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UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Marketing Service

COTTON FIBER TESTING SERVICE 1/

Various tests available under the Cotton Fiber Testing Service are described herein in order to acquaint cotton breeders and others who may utilize the service with the methods employed in making the tests, and with the significance of the results. It is realized that many persons are not familiar with all the techniques used, and an effort has been made to make the descriptions as simple and non-technical as possible. The descriptions are also brief, many important features having been omitted wherever it was felt that their inclusion would not be essential to an understanding of the results obtained from the tests.

Because the proper preparation of samples submitted for tests is extremely important, a number of suggestions are given which it is believed may be helpful to those who wish to have tests made.

Suggestions Regarding Samples of Cotton to be Submitted for Tests

The regulations covering this testing service specify that each sample of ginned lint submitted for fiber tests shall weigh approximately 8 ounces, and that each sample submitted for spinning and fiber tests, or for spinning tests alone, shall weigh not less than 5 pounds. The Department is prepared to make reliable tests on samples of these sizes. In cases where slightly more cotton is available for spinning tests, however, the speed and efficiency of the tests would be increased somewhat if 8 to 10 pounds of lint were made available to the laboratory.

Since the results of the fiber and spinning tests can be no more reliable than the samples themselves, each person submitting samples is urged to take every precaution to insure a representative, uniform sample. The seed cotton to be ginned should, of course, be selected to represent as nearly as possible a true cross-section of the test block for a particular variety or strain. A more uniform sample will be obtained if the seed cotton is thoroughly mixed before it is ginned. When the seed cotton is ginned on a small sample gin, it is important that the first and last part of the sample ginned not be included in the test sample. Moreover, in the case of saw ginning, if the quantity of seed cotton will permit, the gin should be operated a sufficient length of time to permit a seed roll to be built up before the actual material to be submitted for the tests is drawn.

Saw-ginned lint is preferred for tests of cotton shorter than 1-3/8 inches in staple. Where only a roller gin is available, however, cotton ginned in this way will suffice, although it will not be possible to obtain

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1/ For additional information about the service, see "Promulgation of Regulations of the Secretary of Agriculture Governing Cotton Fiber and Spinning Tests under the Act of April 7, 1941." (Mimeographed.)

an accurate grade designation on spinning test samples of short staple roller-ginned lint.

A more accurate picture of the potential quality of a cotton will be obtained if lint from an early picking only is submitted. A weather-damaged, discolored sample that has been exposed in the field will naturally give poorer results than a clean, white sample picked early in the season.

Sampling Methods at the Service Testing Laboratories

In view of the high degree of variability found for all the measurable properties of cotton within a bale or even within a small sample, it is very important that care be exercised in selecting the fibers which are actually to be tested. Otherwise the test specimens may not be truly representative, and a false impression will be obtained of the cotton being tested. To eliminate, insofar as possible, the effects of such variability in the Cotton Fiber Testing Service, representative specimens are assured by drawing 32 small tufts of cotton from as many different parts of the sample. Then, by a careful, standardized procedure, the fibers from the 32 tufts are thoroughly mixed by hand into a long strand or "sliver", from which portions are drawn for the various fiber tests which may be made.

This method of sampling is carried out on every sample of cotton submitted to the Department for fiber tests under the Cotton Service Testing Act.

Description of Fiber Tests

All tests, with the exception of the X-ray tests, are carried out under standard atmospheric conditions of 65 percent relative humidity and 70 degrees F. Before the tests are made the samples are conditioned for at least 4 hours in this atmosphere.

Specimens for all the fiber tests except length as determined with the fibrograph are drawn from the mixed "sliver" previously described.

(1) Fiber length array: With the use of a Suter-Webb fiber sorter, the fibers in a 75-milligram specimen are combed and straightened, and one end of all the fibers placed in a straight line in the field of steel combs. Fibers are withdrawn from the other end of the tuft, are placed on velvet-covered boards in groups which are measured with a rule to the nearest 1/8 inch, and are weighed on a torsion balance. From these results, a "cumulative frequency curve" can be drawn on graph paper, showing the percentage, by weight, of all fibers longer than any given length.

In the laboratories of the Agricultural Marketing Service, it has been found that the following three measures, calculated from the length array data, are of importance: length at the 25 percent point of the array, or "upper quartile" length; mean length; and coefficient of variation. The first of these is simply the fiber length at an arbitrarily selected point in the array. It is the length which is exceeded by 25 percent, by weight, of the fibers in the sample. It is usually slightly longer than

the staple length, and, from tests of more than 700 different samples of upland cotton included in the regional variety series has been found to have the following average relationship to staple length as determined by the classer: 2/

Classer's length (inches) = .1942 + .7090 x upper quartile length (inches).

The mean length obtained from an array is the average length of all the fibers determined from the weight-length data. It is somewhat less than the length at the 25 percent point, and is used as a basis for the different measures of variability.

The coefficient of variation of fiber length, in percent, is a measure of the variability or lack of uniformity of the fibers in a sample. It is obtained by dividing 100 times the standard deviation of length by the mean length. For saw-ginned American upland cotton the coefficient of variation of length usually falls between about 22 and 32 percent, averaging about 27 percent. A coefficient below 22 percent would indicate very uniform cotton; above 32 percent, irregular cotton.

Differences in upper quartile length greater than about 0.025 inch may be considered to be significant when the averages of 3 tests per sample are used. In other words, because of the variability of cotton, and the normal errors of even the most careful sorting technique, a difference of 0.025 inch or less might be expected from different arrays made from the same sample of cotton; but a difference greater than this amount almost certainly indicates a real difference between two samples of cotton.

(2) Fiber Length, Fibrograph: The specimen of cotton to be measured is prepared by placing from 300 to 400 milligrams of cotton drawn from several different parts of the sample, on one of a pair of combs, and then mixing and straightening the fibers by combing them from one comb to the other. The two combs with their fringes of straightened fibers are then placed in a Hertel fibrograph. A beam of light, passing through a slit, is directed through the fringe, beginning with the densest part and gradually moving toward the outer edge composed of the ends of the longest fibers. The light which is allowed to pass through the fringe is picked up by a photoelectric cell, and the electric voltage thus generated is indicated by a galvanometer. By means of a recording pen, a continuous curve is drawn by the instrument on a record card, showing the change in the amount of light transmitted through the fringe of cotton fibers as the slit passes over different portions. Information regarding the fiber length distribution of the cotton is then obtained by analyzing the curve on the record card.

In routine testing, two measures are obtained from the card: the

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2/ This empirical equation and others to be presented in the following pages, as well as the established "benchmarks" for evaluating the various measurements, are subject to change as more data are accumulated and analyzed.

mean fiber length, and the "upper half mean" length, which is the average length of all fibers longer than the mean. The upper half mean has been found to be closely correlated with the classer's designation of the staple length. From the following empirical equation the classer's length can be estimated from the upper half mean (see footnote 2):

Classer's length (inches) = .238 + .823 x upper half mean (inches).

By dividing the mean fiber length by the upper half mean and expressing the quotient in percent, a practical measure of the variability of the fibers in the sample is obtained. This measure of uniformity will average about 76 percent for saw-ginned American upland cotton. If the value is 69 percent or less, it may be considered as an indication of irregular cotton; if 83 percent or above, the cotton is exceptionally uniform.

Pending further studies, a difference of 0.025 inches or more between two upper half means obtained from three tests each may be considered significant. (See remarks concerning the precision of fiber array data.)

(3) Fiber Strength (Round Bundle Method): This test, also known as the Chandler bundle test, involves the preparation and testing of 10 specimens in the following manner: In accordance with a standardized procedure a representative sample of cotton weighing from 50 to 75 milligrams is combed and prepared into a small tuft. This tuft is placed in a wrapping device and wrapped with sewing thread of known diameter, under a known tension. The length of thread in 10 wraps is measured as it is wound, and from this length the cross sectional area of the bundle is determined. After conditioning, the bundle is gripped by steel jaws, placed in a testing machine, and broken. From the load required to break the bundle of fibers, and the area of cross section of the bundle, the tensile strength expressed in thousands of pounds per square inch is calculated. The average strength of 10 bundles is taken as the strength of a particular cotton.

Over a wide range of staple lengths, from very short upland cotton to extra staple Sea Island, it has been found that the tensile strength of cotton fibers ranges from about 50,000 to about 110,000 pounds per square inch. Based on tests of more than 700 samples of upland cotton from the Department's regional variety series, it may be said that 80,000 pounds per square inch is the average strength of American upland cotton. A strength of 85,000 pounds may be said to be very good, and 90,000 pounds or more, excellent. A strength of 75,000 pounds would be considered fair, and 70,000 pounds or less, poor. A difference of 3,000 pounds or more between the averages of 10 breaks for two cottons may be considered significant.

Fiber strength is rather highly correlated with yarn, cord, and fabric strength; and for materials such as tire cord, sewing thread, and all mechanical fabrics in which high strength is important, it is essential that cottons of high fiber strength be employed.

(4) Fiber Strength (Flat Bundle Method): The machine on which this test is made is known as the Pressley cotton fiber strength tester. A small tuft is prepared by manipulating and combing a representative specimen drawn

from the hand mixed sliver and conditioned for at least 4 hours before testing. From this tuft, small ribbons of fibers are drawn and combed, each ribbon being about 1/2 inch wide and containing roughly 1000 fibers. A ribbon is placed in a small pair of clamps, and the ends of the fibers sheared so that the length of the fibers is equal to the thickness of the clamps, or slightly less than 1/2 inch. The clamps are placed in the tester, and a load applied by allowing a weight to roll down a balance arm on the tester. When the fibers have been broken, the strength is read directly from the balance arm. The clamps are then removed and opened, and the broken ribbon is weighed on a torsion balance.

The quotient obtained by dividing the breaking load by the weight of the ribbon is taken as the strength index. This index usually ranges between 5.0 or less to 10.0 or slightly higher.

The variability of flat bundle strength indexes from a particular cotton has been found to average relatively about the same as that for 10 Chandler strength bundles. For that reason, 10 breaks are made in using the flat bundle method. From tests of more than 100 different cottons, the following conversion formula has been developed (see footnote 2):

Estimated round bundle strength (in thousandths of pounds per square inch) = 10.8116 x flat bundle strength index -.1200.

In view of the extensive data that have been published on fiber strength as determined by the round bundle or Chandler method, it is recommended that the strength indexes obtained with the flat bundle method be converted to round bundle strength. (The remarks pertaining to the round bundle strengths, presented in the previous section, are thus applicable to the results obtained with the flat bundle test).

(5) Fiber Fineness (Weight per inch) and Maturity: In making these tests a fiber length array is first prepared. For the fineness test, 100 fibers are then drawn from each length group, and weighed. The average weight per inch of fiber in the cotton, in terms of micrograms (1/1000 of milligrams) is obtained by weighting the data for the different length groups in proportion to their relative weights in the array.

The fineness of cotton has been found to range from as low as about 2.0 micrograms per inch for the finest Sea Island to 12.0 micrograms or more for the coarsest Indian cotton. Most American upland cottons of normal maturity will fall between 3.5 and 6.0 micrograms per inch. A value of below about 4.0 micrograms indicates that the cotton is fine-fibered; above about 5.2 micrograms, that it is coarse-fibered.

Fineness is usually, but not always, inversely proportioned to length. That is, longer stapled cottons are usually finer fibered than shorter stapled cottons. Occasionally a long fibered but fairly coarse cotton is found, but this may be considered the exception rather than the rule. Other things being equal, a finer fibered cotton possesses a higher spinning quality than a coarser cotton. There is a definite place, however, for many of the coarser cottons, as in some types of manufactured products a "harsh" feel, evidently associated with the coarseness of the fibers, is highly desirable.

A false impression of inherent fineness is frequently imparted by highly immature cottons, and for this reason a measure of immaturity is almost a necessity in evaluating cottons on the basis of their fiber weight-fineness. Immaturity tests are made in the Department's service testing laboratories in the following manner:

A microscope slide is prepared for each length group in a fiber array by placing somewhat more than 100 fibers on a slide with a cover glass, and "mercerizing" or swelling them by adding a few drops of 18 percent caustic soda solution. The slide is examined with a microscope, and the number of thin-walled or immature fibers determined by inspection and counting. A swollen fiber is considered to be thin-walled or immature if its wall thickness is less than one-half the width of the lumen, or cavity within the fiber. The weighted average immaturity count is obtained from the counts of the different length groups in an array.

An average of about 27 percent immature fibers has been obtained from more than 700 cottons included in the regional variety series. A cotton with 22 percent, or fewer, thin-walled fibers may be considered highly mature; from 22 plus to 32 percent, normal; and above 32 percent, immature.

To some extent "maturity" appears to be a varietal characteristic, but in general, immaturity counts of 38 to 40 percent or above almost certainly indicate a prematurely retarded fiber development, as caused by drought, frost, weevil damage, etc.

(6) Fiber Fineness (Cross Section Method): In this test a very thin cross section is prepared by hand with the use of a modified Hardy type microtome, the fibers first being inserted in the device and treated with a special colodion preparation. The section is placed on a glass slide, and a photomicrograph of 250 diameters is made. A 4X photographic enlargement then provides a picture of the cross sections of the fibers, magnified 1000 diameters. Measurements are then made of 100 fibers selected at random from each of two areas on the enlargement. From these measurements, the average "diameter" in microns, circularity ratio, and wall thickness are calculated.

In these calculations the "diameter" of a fiber is assumed to be one-half the sum of the long axis and the short axis of the fiber cross section. The circularity ratio is the ratio of the long axis to the short axis of the fiber, and the wall thickness is one-half the difference of the over-all width less the lumen width.

These measurements, and their coefficients of variation, provide a picture of the cross-sectional characteristics not obtainable in any other way.

(7) Cellulose Alinement (X-ray): Each specimen to be measured is first prepared in much the same way as the Chandler bundle. (See discussion on page 4.) The bundle is then placed under tension in a camera attached to the X-ray machine, and the X-ray diffraction pattern recorded on a photographic film. With the use of a microphotometer of special design, an angular measure is obtained of a portion of the arc diffracted from the 002 spacing

in the crystal. This angle is an index of the average angle between the long axis of the cellulose molecules in the crystal and that of the fiber.

The angle of the cellulose molecules has been found to be correlated with the strength of the undamaged fiber. Thus, even though a cotton may have been damaged by fungi or light during exposure in the field, the X-ray angle provides an indication of the probable strength of the fiber before the damage occurred. It has been found, however, that conditions with respect to temperature and moisture during certain periods of the growth of the fiber also have an important influence on the angle of cellulose molecule alinement.

An average angle of about 34 degrees has been found for a large number of American upland cottons. An angle of 32 degrees indicates very good strength; below 31 degrees, excellent strength. An angle of 38 degrees or more indicates poor strength.

Description of Spinning Tests

The spinning tests made in connection with the Cotton Fiber Testing Service are conducted by trained technologists who use techniques developed and standardized in the laboratories of the Agricultural Marketing Service over a period of years. The manufacturing equipment used is essentially of commercial design, although a few minor modifications have been made to adapt some of the machines to the special requirements of spinning tests of small samples.

It is common commercial practice to produce "carded yarns" from most cottons shorter than 1-1/8 inches in staple length, and "combed yarns" from most cottons longer than 1-1/8 inches in staple length. In lengths of about 1-1/8 inches, some cottons are spun into carded and others into combed yarns, depending upon the kind of product being made. The difference between the two qualities of yarn lies in the fact that in the production of combed yarn, the cotton is passed through a combing machine, in addition to the card. The comber takes out from 9 to 20 percent additional waste in the form of "noils", consisting chiefly of short fiber, and neps and particles of foreign matter that have passed through the card. Combed yarns are smoother, cleaner, and stronger than carded yarns. Practically all commercial yarn finer than about 45s to 50s count is combed.

As indicated in the regulations covering the service testing, cottons up to and including 1-5/32 inches in staple length submitted for spinning tests will be spun into carded yarns, unless otherwise requested; and cottons of 1-3/16 inch length or longer, into combed as well as carded yarns.

(1) Spinning Test (Carded Yarns): As soon as the test sample is opened at the spinning laboratory, a representative sample is drawn and sent to Washington, D. C. for classification by the Appeal Board of Review Examiners. The spinning test sample is then carefully weighed and passed successively through nine manufacturing processes, the final product being a quantity of spun yarn. Machine roll settings and yarn twists are selected on the basis of the technologists' experience with cottons of all staple lengths and qualities, to produce the best yarns possible from the available equipment.

Three counts of yarn are spun, including 22s and two finer counts selected to represent a fine and an intermediate count for the particular staple length of the cotton.

The spinning tests are carried out under relative humidities of 50 percent in the picker room, 60 percent in the card room, and 70 percent in the spinning rooms of each laboratory. The humidifying or conditioning systems are manually controlled in the picker room but automatically controlled in the card and spinning rooms. Yarn testing is carried out under standard conditions of 65 percent R.H. at a temperature of 70° F.

(a) Manufacturing Waste: The percentage of each important type of waste removed during manufacturing is determined. These include (1) picker waste, and (2) flat strips, cylinder and doffer strips, and other waste (motes and fly waste) removed by the card. When the results are reported, the total percentage of picker and card loss is compared with an average of similar values obtained from large numbers of cottons of the same grade. Any departure from the average with regard to the quantity and quality of the waste removed is noted and discussed.

(b) Yarn Strength: The yarns obtained from the manufacturing laboratory are tested for skein strength and size in the yarn testing laboratory, the recognized standard procedure for such tests being followed. The individual strength and size values for from 25 to 60 skeins of yarn are averaged for each count spun. A strength index is obtained by determining the percentage that the strength of a given yarn is of an average value obtained from the following equation:

$$S = \frac{428.69 + 2145.18L - 18.42C}{C}$$

in which S is the skein strength of carded yarn in pounds,
L is the staple length of the cotton in inches,
and C is the count of the yarn.

This equation was obtained from an analysis of tests of more than 700 pure-bred American upland cottons included in the Department's regional variety studies.

The skein strength of a yarn is the most important single index of quality obtained from a spinning test. It is an indication of the spinning and weaving quality of a cotton and of its utility, or suitability for various kinds of products. An index of 100 for a particular cotton would indicate that it was equal in strength to the average obtained in the Department's laboratories for the regional variety studies. If the index is above 100, its strength is superior; if below 100, inferior.

(c) Yarn Appearance: The test yarns are also graded for appearance, giving an index of their suitability for threads and fabrics such as sewing thread, dress goods, and the like, in which appearance is an important quality element. This is done by winding the yarns on black boards and comparing them with standards developed by the Department. Yarn may range from "A+" to "D-" in appearance. As a general rule, in yarns of approximately 20s to 30s count, "B" is the lowest grade that may be considered generally satisfactory for most types of carded yarns, and a yarn graded as "B+" or

above is usually desired for goods in which appearance is an important factor. In the finer counts of carded yarns slightly lower grades of appearance are usually unavoidable but are generally acceptable. Yarn appearance, which includes such factors as evenness, smoothness, and cleanliness, has been found to be affected by both variety and growth conditions.

(d) Manufacturing Performance: The fourth item of quality provided by the spinning test is the over-all manufacturing performance. It is important to a cotton manufacturer to know whether a cotton has any peculiarities that might have an effect on the efficiency of a mill when spun on a commercial scale. For example, a cotton might require an unusually low amount of roving and yarn twist, a characteristic that would reduce manufacturing costs to some extent. Or another cotton might reveal during the test a tendency toward roller lapping for one of several reasons, foretelling serious trouble and increased manufacturing costs for a mill purchasing such cotton. Throughout the conduct of a spinning test, the technologists make frequent observations at significant points, and note any unusual features. These are later summarized in a brief report of the manufacturing performance of each sample tested.

(2) Spinning Test (Combed Yarn): As previously explained, when cottons of 1-3/16 inch staple or longer are submitted for tests, combed as well as carded yarns are spun and tested in the laboratories. (Any sample longer than 1 inch in staple will be combed, however, in cases where specific requests are made.) The chief advantage of employing both types of test for long staple cottons is that it not only permits a comparison of a cotton with findings from large numbers of carded cotton, but it also provides concrete evidence of the kind of yarn the cotton will produce when manufactured in the usual manner for such a staple length. It shows the actual strength and appearance of combed yarn spun from the sample, and also demonstrates whether the improvement in yarn strength made by the combing process is normal, or above or below normal in this respect.

The items relating to manufacturing waste, yarn strength, yarn appearance, and manufacturing performance for a test involving combed yarns are handled in the same way as those for a carded yarn test. (See discussion on page 7.)

(3) Other Analyses Included in Reports of Spinning Tests: When both fiber and spinning tests are requested an effort is made in reporting the results to explain, as far as possible, the spinning test results in the light of the fiber properties. Such an analysis can be of considerable value to a cotton breeder by pointing out the good and the bad fiber features and showing how they influence the factors in which the manufacturer is interested.

The report of the spinning tests also includes a brief statement as to the general type of manufactured product for which the sample appears to be suited, as for example, sewing thread, tire cord, mechanical fabrics, print cloth, sheeting, or coarse or fine dress fabrics.

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