $\pm$ 141 csp units)

The factor of fiber strength (Pressley) included in the 3 foregoing equations was determined by the recently improved method which involves the 1/8" gauge spacing between the jaws of the testing instrument. Heretofore, however, fiber strength evaluated by the Pressley method has been determined with the zero (0) gauge spacing between the jaws of the testing machine. The old method, moreover, is currently employed in many cotton fiber laboratories and it may continue to be used in the future. For those reasons, therefore, a supplemental predicting equation, involving the 3 most important factors of raw-cotton quality to yarn strength, one of which is Pressley fiber strength obtained by using the zero (0) gauge spacing between the testing jaws, is included in this report, as shown on the following page.

Equation, including 3 factors of cotton quality.

$$X'_{91} = -548.82 - 19.48X_{41} + 2{,}621.19X_{17} + 13.43X_{33} - 85.26X_{104}$$

Where $X'_{91}$ = estimated count-strength product, in csp units

$X_{41}$ = size of yarn, as yarn number

$X_{17}$ = upper half mean length, in inches

$X_{33}$ = fiber strength (Pressley), zero gauge, in 1,000 lb. per sq. in.

$X_{104}$ = fiber weight per inch (Micronaire), in micrograms

($\bar{R} = 0.893$; $\bar{R}^2 \times 100 = 80$ percent; and $\bar{S} = \pm 160$ csp units)

## Yarn Appearance

Ten equations were developed for predicting directly the appearance of any size of carded, warp singles yarn from 8s to 50s or 60s, on the basis of varying numbers and combinations of factors in raw-cotton quality (including the alternative Causticaire and Micronaire measures of fiber fineness), as listed in the lower part of table 4. Those equations are adapted to current commercial production of American upland cotton and 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.

Three equations for predicting yarn appearance, as identified by equation number shown in the listing of table 4, are recommended, as follows:

Equation (13), including 2 factors of cotton quality.

$$X'_{100} = +61.57 - 0.47X_{41} + 5.53X_{134} + 0.39X_{135}$$

Where $X'_{100}$ = estimated yarn appearance, in index units

$X_{41}$ = size of yarn, as yarn number

$X_{134}$ = fiber weight per inch (Causticaire), in micrograms

$X_{135}$ = fiber maturity (Causticaire), as an index

($\bar{R} = 0.744$; $\bar{R}^2 \times 100 = 55$ percent; and $\bar{S} = \pm 7.2$ index units)

<u>Equation (15), including one factor of cotton quality.</u>

$$X'_{100} = +83.66 - 0.47X_{41} + 7.39X_{104}$$

Where $X'_{100}$ = estimated yarn appearance, in index units

$X_{41}$ = size of yarn, as yarn number

$X_{104}$ = fiber weight per inch (Micronaire), in micrograms

($\bar{R} = 0.742$; $\bar{R}^2 \times 100 = 55$ percent; and $\bar{S} = \pm\ 7.2$ index units)

<u>Equation (16), including one factor of cotton quality.</u>

$$X'_{100} = +85.80 - 0.46X_{41} + 6.97X_{134}$$

Where $X'_{100}$ = estimated yarn appearance, in index units

$X_{41}$ = size of yarn, as yarn number

$X_{134}$ = fiber weight per inch (Causticaire) in micrograms

($\bar{R} = 0.738$; $\bar{R}^2 \times 100 = 54$ percent; and $\bar{S} = \pm\ 7.2$ index units)

## Neps in Card Web

Six equations were developed for predicting the number of neps per 100 sq. in. of card web, on the basis of varying numbers and combinations of factors in raw-cotton quality (including the alternative Causticaire and Micronaire measures of fiber fineness), as listed in the upper part of table 7. Those equations are adapted to current commercial production of American upland cotton and they represent 328 selected commercial cottons covering a relatively wide range of quality, crop year 1954.

Three equations for predicting number of neps per 100 sq. in. of card web, as identified by equation number shown in the listing of table 7, are recommended, as appear on the following page.

Equation (19), including 2 factors of cotton quality.

$$X'_{186} = +135.43 - 1.29X_{135} - 4.70X_{134}$$

Where $X'_{186}$ = estimated number of neps per 100 sq. in. of card web
$X_{135}$ = fiber maturity (Causticaire), as an index
$X_{134}$ = fiber weight per inch (Causticaire), in micrograms

($\bar{R} = 0.606$; $\bar{R}^2 \times 100 = 37$ percent; and $\bar{S} = \pm 6.8$ neps per 100 sq. in. of card web)

Equation (20), including one factor of cotton quality.

$$X'_{186} = +144.18 - 1.65X_{135}$$

Where $X'_{186}$ = estimated number of neps per 100 sq. in. of card web
$X_{135}$ = fiber maturity (Causticaire), as an index

($\bar{r} = -0.572$; $\bar{r}^2 \times 100 = 33$ percent; and $\bar{s} = \pm 7.0$ neps per 100 sq. in. of card web)

Equation (21), including one factor of cotton quality.

$$X'_{186} = +60.69 - 10.98X_{104}$$

Where $X'_{186}$ = estimated number of neps per 100 sq. in. of card web
$X_{104}$ = fiber weight per inch (Micronaire), in micrograms

($\bar{r} = -0.544$; $\bar{r}^2 \times 100 = 30$ percent; and $\bar{s} = \pm 7.2$ neps per 100 sq. in. of card web)

## Picker and Card Waste

Five equations were developed for predicting the percentage of picker and card waste, on the basis of varying numbers and combinations of factors in raw-cotton quality (including the alternative Causticaire and Micronaire measures of fiber fineness), as listed in the lower part of table 7. Those equations are adapted to current commercial production of American upland cotton and they represent 328 selected commercial cottons covering a relatively wide range, crop year 1954.

Three equations for predicting percentage of picker and card waste, as identified by equation number shown in the listing of table 7, are recommended, as follows:

Equation (24), including 3 factors of cotton quality.

$$X_7' = +28.70 - 0.15X_{88} - 4.03X_{17} - 0.54X_{104}$$

Where $X_7'$ = estimated percentage of picker and card waste

$X_{88}$ = grade of cotton, as an index

$X_{17}$ = upper half mean length, in inches

$X_{104}$ = fiber fineness (Micronaire), in micrograms

($\bar{R} = 0.624$; $\bar{R}^2 \times 100 = 39$ percent; and $\bar{S} = \pm 0.90$ percent of picker and card waste)

Equation (26), including 2 factors of cotton quality.

$$X_7' = +25.92 - 0.16X_{88} - 2.74X_{17}$$

Where $X_7'$ = estimated percentage of picker and card waste

$X_{88}$ = grade of cotton, as an index

$X_{17}$ = upper half mean length, in inches

($\bar{R} = 0.598$; $\bar{R}^2 \times 100 = 36$ percent; and $\bar{S} = \pm 0.92$ percent of picker and card waste)

Equation (27), including one factor of cotton quality.

$$X_7' = +23.08 - 0.16X_{88}$$

Where $X_7'$ = estimated percentage of picker and card waste

$X_{88}$ = grade of cotton, as an index

($\bar{r} = -0.576$; $\bar{r}^2 \times 100 = 33$ percent: and $\bar{s} = \pm 0.94$ percent of picker and card waste)

## ILLUSTRATION OF CALCULATIONS NECESSARY FOR USING THE PREDICTING EQUATIONS

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. For the purpose of illustration, therefore, only the method of predicting yarn strength by equation (5), as shown in table 4, will be described below.

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 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 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 pounds of yarn strength.

The equation used in the example cited includes 4 factors, namely, yarn size and 3 elements of raw-cotton quality, as follows:

$$X'_{91} = +10.28 - 19.48X_{41} + 18.25X_{173} + 1{,}392.25X_{17} - 80.56X_{104}$$

Where $X'_{91}$ = predicted yarn strength, in csp units

$X_{41}$ = yarn size, as yarn number

$X_{173}$ = fiber strength (Pressley), 1/8" gauge, as an index

$X_{17}$ = upper half mean length, in inches

$X_{104}$ = fiber weight per inch (Micronaire), in micrograms

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

$X_{41}$ = size of yarn (22s and 50s)

$X_{173}$ = 108, fiber strength (Pressley), 1/8" gauge, as an index

$X_{17}$ = 1.12, upper half mean length, in inches

$X_{104}$ = 4.6, fiber weight per inch (Micronaire), in micrograms

| Factors in equation | Calculations for predicting strength of-- 22s | 50s |
|---|---|---|
| Constant = | + 10.28 | + 10.28 |
| - 19.48 x 22= | - 428.56 | -- |
| - 19.48 x 50= | -- | - 974.00 |
| + 18.25 x108= | +1,971.00 | +1,971.00 |
| +1,392.25 x 1.12= | +1,559.32 | +1,559.32 |
| - 80.56 x 4.6 | - 370.58 | - 370.58 |
| Total | +2,741.46 | +2,196.02 |
| $\frac{+2,741.46}{22}$ = | 124.61 | -- |
| $\frac{2,196.02}{50}$ = | -- | 43.92 |
| Actual yarn strength, in lbs. | 128.00 | 46.00 |
| Difference, in lbs. | - 3.39 | -2.08 |
| Difference, in percent | - 2.64 | -4.52 |

Yarn appearance. The calculations and procedure for predicting yarn appearance, by use of the equations reported, are similar to those illustrated above for yarn strength. There is, however, one exception to be noted, namely, that the predicted value obtained is in terms of index units of yarn appearance. It is not necessary, therefore, to divide the estimated value of yarn appearance by the yarn number in question, as is the case in deriving a predicted value of yarn strength from an estimated value of count-strength product.

Neps in card web. Calculations and procedure, similar to the foregoing, are required in making predictions of number of neps per 100 sq. in. of card web, on the basis of the equations reported. No factor of yarn size, however, is involved in making estimates of nep count of card web, as in the cases for yarn strength and yarn appearance.

Picker and card waste. Similar calculations and procedure are required for estimating the percentage of picker and card waste from the equations reported, as in the case of neps of card web.

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" (4), by ASTM Standards on Textile Materials (1), and in Summary of Fiber and Spinning Test results for Crop of 1954 (5). 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. 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.

Fiber strength. Fiber strength at the 1/8" gauge is another independent variable that has been used in a number of the 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.

In one equation included in this report, as well as in report (8) and previous reports of this series, fiber strength was used, as determined by the Pressley tester with the zero gauge spacing between the gripping jaws, and as expressed as 1,000 pounds per square inch. The formula for converting the Pressley strength index identified with the 0 gauge spacing into terms of 1,000 lbs. psi (for use in those predicting equations) is shown, as follows:

$$X_{33} = 10.81X_{22} - 0.12$$

Where $X_{33}$ = estimated fiber strength, expressed as 1,000 lb. psi

$X_{22}$ = Pressley strength index at 0 gauge spacing

Yarn appearance index. This factor is used as the dependent variable in one set of the equations here reported. The conversion chart for obtaining index values of yarn appearance for samples of carded yarn processed from cotton, corresponding to various grade designations of yarn appearance assigned by comparison with the ASTM standards for yarn appearance, is shown in table 2.

Caution. A note of explanation and reservation should be given at this point regarding the results and equations reported in this instance for yarn appearance, for neps in card web, and for picker-and card waste. Each of those properties, as is well known, is significantly affected by the rate of card production used. While the bulk or 80 percent of the cottons included in this study were processed at a card-production rate of 9-1/2 pounds per hour, the long cottons or 13 percent of the total were carded at a relatively slow rate (6-1/2 pounds per hour) and the short cottons or 7 percent of the total were carded at a comparatively fast rate (12-1/2 pounds per hour). Those rates of card production are in line with the general practices used in processing cotton at commercial textile plants.

In the light of the foregoing, the three rates of card production reported herein for processing the different length categories of cotton caused the analyses to show less effect of fiber length and other properties associated with fiber length on yarn appearance, nep count of card web, and percentage of picker-and-card waste than would have been the case, if all the cottons in the series had been processed at one rate of card production. Therefore, because of limitations in the basic data which went into these analyses, the effects of such card-rate differences could not be included in the analyses. Such being the case, appropriate allowances should be made in applying the predicting equations and in studying the results of this report in reference to yarn appearance, neps in card web, and picker-and-card waste. No such allowances, however, need be made with the equations and results pertaining to yarn strength or count-strength product, as the effect of carding rate on yarn strength is too small to be of any practical significance.

## DISCUSSION

Consideration has been given in this report to several new or improved fiber test measures which have special application to cotton, possess merit, and offer promise. Further information than that already given, however, may be desired with respect to such fiber tests and measures. To that end, attention is directed to the new publication by Burley and Carpenter (2) entitled "The Evaluation of Results Obtained on Available Types of Fiber Strength Testers Using Various Gauge Spacings and Their Relation to Yarn Strength" and to the recent report published by Webb and Burley (10) entitled "The Causticaire Method for Measuring Cotton-Fiber Maturity and Fineness: Improvement and Evaluation."

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 a particular 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, the latter of which 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 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 microgram per inch |
| 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 a dependent variable 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 equations for the length factor should be divided by 32. No further calculations or adjustment, 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 count-strength product, yarn strength, yarn appearance, number of neps per unit of area in card web, or percentage of picker and card waste, 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, therefore, is consistency under those conditions.

Meaning of standard error of estimate. The standard error of estimate ($\bar{S}$ or $\bar{s}$) identified with each predicting or estimating equation reported indicates the range within which 67 percent of the actual values for a particular dependent variable (count-strength product, yarn strength, yarn appearance, number of neps per 100 sq. in. of card web, or percentage of picker and card waste), 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.

Comparative precision of yarn-strength predictions identified with count-strength-product and individual yarn-size equations. As discussed in report (19), one of the principal objectives of that study was to develop an all-purpose equation rather than equations for specific sizes of yarn, such as 22s and 50s. With equations for individual yarn sizes, subsequent and supplemental use of a conversion formula also is required in order to obtain predictions of strength of sizes of yarn other than that for which the equation was developed.

The comparative predictions and differences shown in report (19) indicate that the count-strength-product equation gives practically the same precision of prediction as do the equations for specific yarn sizes used either separately or in conjunction with a conversion formula. A tendency, however, is noticed for the latter method to yield yarn-strength estimates slightly more accurate. But, on an average, the standard error is only ± 0.23 pound more for the count-strength-product equation than for the equations developed for 22s and 50s yarn, used either separately or in conjunction with the conversion formula. For 14s yarn, the standard error with the count-strength-product equation is ± 0.40 pound more; for 22s, ± 0.07 pound more; for 36s, ± 0.10 pound more; for 44s, ± 0.54 pound more; for 50s, ± 0.26 pound more; and for 60s, there is no difference. Such small disparities, for all practical purposes, may be disregarded.

Thus, on the basis of the comparative statistical values cited above, it is apparent that there is a very close agreement in the results by the two methods of calculating yarn-strength predictions. However, by the count-strength-product method, only one equation is necessary for any size of yarn over a wide range; by the strength equations for specific sizes of yarn, two or more equations are necessary as well as a conversion formula. For broad and practical purposes, therefore, a count-strength-product equation possesses distinct advantages over several individual yarn-size equations for predicting the strength of various sizes of yarn.

Comparison of evaluated relations obtained with different dependent variables. Referring to the upper part of table 4, it will be seen that, with varying numbers and combinations of factors, the coefficients of correlation ($\bar{R}$) for count-strength product ranged from 0.930 to 0.910. Thus, 86 percent to 84 percent of the variance in count-strength product was explained by the factors included in the respective analyses. Those correlation values are relatively high and they are in line with corresponding ones previously presented in this series of reports.

With yarn appearance, as shown in the lower part of table 4, the correlation values are noticeably smaller than those with count-strength product. The $\bar{R}$ values obtained with yarn appearance ranged from 0.750 to 0.738 and the amount of variance explained in yarn appearance by the factors included in the respective analyses ranged only from 56 percent to 54 percent. The narrow range in coefficients of correlation ($\bar{R}$ or $\bar{r}$) and in the amount of variance of yarn appearance explained by varying numbers of cotton-quality factors, including only one (either Micronaire or Causticaire fiber fineness), suggests that yarn appearance is. to a considerable degree, a function of the mechanical processing in textile organizations; and that, as a consequence, it is not influenced by cotton-quality factors to the degree that count-strength product or yarn strength is influenced by those factors.

In this connection, it must be remembered that evaluations of yarn appearance are not as precise, significant, and representative as determinations of yarn strength and count-strength product are. That is, even with the best yarn-appearance evaluations that are now possible, the personal equation is more of a factor influencing such designations than it is in the case of standardized tests for yarn strength. However, it may be expected that such correlation values with yarn-appearance will be improved over those reported in this instance when some expected developments materialize from further study and experience. Those developments involve better controlled conditions throughout textile processing, more representative and comprehensive standards for yarn-appearance, and more precise, as well as more standardized procedures for making yarn-appearance evaluations.

In the case of number of neps per 100 sq. in. of card web, by reference to the upper part of table 7. it will be seen that the correlation values reported are even smaller but more variable than those previously considered for yarn appearance. With nep count of card web, the coefficients of correlation ($\bar{R}$ or $\bar{r}$) ranged from 0.612 to - .471 and the amount of variance in nep count explained by the factors considered extended from 37 percent to 22 percent. Nep count of card web, however, represents a differential condition that is highly influenced by complex interactions occurring between the various types of thin-walled fibers and mechanical processing.

Furthermore, as there are so many tangible and intangible factors of a biological and mechanical nature involved in the formation of neps, the effects of many of which are neither understood nor evaluated today, the relatively small correlation values here reported are not surprising. Even so, the correlation values obtained with nep count of card web in this instance are somewhat larger and better than those which have been presented previously in this series of reports, or which have been published by others elsewhere, when large numbers and wide ranges of cottons were represented in the analyses. The extremely complex nature of the nep problem in cotton, various difficulties associated with the evaluation of contributory factors to nep formation, and the need for different methods of approach in the solution of the nep problem have been discussed in considerable detail by Webb and Richardson in their report (21).

One of the weakest, if not the weakest, link in the studies conducted thus far on the nep problem is the fact that the evaluation of neps per unit of area, volume, or weight in card web or raw cotton is such a variable entity. Even by use of the most standardized procedures that have been developed to date, different technicians in the same laboratory or mill frequently obtain variable nep counts for a given sample, and sometimes the same technician obtains diverse nep counts at different times for the same sample. There are many border line cases in making nep counts; that is, what is and is not a nep, or what should or should not be counted as a nep, all of which affects appreciably the final evaluation of nep content. In addition, the sampling problem is complex and difficult, as the nep count varies so much throughout a sizeable sample of raw cotton and card web. All things considered, therefore, it is a wonder that the correlation values obtained to date for the relations between nep count of card web and the factors of raw-cotton quality considered in the analyses are as large as they are.

Finally, with respect to percentage of picker and card waste, the correlation values obtained in this study are slightly larger and less variable than in the case of nep count of card web. Referring to the lower part of table 7, it will be seen that the correlation coefficients ($\bar{R}$ and $\bar{r}$) extended from 0.625 to - 5.76 and that the amount of variance in total picker and card waste explained by the various factors of cotton quality ranged from 39 percent to 33 percent. Those results are not surprising, as cotton fiber properties per se are not concerned with nor influence percentage of picker and card waste, in the same sense as they do in the case of yarn strength or count-strength product. Grade index of raw cotton, as naturally would be expected, is the principal cotton-quality factor influencing percentage of picker and card waste.

Alternative fiber strength measures. It is of interest to examine the equations and correlation results developed for count-strength product, when using the 3 most important cotton fiber properties and including the alternative measures of fiber strength (Pressley), as determined with the 1/8" gauge spacing and with the 0 gauge spacing. The two equations obtained, as previously covered in this report, are as follows:

$$X'_{91} = +10.28 - 19.48X_{41} + 18.25X_{173} + 1,392.25X_{17} - 80.56X_{104}$$

$$X'_{91} = -548.82 - 19.48X_{41} + 13.43X_{33} + 2,621.19X_{17} - 85.26X_{104}$$

Where $X'_{91}$ = estimated count-strength product, in csp units

$X_{41}$ = size of yarn, as yarn number

$X_{173}$ = fiber strength (Pressley), 1/8" gauge, as an index

$X_{33}$ = fiber strength (Pressley), 0 gauge, 1,000 lbs. psi

$X_{17}$ = upper half mean length, in inches

$X_{104}$ = fiber weight per inch (Micronaire), in micrograms

The correlation values representing the two respective equations listed above are, as follows:

$\bar{R} = 0.922$; $\bar{R}^2 \times 100 = 85$ percent; and $\bar{S} = \pm 137$ csp units

$\bar{R} = 0.893$; $\bar{R}^2 \times 100 = 80$ percent; and $\bar{S} = \pm 160$ csp units

On the basis of the above comparative statistical values, it is apparent that, when fiber strength determined at the 1/8" gauge spacing was used in the analysis, the correlation coefficient ($\bar{R}$) was 0.029 larger, 5 percent more variance in count-strength product was explained by the factors used, and the standard error of estimate (S) was 23 csp units smaller, than when fiber strength measured at the 0 gauge spacing was used in the parallel analysis.

The relative importance of the factors to count-strength product, as based on the beta coefficients obtained for the two parallel analyses are, as follows:

| | |
|---|---|
| (1) Yarn size | (1) Yarn size |
| (2) Fiber strength, 1/8" gauge | (2) Upper half mean length |
| (3) Upper half mean length | (3) Fiber strength, 0 gauge |
| (4) Micronaire wt./in. | (4) Micronaire wt./in. |

In the light of the foregoing tabulation, it may be noted that fiber strength at the 1/8" gauge spacing ranks second in importance to count-strength product and that upper half mean length ranks third. In the parallel analysis, however, upper half mean length ranks second in importance to count-strength product and fiber strength at the 0 gauge spacing ranks third.

Comparison of correlation results with count-strength product for different crop years. One of the analyses and equations recently reported by Webb in publication (8) included 4 factors (yarn size, upper half mean length, fiber strength at the 0 gauge, and Micronaire fiber fineness (wt./in.) in relation to count-strength product. That analysis was based on data representing 842 commercial American upland cottons, grown in approximately 100 selected cotton improvement groups across the U. S. Cotton Belt, for the 3 crop years of 1948-50, and involved a total of 3,267 lots of yarn, ranging in sizes from 14s to 60s.

In the present study and report, a corresponding analysis included the same group of factors identified with 328 similar cottons, grown in 111 selected cotton improvement groups, for the crop year of 1954. A total of 678 lots of yarn, ranging in size from 8s to 50s, was used in this analysis. A comparison of the two sets of results obtained from parallel analyses are shown, as follows:

| | 1948-50 | 1954 |
|---|---|---|
| Coef. of correlation ($\bar{R}$) ---------- | 0.896 | 0.893 |
| Variance explained ($\bar{R}^2$ x 100) ------ | 80 pct. | 80 pct. |
| St. error of est.($\bar{S}$), absolute ----- | $\pm$160 csp | $\pm$160 csp |
| St. error of est. (S), relative ---- | $\pm$ 7.3 pct. | $\pm$ 7.0 pct. |

| Factors | Rank | Beta coefficients for 1948-50 | Beta coefficients for 1954 |
|---|---|---|---|
| Yarn size--------------- | (1) | -0.691 | -0.816 |
| Upper half mean length-- | (2) | + .442 | + .540 |
| Fiber strength, 0 gauge-- | (3) | + .384 | + .182 |
| Micronaire (wt./in.)---- | (4) | - .082 | - .107 |

On the basis of the comparative values shown in the foregoing tabulations, it is readily apparent that the corresponding results obtained from parallel multiple correlation analyses, one involving 842 cottons and 3,267 lots of yarn (14s to 60s) from the 3 crop years of 1948-50 and the other including 328 cottons and 678 lots of yarn (8s to 50s) from the 1954 crop, are remarkably similar. Such consistent results give added confidence to the statistical values and equations presented in this report, as well as to those contained in previous reports from this series of relationship studies.

## LITERATURE CITED


(1) ASTM Standards on Textile Materials.
1954. Methods of Testing Cotton Fibers; Tests and Tolerances for Cotton Yarns. (Published annually by Amer. Soc. Testing Materials, 1916 Race St., Phila. 3, Pa.)

(2) Burley, Samuel T., Jr., and Carpenter, Frances
1955. The Evaluation of Results Obtained on Available Types of Fiber Strength Testers Using Various Gauge Spacings and Their Relation to Yarn Strength. U. S. Dept. Agr., Agr. Market. Service. AMS-71 19 pp., illus. (September 1955.)

(3) United States Department of Agriculture.
1938. The Classification of Cotton, U. S. Dept. Agr. Misc. Pub. 310. 54 pp., illus. (May 1938.)

(4) ______
1955. Cotton Testing Service. Agr. Market. Service. No. 16, 49 pp. illus. (Revised February 1955.)

(5) ______
1955. Summary of Fiber and Spinning Test Results for Some Varieties of Cotton Grown by Selected Cotton Improvement Groups, Crop of 1954. Agr. Market. Service, Agr. Inf. Bul. No. 137. 43 pp. (February 1955.)

(6) Webb, Robert W.
1947. Relation and Relative Importance of Some Cotton Fiber Properties to Certain Manufacturing Qualities. (Paper presented at a meeting of the Fiber Society, New Orleans, La.) U. S. Dept. Agr., Prod. and Market. Admin. 22 pp. (February 1947.)

(7) ______
1954. Comparison of the Relations of Six Factors of Raw-Cotton Quality to Skein Strength of Carded Yarns for Eight Crop Years, 1945-52. U. S Dept. Agr., Agr. Market. Service. 33 pp., illus. (May 1954.)

(8) ______
1955. Improved Equations for Predicting Skein Strength of Carded Yarn with Special Reference to Current Commercial Production of American Cotton. U. S. Dept. Agr., Agr. Market. Service. 18 pp. (April 1955.)

(9) ______
1955. Influence of Yarn Size on the Relative Contributions of Six Cotton Fiber Properties to Strength of Carded Yarn. U. S. Dept. Agr., Agr. Market. Service. Market. Res. Rpt. No. 109. 59 pp., illus. (December 1955.)

(10) Webb, Robert W. and Burley, Samuel T., Jr.
1953. The Causticaire Method for Measuring Cotton-Fiber Maturity and Fineness; Improvement and Evaluation. U. S. Dept. Agr., Agr. Market. Service, Market. Res. Rpt. No. 57. 62 pp., illus. (December 1953.)

(11) _____ and Richardson, Howard B.
1945. Relationships Between Properties of Cotton Fibers and Strength of Carded Yarns. U. S. Dept. Agr. War Food Admin. 58 pp. illus. (March 1945.)

(12) _____ and Richardson, Howard B.
1945. Relationships of Cotton Fiber Properties to Strength and Elongation of Tire Cord. U. S. Dept. Agr. War Food Admin. 59 pp., illus. (June 1945.)

(13) _____ and Richardson. Howard B.
1945. Comparative Significance of Alternative Cotton Fiber Length and Strength Measures in Relation to Yarn Strength. U. S. Dept. Agr. Prod. and Market. Admin. 62 pp., illus. (September 1945.)

(14) _____ and Richardson, Howard B.
1946. Relationships Between Properties of Cotton Fibers and Appearance of Carded Yarns. U. S. Dept. of Agr. Prod. and Market. Admin. 54 pp., illus. (March 1946.)

(15) _____ and Richardson, Howard B.
1946. Relationships Between Properties of Cotton Fibers and Percentages of Wastes Associated with the Manufacture of Carded Yarns. U. S. Dept. Agr. Prod. and Market. Admin. 63 pp. (July 1946.)

(16) _____ and Richardson, Howard B.
1947. Relation and Importance of Certain Fiber Properties of Long Staple Cottons to Strength and Appearance of Combed Yarns, and to Percentage of Manufacturing Waste. U. S. Dept. Agr. Prod. and Market. Admin. 84 pp. (July 1947.)

(17) _____, Richardson, Howard B. and Popka, Doretta H.
1949. Relation of Six Elements of Cotton Quality to Strength of 22s Yarn (Regular Draft), by Crop Year, Variety, and Staple Length. U. S. Dept. Agr. Prod. and Market. Admin. 61 pp. (October 1949.)

(18) _____ and Richardson, Howard B.
1950. Relation of Six Elements of Raw-Cotton Quality to Strength of 22s and 50s Yarn (Long Draft). U. S. Dept. Agr. Prod. and Market. Admin. 63 pp. (April 1950.)

(19) Webb, Robert W. and Richardson, Howard B.
1950. Relation of Count-Strength Product of Long Draft Processed Yarn to Six Elements of Raw-Cotton Quality and Yarn Size. U. S. Dept. Agr. Prod. and Market. Admin. 61 pp., illus. (August 1950.)

(20) _____ and Richardson, Howard B.
1950. Relation of Appearance of Long-Draft Processed Carded Yarn to Six Elements of Raw-Cotton Quality and Yarn Size. U. S. Dept. Agr. Prod. and Market. Admin. 53 pp., illus. (November 1950.)

(21) _____ and Richardson, Howard B.
1951. Neps in Card Web and Related to Six Elements of Raw-Cotton Quality. U. S. Dept. Agr. Prod. and Market. Admin. 54 pp. (May 1951.)

(22) _____ and Richardson, Howard B.
1951. Relation of Neps in Card Web, Six Elements of Raw-Cotton Quality, and Yarn Size to Appearance of Long-Draft Carded Yarn. U. S. Dept. Agr. Prod. and Market. Admin. 58 pp. (October 1951.)

(23) _____ and Richardson, Howard B.
1951. Fiber Measurements of Second-Drawing Sliver Compared with Those of Raw Cotton in Relation to Yarn Strength and Yarn Appearance. U. S. Dept. Agr. Prod. and Market. Admin. 80 pp., illus. (November 1951.)

(24) _____ and Richardson, Howard B.
1952. Relation of Rate of Carding and Factors of Cotton Quality to Strength and Appearance of Carded Yarn, Neps in Card Web, and Percentage of Card Waste. U. S. Dept. Agr. Prod. and Market. Admin. 44 pp. (June 1952.)

(25) _____ and Richardson, Howard B.
1953. Relation of Rate of Carding and Factors of Cotton Quality to Strength and Appearance of Combed Yarn, Neps in Card Web, Card Waste, and Comber Waste. U. S. Dept. Agr. Prod. and Market. Admin. 61 pp. (March 1953.)

(26) _____ and Richardson, Howard B.
1953. An Evaluation of the Significance and Use of the K Factor of Yarn Strength and Its Relation to Raw-Cotton Quality. U. S. Dept. Agr., Prod. and Market. Admin. 32 pp. (June 1953.)

# APPENDIX

Table 1.--Code for obtaining the index value of raw cotton from its grade

| Grade | 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.--Index values and adjective ratings for grades of yarn appearance

| Grade | Description | Index |
|---|---|---|
| A | Excellent | 130 |
| B+ | Very good | 120 |
| B | Good | 110 |
| C+ | Average | 100 |
| C | Fair | 90 |
| D+ | Poor | 80 |
| D and below | Very poor | 70 |

Table 3.--Comparison of statistical values, representing data identified with the independent and dependent variables used in multiple and simple correlation analyses, 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: | | | | | | |
| 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 fiber wt./in. .......... microgram | 328 | 4.17 | ± .44 | 5.5 | 2.7 | 2.8 |
| Micronaire fiber wt./in. ........... microgram | 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 | 83.72 | ± 4.79 | 97.0 | 66.0 | 31.0 |
| Causticaire fiber maturity ............ index | 328 | 78.79 | ± 2.98 | 85.0 | 62.0 | 23.0 |
| Yarn size ............................ number | 678 | 33.85 | ± 14.83 | 50.0 | 8.0 | 42.0 |
| Dependent variables: | | | | | | |
| Count-strength product .................. csp | 678 | 2,272.85 | ±353.69 | 3,366. | 1,452. | 1,914. |
| Yarn appearance ....................... index | 678 | 99.35 | ± 10.73 | 120. | 70. | 50. |
| Neps in card web ......... no. per 100 sq. in. | 328 | 13.98 | ± 8.58 | 101. | 3. | 98. |
| Picker and card waste ............... percent | 328 | 7.66 | ± 1.15 | 12.3 | 5.0 | 7.3 |

1/ Values shown indicate the number of observations used in each correlation analysis.

Table 4.--Summary of regression equations showing the relation of varying numbers and combinations of cotton-quality measures to count-strength product and to appearance 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 | Regression equations involving-- Estimate | 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 wt./in., micrograms | $X_{104}$ Micronaire wt./in., micrograms | $X_{135}$ Causticaire maturity, index | $X_{173}$ F. strength, 1/8" gauge, index | Constant | Statistical values ($\bar{R}$) Coef. of correlation | ($\bar{R}^2$ x 100) Variance explained 2/ | ($\bar{S}$) Standard error of estimate Absolute 3/ | Relative |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Number | | | | | | | | | | | | Percent | | Percent 4/ |
| (1) | C x S product---- | 6 | $X'_{91}$ = | -19.41 | +10.91 | +1,536.21 | +7.53 | ---- | -98.94 | ---- | +15.43 | -1,464.55 | 0.930 | 86.53 | ±130. | ±5.7 |
| (2) | do---------- | 5 | $X'_{91}$ = | -19.42 | +11.20 | +1,540.20 | ---- | ---- | -97.44 | ---- | +15.57 | - 914.48 | .930 | 86.50 | ±130. | ±5.7 |
| (3) | do---------- | 7 | $X'_{91}$ = | -19.36 | +10.79 | +1,611.72 | +7.25 | -43.11 | ---- | -8.43 | +15.34 | -1,079.20 | .930 | 86.41 | ±130. | ±5.7 |
| (4) | do---------- | 4 | $X'_{91}$ = | -19.41 | + 9.71 | +1,824.18 | ---- | ---- | ---- | ---- | +14.91 | -1,411.42 | .924 | 85.32 | ±136. | ±6.0 |
| (5) | do---------- | 4 | $X'_{91}$ = | -19.48 | ---- | +1,392.25 | ---- | ---- | -80.56 | ---- | +18.25 | + 10.28 | .922 | 84.96 | ±137. | ±6.0 |
| (6) | do---------- | 3 | $X'_{91}$ = | -19.47 | ---- | +1,649.26 | ---- | ---- | ---- | ---- | +17.39 | - 514.45 | .917 | 84.14 | ±141. | ±6.2 |
| (7) | Y. appearance---- | 7 | $X'_{100}$ = | - .47 | + .20 | + 18.08 | + .27 | + 6.01 | ---- | + .35 | - .18 | + 20.92 | .750 | 56.29 | ± 7.1 | ±7.2 |
| (8) | do---------- | 6 | $X'_{100}$ = | - .47 | + .22 | + 14.47 | + .29 | ---- | + 7.39 | ---- | - .18 | + 42.39 | .749 | 56.04 | ± 7.1 | ±7.2 |
| (9) | do---------- | 5 | $X'_{100}$ = | - .47 | + .23 | + 14.62 | ---- | ---- | + 7.45 | ---- | - .18 | + 63.44 | .748 | 56.02 | ± 7.1 | ±7.2 |
| (10) | do---------- | 5 | $X'_{100}$ = | - .47 | ---- | + 16.33 | ---- | + 6.52 | ---- | + .34 | - .13 | + 56.92 | .747 | 55.74 | ± 7.1 | ±7.2 |
| (11) | do---------- | 4 | $X'_{100}$ = | - .47 | ---- | + 11.58 | ---- | ---- | + 7.80 | ---- | - .12 | + 82.44 | .744 | 55.37 | ± 7.2 | ±7.2 |
| (12) | do---------- | 4 | $X'_{100}$ = | - .47 | ---- | + 6.49 | ---- | + 6.26 | ---- | + .34 | ---- | + 55.83 | .744 | 55.36 | ± 7.2 | ±7.2 |
| (13) | do---------- | 3 | $X'_{100}$ = | - .47 | ---- | ---- | ---- | + 5.53 | ---- | + .39 | ---- | + 61.57 | .744 | 55.31 | ± 7.2 | ±7.2 |
| (14) | do---------- | 3 | $X'_{100}$ = | - .46 | ---- | ---- | ---- | ---- | + 7.24 | ---- | - .06 | + 89.97 | .743 | 55.15 | ± 7.2 | ±7.2 |
| (15) | do---------- | 2 | $X'_{100}$ = | - .47 | ---- | ---- | ---- | ---- | + 7.39 | ---- | ---- | + 83.66 | .742 | 55.06 | ± 7.2 | ±7.2 |
| (16) | do---------- | 2 | $X'_{100}$ = | - .46 | ---- | ---- | ---- | + 6.97 | ---- | ---- | ---- | + 85.80 | .738 | 54.51 | ± 7.2 | ±7.3 |

1/ Identification of equations, as listed in descending order of percentage of variance in dependent variable explained by the collective factors used in each analysis.

2/ Amount of variance explained in count-strength product (upper section of table) and in yarn appearance (lower section of table) by the collective factors used in each analysis.

3/ Standard error of estimate ($\bar{S}$) is in terms of count-strength-product units (upper section of table) and of yarn-appearance index units (lower section of table).

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

Table 5.--Summary of beta coefficients showing the relative importance of the respective independent variables to count-strength product, when varying numbers and combinations of cotton-quality measures 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/ | | Relative importance | |
|---|---|---|---|---|---|---|---|
| | | | | Total | Identification | Rank | Beta coefficients 4/ |
| Number | Number | Number | Number | Number | | | |
| (1) | 328 | 678 | 678 | 6 | Yarn size | 1 | -0.814 ± 0.015 |
| | | | | | Fiber strength, 1/8" gauge | 2 | + .332 ± .020 |
| | | | | | Upper half mean length | 3 | + .316 ± .021 |
| | | | | | Grade index | 4 | + .131 ± .015 |
| | | | | | Micronaire wt./in. | 5 | - .124 ± .016 |
| | | | | | Length uniformity ratio | 6 | + .024* ± .014 |
| (2) | 328 | 678 | 678 | 5 | Yarn size | 1 | - .814 ± .015 |
| | | | | | Fiber strength, 1/8" gauge | 2 | + .335 ± .020 |
| | | | | | Upper half mean length | 3 | + .317 ± .021 |
| | | | | | Grade index | 4 | + .134 ± .015 |
| | | | | | Micronaire wt./in. | 5 | - .122 ± .016 |
| (3) | 328 | 678 | 678 | 7 | Yarn size | 1 | - .812 ± .015 |
| | | | | | Upper half mean length | 2 | + .332 ± .023 |
| | | | | | Fiber strength, 1/8" gauge | 3 | + .330 ± .020 |
| | | | | | Grade index | 4 | + .129 ± .015 |
| | | | | | Causticaire fiber maturity | 5 | - .073 ± .018 |
| | | | | | Causticaire wt./in. | 6 | - .056* ± .022 |
| | | | | | Length uniformity ratio | 7 | + .023* ± .015 |
| (4) | 328 | 678 | 678 | 4 | Yarn size | 1 | - .814 ± .015 |
| | | | | | Upper half mean length | 2 | + .376 ± .021 |
| | | | | | Fiber strength, 1/8" gauge | 3 | + .320 ± .021 |
| | | | | | Grade index | 4 | + .116 ± .016 |
| (5) | 328 | 678 | 678 | 4 | Yarn size | 1 | - .817 ± .015 |
| | | | | | Fiber strength, 1/8" gauge | 2 | + .392 ± .020 |
| | | | | | Upper half mean length | 3 | + .287 ± .022 |
| | | | | | Micronaire wt./in. | 4 | - .101 ± .016 |
| (6) | 328 | 678 | 678 | 3 | Yarn size | 1 | - .816 ± .016 |
| | | | | | Fiber strength, 1/8" gauge | 2 | + .374 ± .021 |
| | | | | | Upper half mean length | 3 | + .340 ± .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 (wt./in.).

4/ The sign indicates the direction of the contribution of the independent variable to C x S product.

* Statistically insignificant, being less than 3 times its standard error.

Table 6.--Summary of beta coefficients showing the relative importance of the respective independent variables to yarn appearance, when varying numbers and combinations of cotton-quality measures 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/ | | Relative importance | |
|---|---|---|---|---|---|---|---|
| | | | | Total | Identification | Rank | Beta coefficients 4/ |
| Number | Number | Number | Number | Number | | | |
| (7) | 328 | 678 | 678 | 7 | Yarn size | 1 | -0.651 ± 0.026 |
| | | | | | Causticaire wt./in. | 2 | + .256 ± .039 |
| | | | | | Fiber strength, 1/8" gauge | 3 | - .130 ± .037 |
| | | | | | Upper half mean length | 4 | + .123* ± .042 |
| | | | | | Causticaire fiber maturity | 5 | + .100 ± .032 |
| | | | | | Grade index | 6 | + .080* ± .028 |
| | | | | | Length uniformity ratio | 7 | + .028* ± .026 |
| (8) | 328 | 678 | 678 | 6 | Yarn size | 1 | - .647 ± .026 |
| | | | | | Micronaire wt./in. | 2 | + .305 ± .029 |
| | | | | | Fiber strength, 1/8" gauge | 3 | - .131 ± .037 |
| | | | | | Upper half mean length | 4 | + .098* ± .038 |
| | | | | | Grade index | 5 | + .086 ± .028 |
| | | | | | Length uniformity ratio | 6 | + .030* ± .026 |
| (9) | 328 | 678 | 678 | 5 | Yarn size | 1 | - .647 ± .026 |
| | | | | | Micronaire wt./in. | 2 | + .308 ± .028 |
| | | | | | Fiber strength, 1/8" gauge | 3 | - .127 ± .037 |
| | | | | | Upper half mean length | 4 | + .099* ± .038 |
| | | | | | Grade index | 5 | + .091 ± .027 |
| (10) | 328 | 678 | 678 | 5 | Yarn size | 1 | - .653 ± .026 |
| | | | | | Causticaire wt./in. | 2 | + .278 ± .039 |
| | | | | | Upper half mean length | 3 | + .111* ± .042 |
| | | | | | Causticaire fiber maturity | 4 | + .098 ± .032 |
| | | | | | Fiber strength, 1/8" gauge | 5 | - .091* ± .035 |
| (11) | 328 | 678 | 678 | 4 | Yarn size | 1 | - .649 ± .027 |
| | | | | | Micronaire wt./in. | 2 | + .322 ± .028 |
| | | | | | Fiber strength, 1/8" gauge | 3 | - .088* ± .035 |
| | | | | | Upper half mean length | 4 | + .079* ± .038 |
| (12) | 328 | 678 | 678 | 4 | Yarn size | 1 | - .654 ± .027 |
| | | | | | Causticaire wt./in. | 2 | + .267 ± .039 |
| | | | | | Causticaire fiber maturity | 3 | + .097* ± .033 |
| | | | | | Upper half mean length | 4 | + .044* ± .033 |
| (13) | 328 | 678 | 678 | 3 | Yarn size | 1 | - .647 ± .030 |
| | | | | | Causticaire wt./in. | 2 | + .236 ± .035 |
| | | | | | Causticaire fiber maturity | 3 | + .111 ± .035 |
| (14) | 328 | 678 | 678 | 3 | Yarn size | 1 | - .640 ± .026 |
| | | | | | Micronaire wt./in. | 2 | + .299 ± .026 |
| | | | | | Fiber strength, 1/8" gauge | 3 | - .041* ± .037 |
| (15) | 328 | 678 | 678 | 2 | Yarn size | 1 | - .647 ± .026 |
| | | | | | Micronaire wt./in. | 2 | + .305 ± .026 |
| (16) | 328 | 678 | 678 | 2 | Yarn size | 1 | - .639 ± .026 |
| | | | | | Causticaire wt./in. | 2 | + .297 ± .026 |

1/ Equation identification, as shown in table 4.

2/ Number of observations used in each correlation analysis.

3/ Including alternative measures of fiber fineness (wt./in.).

4/ The sign indicates the direction of the contribution of the independent variable to yarn appearance.

* Statistically insignificant, being less than 3 times its standard error.

Table 7.—Summary of regression equations showing the relation of varying numbers and combinations of cotton-quality measures to number of neps per 100 square inches of card web and to percentage of picker-and-card waste, as based on multiple or simple linear correlation analyses, representing 328 American upland cottons from selected cotton improvement groups, crop year 1954

| Equation 1/ | Dependent variable | Factors used in analysis | Regression equations involving-- Estimate | Coefficients for independent variables of $X_{88}$ Grade of cotton, index | $X_{17}$ U. H. M. length, inches | $X_{19}$ L. unif. ratio index | $X_{134}$ Causticaire wt./in., Micrograms | $X_{104}$ Micronaire wt./in., Micrograms | $X_{135}$ Caust. Maturity, index | $X_{173}$ F. strength 1/8" gauge, index | Constant | Statistical values ($\bar{R}$ or $\bar{r}$) Coef. of correlation 2/ | ($\bar{R}^2$ or $\bar{r}^2$ x 100) Variance explained 3/ | ($\bar{S}$ or $\bar{s}$) St. error of estimate |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number | | Number | | | | | | | | | | | Percent | 4/ |
| (17) | Neps in card web------- | 6 | $X'_{186}$ = | -0.21 | -12.68 | +0.33 | -4.81 | — | -1.29 | +0.15 | +128.78 | 0.612 | 37.48 | ±6.8 |
| (18) | do--------------- | 3 | $X'_{186}$ = | — | — | — | -4.31 | — | -1.33 | + .06 | +130.58 | .606 | 36.72 | ±6.8 |
| (19) | do--------------- | 2 | $X'_{186}$ = | — | — | — | -4.70 | — | -1.29 | — | +135.43 | .606 | 36.68 | ±6.8 |
| (20) | do--------------- | 1 | $X'_{186}$ = | — | — | — | — | — | -1.65 | — | +144.18 | - .572 | 32.68 | ±7.0 |
| (21) | do--------------- | 1 | $X'_{186}$ = | — | — | — | — | -10.98 | — | — | + 60.69 | - .544 | 29.55 | ±7.2 |
| (22) | do--------------- | 1 | $X'_{186}$ = | — | — | — | -9.29 | — | — | — | + 52.75 | - .471 | 22.18 | ±7.6 |
| (23) | Picker and card waste-- | 4 | $X'_7$ = | - .15 | - 4.22 | — | - .41 | — | - .03 | — | + 30.76 | .625 | 39.00 | ± .90 |
| (24) | do--------------- | 3 | $X'_7$ = | - .15 | - 4.03 | — | — | - .54 | — | — | + 28.70 | .624 | 38.92 | ± .90 |
| (25) | do--------------- | 6 | $X'_7$ = | - .15 | - 4.86 | + .02 | - .42 | — | - .03 | + .01 | + 29.89 | .623 | 38.80 | ± .90 |
| (26) | do--------------- | 2 | $X'_7$ = | - .16 | - 2.74 | — | — | — | — | — | + 25.92 | .598 | 35.77 | ± .92 |
| (27) | do--------------- | 1 | $X'_7$ = | - .16 | — | — | — | — | — | — | + 23.08 | - .576 | 33.20 | ± .94 |

1/ Identification of equations, as listed in descending order of percentage of variance in dependent variable explained by the collective factors used in each analysis.

2/ The sign attached to the coefficient of simple correlation ($\bar{r}$) indicates the direction of the correlation.

3/ Amount of variance explained in number of neps per 100 sq. in. of card web (upper section of table) and in percentage of picker-and-card waste (lower section of the table) by the collective factors used in each analysis.

4/ Standard error of estimate ($\bar{S}$ or $\bar{s}$) is in terms of number of neps per 100 sq. in. of card web (upper section of table) and of percentage of picker-and-card waste (lower section of table).

Table 8.--Summary of beta coefficients showing the relative importance of the respective independent variables to number of neps per 100 square inches of card web, when varying numbers and combinations of cotton-quality measures 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 card web | Observations 2/ | Independent variables 3/ | | Relative importance | |
|---|---|---|---|---|---|---|---|
| | | | | Total | Identification | Rank | Beta coefficients 4/ |
| Number | Number | Number | Number | Number | | | |
| (17) | 328 | 328 | 328 | 6 | Caustícaire fiber maturity--------- | 1 | -0.447 ±0.054 |
| | | | | | Causticaire wt./in.---------------- | 2 | - .245 ± .065 |
| | | | | | Fiber strength, 1/8" gauge--------- | 3 | + .132*± .062 |
| | | | | | Grade index------------------------ | 4 | - .107*± .048 |
| | | | | | Upper half mean length------------- | 5 | - .103*± .069 |
| | | | | | Length uniformity ratio------------ | 6 | + .043*± .045 |
| (18) | 328 | 328 | 328 | 3 | Causticaire fiber maturity--------- | 1 | - .460 ± .053 |
| | | | | | Causticaire wt./in.---------------- | 2 | - .220 ± .055 |
| | | | | | Fiber strength, 1/8" gauge--------- | 3 | + .051*± .047 |
| (19) | 328 | 328 | 328 | 2 | Causticaire fiber maturity--------- | 1 | - .449 ± .052 |
| | | | | | Causticaire wt./in.---------------- | 2 | - .240 ± .052 |
| (20) | 328 | 328 | 328 | 1 | Causticaire fiber maturity--------- | 1 | - .572 5/ |
| (21) | 328 | 328 | 328 | 1 | Micronaire wt./in.----------------- | 1 | - .544 5/ |
| (22) | 328 | 328 | 328 | 1 | Causticaire wt./in.---------------- | 1 | - .471 5/ |

1/ Equation identified, as shown in table 7.
2/ Number of observations used in each correlation analysis.
3/ Including alternative measures of fiber fineness (wt./in.).
4/ The sign indicates the direction of the contribution of the independent variable to number of neps per 100 sq. in. of card web.
5/ Coefficient of simple correlation (r̄).
* Statistically insignificant, being less than 3 times its standard error.

Table 9.--Summary of beta coefficients showing the relative importance of the respective independent variables to percentage of picker-and-card waste, when varying numbers and combinations of cotton-quality measures 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 waste | Observations 2/ | Independent variables 3/ | | Relative importance | |
|---|---|---|---|---|---|---|---|
| | | | | Total | Identification | Rank | Beta coefficients 4/ |
| Number | Number | Number | Number | Number | | | |
| (23) | 328 | 328 | 328 | 4 | Grade index | 1 | -0.541 ± 0.044 |
| | | | | | Upper half mean length | 2 | - .255 ± .054 |
| | | | | | Causticaire wt./in. | 3 | - .155* ± .064 |
| | | | | | Causticaire fiber maturity | 4 | - .085* ± .053 |
| (24) | 328 | 328 | 328 | 3 | Grade index | 1 | - .545 ± .044 |
| | | | | | Upper half mean length | 2 | - .244 ± .047 |
| | | | | | Micronaire wt./in. | 3 | - .201 ± .048 |
| (25) | 328 | 328 | 328 | 6 | Grade index | 1 | - .556 ± .047 |
| | | | | | Upper half mean length | 2 | - .294 ± .068 |
| | | | | | Causticaire wt./in. | 3 | - .160* ± .064 |
| | | | | | Causticaire fiber maturity | 4 | - .086* ± .053 |
| | | | | | Fiber strength, 1/8" gauge | 5 | + .054* ± .061 |
| | | | | | Length uniformity ratio | 6 | + .015* ± .045 |
| (26) | 328 | 328 | 328 | 2 | Grade index | 1 | - .577 ± .044 |
| | | | | | Upper half mean length | 2 | - .166 ± .044 |
| (27) | 328 | 328 | 328 | 1 | Grade index | 1 | - .576 5/ |

1/ Equation identification, as shown in table 7.

2/ Number of observations used in each correlation analysis.

3/ Including alternative measures of fiber fineness (wt./in.).

4/ The sign indicates the direction of the contribution of the independent variable to percentage of picker and card waste.

5/ Coefficient of simple correlation ($\bar{r}$).

* Statistically insignificant, being less than 3 times its standard error.

☆ U. S. GOVERNMENT PRINTING OFFICE : 1956 O - 380818