Designation: D1440 – 07 (Reapproved 2012)

Standard Test Method for Length and Length Distribution of Cotton Fibers (Array Method)[1]

This standard is issued under the fixed designation D1440; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the determination of the fiber length and length distribution in loose cotton fibers.

NOTE 1—For another method for measuring fiber length, see Test Method D1447.

1.2 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D123 Terminology Relating to Textiles
D1441 Practice for Sampling Cotton Fibers for Testing
D1447 Test Method for Length and Length Uniformity of Cotton Fibers by Photoelectric Measurement
D1776 Practice for Conditioning and Testing Textiles
D7139 Terminology for Cotton Fibers

3. Terminology

3.1 For all terminology related to D13.11, Cotton Fibers, see Terminology D7139.

3.1.1 The following terms are relevant to this standard: coefficient of variation, length group, length interval, mean length, pull, upper quartile length.

3.2 For all other terminology related to textiles see Terminology D123.

4. Summary of Test Method

4.1 A sorting apparatus consisting of two banks of parallel combs is used to straighten and align the fibers in a 75-mg test specimen. The fibers are pulled from one bank of combs and transferred to the other in such a manner that one end of each fiber is aligned with the base comb. The transfer is repeated to straighten the other ends of the fibers. As the fibers are withdrawn from the combs for the third time, they are placed in order of length on velvet covered boards. The pulls are measured, and those that fall within each length interval are collected and weighed. From these weight-length data, the upper quartile length, mean length, and coefficient of length variation are calculated.

5. Significance and Use

5.1 The array method provides objective measurements for determining the fiber length and length distribution in a sample of cotton. The results can be plotted to show the length-weight distribution of all the fibers in the sample. Data obtained from array tests are useful in fiber length research studies, for investigation of changes in fiber length distribution in ginning and mill processing, and for other research purposes.

5.2 Upper quartile length is correlated with, but usually longer than, Fibrograph and 2.5 % span length as defined in Test Method D1447. Judgment must be used in making comparisons between length measures from arrays and measures obtained by other methods, which may be basically different.

5.3 The coefficient of length variation is a measure of length distribution, or nonuniformity of length. Because the fiber weight-length distribution is usually highly skewed, statistical judgments based on the assumption of normality are not justified.

5.4 The array method makes a physical separation of fibers of different lengths. It therefore serves as a standard, or benchmark, with which other methods may be compared and by which their precision and accuracy may be judged.

5.5 Test Method D1440 for testing length and length distribution of cotton fibers (array method) is not commonly used for acceptance testing of commercial shipments.

6. Apparatus and Materials

6.1 *Double Bank Sorter,* and equipment as illustrated in Fig. 1. The method outlined here is especially adapted to the

[1] This test method is under the jurisdiction of ASTM Committee D13 on Textiles and is the direct responsibility of Subcommittee D13.11 on Cotton Fibers.

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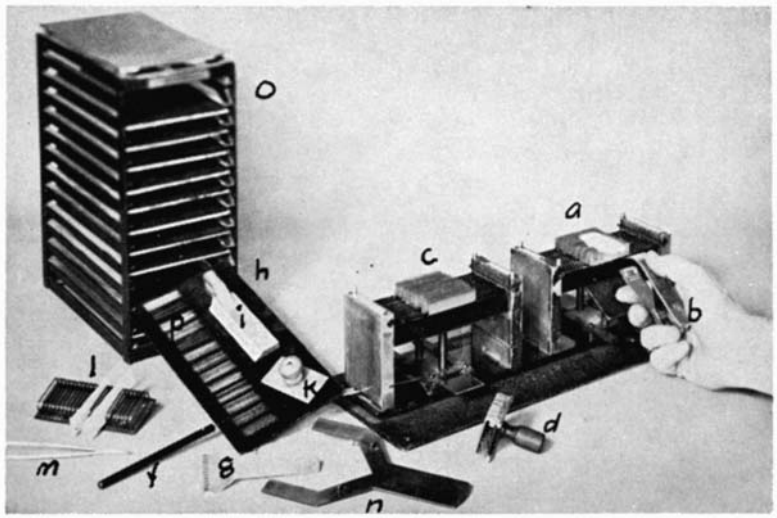
[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.



a and *c*—Banks of combs.
b—Forceps, tips padded with hard leather, for transferring fibers from one set of combs to the other.
d—Depressor for placing fibers in combs.
f—Dissecting needle.
g—Fork for scooping up fiber groups off velvet surface.
h—Aluminum plate covered with velvet cloth.
i—Special rule for measuring length of fiber groups.
k—Smooth plate for placing fibers onto velvet surfaces.
l—Wire rack for holding fiber groups wrapped in papers.
m—Smooth pointed tweezers.
n—Lift for raising combs in place.
o—Rack for holding velvet-covered boards.
p—Velvet-covered boards on which several pulls have been arrayed.

NOTE 1—Other accessories required for length arraying, not shown above, consist of the following: small whisk broom for cleaning velvet surfaces, one pair of tweezers with smooth round tips, forceps similar to *b* but having tips padded with rubber for laying groups on velvet surfaces, small papers for wrapping groups of fibers (papers 2½ by 3 in. (62 by 75 mm)) with small envelopes for them (2½ by 4¼ in. (62 by 110 mm)), and balances having ranges from 0 to 25 mg and 0 to 100 mg.

FIG. 1 Combs and Accessories for Arraying Fibers According to Length

Suter-Webb Duplex Cotton Fiber Sorter,[3] but the procedure may be carried out with other similar apparatus with more or less obvious alterations.

6.2 *Balance,* with a capacity of at least 25 mg and a sensitivity of ±0.05 mg.

6.3 *Balance,* with a capacity of at least 100 mg and a sensitivity of ±0.1 mg.

6.4 *Standard Calibration Cotton Samples,* for the calibration of array length measurements.

NOTE 2—Standard calibration cotton samples are available from the Cotton Division, Agricultural Marketing Service, U.S. Department of Agriculture, 3275 Appling Rd., Memphis, TN 38133.

6.5 *Secondary Standard Cotton*—Lots of cotton the length of which has been established by extensive comparisons with USDA standards.

7. Sampling

7.1 Prepare the laboratory sample as directed in Practice D1441. Take either two or three subsamples depending on the precision desired. Take subsamples that weigh approximately 80 mg each for use in preparing the test specimen in one of the following manners:

7.1.1 From a hand sliver, carefully separate a 2-in. (50-mm) length of the sliver for each subsample.

7.1.2 From a mechanically blended 3-g sliver, separate 2-in. (50-mm) subsamples.

7.1.3 From a mechanically blended 10-g sliver, pull out of the middle of the sample a subsample about 2 in. (50 mm) long, extending through its whole thickness, and wide enough to weigh approximately 80 mg. Take subsamples from near the beginning, midway, and near the end of the sliver.

7.2 If the laboratory samples have not been in the standard atmosphere for at least 2 h before the preparation of subsamples, bring the subsamples to approximate equilibrium with the standard atmosphere for testing before preparing specimens. Exposure to moving air in the laboratory for 2 h is sufficient.

8. Preparation of Test Specimen

8.1 Prepare one specimen from each of the three subsamples. Gently parallelize the fibers by hand. Remove all foreign matter, but do not discard any fibers.

8.2 Separate from each subsample, by longitudinal division, a portion weighing approximately 76 mg. If the specimen

[3] The sole source of supply of the apparatus known to the committee at this time is the Alfred Suter Co., New York, NY. If you are aware of alternative suppliers, please provide this information to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.

weighs more than 77 mg, reduce its weight by removing a small group of fibers from the side of the specimen. If the specimen weighs less than 75 mg, add a small group of fibers taken from the side of the subsample. Never remove fibers from either the specimen or subsample by pulling from the ends, as this tends to remove the longest fibers. After adjusting the specimen weight to approximately 76 mg, condition the specimen and the remaining portion of the subsample in accordance with Section 9.

9. Conditioning

9.1 Practice D1776 covers the conditioning of textiles for testing. If the laboratory samples have a moisture content of 10 % or higher, Practice D1776 should be used to condition the samples for testing. For samples below 10 % moisture content, the conditioning procedure outlined in 9.2 and 9.3 is considered adequate for length testing by this test method.

9.2 If the laboratory samples have not been in the standard atmosphere for at least 2 h before the preparation of the subsample, bring the subsamples to approximate equilibrium with the standard atmosphere for testing before preparing specimens. Exposure to moving air in the laboratory for 4 h is sufficient.

9.3 After the specimens have been prepared, condition them in the standard atmosphere for testing. Exposure to moving air in the standard atmosphere for a minimum period of 2 h is adequate for this test method.

10. Procedure

10.1 Weigh the conditioned specimen to the nearest 0.1 mg. Do not touch the specimen with the fingers after conditioning. If the specimen weighs more than 75.4 mg, use the tweezers (Fig. 1, *m*) to remove a small group of fibers from the side of the specimen. If the weight is less than 74.6 mg, add a small group of fibers taken with tweezers from the side of the subsample. Do all sorting, measuring, and weighing in the standard atmosphere for testing.

10.2 Before testing other samples, each technician shall have made an array on a check test cotton (Note 2), if this has not been done during the previous month. Results of regularly scheduled check tests may be used for this purpose. If the results do not agree with the standard value for the check test cotton within ±0.02 in. (0.51 mm) in both upper quartile and mean length and ±2.0 % for the coefficient of length variation, the technician must make some appropriate change in technique and repeat the check test until acceptable results are obtained.

10.3 If two or three technicians are available, have each technician sort one of the three specimens.

10.4 *First Transfer:*

10.4.1 Place the test specimen in the left bank of combs perpendicular to and approximately in the center of the combs. Using the depressor (Fig. 1, *d*), depress the test specimen at least 1⁄16 in. (2 mm) below the tips of the comb teeth, but no lower than half the length of the teeth. The comb fork can be used to raise any fibers that are depressed below this level.

10.4.2 Drop front combs of the left bank until a smaller number of fibers protrude beyond the comb nearest the operator.

10.4.3 Grip the ends of a few of these fibers with the forceps (Fig. 1, *b*) and withdraw them from the combs with a smooth horizontal motion.

10.4.4 Continue holding the fiber ends with the forceps. Place the forceps at the farther edge of the right bank of combs and draw the fibers carefully through the combs until the edge of the forceps is just touching the near edge of the first comb. Release the fibers from the forceps. With the depressor, push the fibers down for a short distance into the teeth of the combs. Repeat this procedure until the transfer of all protruding fibers is complete. The fibers should not protrude more than 1⁄16 in. (2 mm) beyond the nearer comb of the right bank.

10.4.5 Drop an additional comb of the left bank and continue transferring the fibers. Do not withdraw in one pull all of the fibers protruding from a comb, but take four or more separate pulls, withdrawing in each pull those fibers which protrude farthest. The width of the specimen placed in the right comb bank should be no greater than the width of the forceps being used.

10.4.6 Continue the transferring procedure, dropping combs as necessary, until all the fibers have been transferred from the left to the right set of combs.

10.4.7 Using the dissecting needle (Fig. 1, *f*), gently untangle the fiber ends extending beyond the front comb. With the forceps, pull out any fibers that extend more than approximately 1⁄16 in. (2 mm) beyond the front comb and replace them in the same bank of combs in the manner described in 10.4.4. Continue until the front ends of the fibers are straight and even.

10.4.8 Drop the back combs of the bank containing the specimen until fibers are encountered. Pull these protruding fibers from the back of the combs and place them on the test specimen in the same manner as was done in the transfer of the specimen. Continue this straightening process until fibers pulled from the back combs extend through the front comb and the ends of the specimen are straight and even. This completes the first transfer.

10.5 *Second Transfer:*

10.5.1 Raise the empty bank of combs to the working position and rotate the sorting apparatus 180° so that the specimen is on the left.

10.5.2 Repeat the procedure used in the first transfer, steps 10.4.2 – 10.4.8, transferring the specimen back to the first set of combs.

10.6 *Array:*

10.6.1 Insert top combs.

10.6.2 Revolve the sorting apparatus 180° and drop front combs until the longest fibers are reached.

10.6.3 Using the rubber-tipped forceps (Fig. 1, *b*), pull out a few of the longest fibers protruding from the front comb. Lay the pull near one end of the velvet covered board and near the long edge that is farthest from the hand holding the forceps. Continue holding with the forceps and cover the pull with the smooth plate (Fig. 1, *k*), press down gently and move forceps and plate together toward the nearer edge of the board, thus dragging the fibers across the velvet and straightening them.

Press the fibers down firmly against the velvet, release from the forceps, and continue the sliding movement of the plate to press down the front ends of the fibers.

10.6.4 Continue the process of withdrawal and placement of fibers on the velvet boards, placing each successive pull approximately 3⁄16 in. (5 mm) from and parallel to the preceding pull. It is convenient, but not essential, to place 10 pulls on each board. In an acceptable array, the pulls may vary in density, but will be in order of length. The total number of pulls in an array should not be less than 65 nor more than 100. To facilitate accurate measurement, keep the ends as clearly defined and as nearly in line as possible. Fiber slippage and gripping of uneven ends during transfer, withdrawal, and laying down will result in ragged and uneven arrays which are difficult to measure.

10.6.5 Continue the process of withdrawing fibers from the combs and placing them on the boards, dropping combs as necessary, until all the fibers have been placed on the boards.

10.7 *Measuring and Grouping:*

10.7.1 Have the original operator and one other technician carefully and independently measure the pulls on the velvet boards with the special scale (Fig. 1, *i*). Begin measuring with the first pull laid down and record the number of pulls in each length group (a convenient data form is illustrated in Fig. 2). Continue until all the pulls have been measured. Pulls whose lengths fall clearly within the limits of a length interval are easily allocated to the proper length group. The length of each pull is determined by the point where most of the fibers end rather than by the ends of the longest fibers. If a pull seems to end exactly on the dividing line between two length intervals, assign it to the longer length group.

10.7.2 If the two technicians disagree by more than two pulls in a single length group, have both remeasure the array. When agreement within 2 pulls per length group is reached, average the two counts of the number of pulls in each length group, beginning with the longest (Fig. 2). If the average is not a whole number, record the next smaller whole number and carry down one pull to the next (shorter) length group. The 5⁄16 and 3⁄16 groups in Fig. 2 are examples of this.

10.7.3 Rake the pulls together into length groups on the basis of the average of the two counts. Place each length group in a folded black paper marked with its midpoint length, and place them in order in the metal rack (Fig. 1, *l*).

10.8 *Weighing:*

10.8.1 Beginning with the longest, weigh each length group on the 25-mg balance. Record the weights to the nearest 0.1 mg in appropriate spaces on the data sheet (Fig. 2).

10.8.2 If the sum of the weights is 75.0 ± 2.0 mg, record it on the data sheet. If the sum is not within these limits, reweigh the array. If the sum of the second weighings is not within the prescribed limits, discard the array.

10.8.3 If tests for fiber weight per unit length or maturity are to be made on the same array, replace the length groups in their papers and preserve each array in a properly labeled envelope.

11. Calculation

11.1 Perform the calculations on a work sheet similar to that shown in Fig. 2.

11.1.1 *Upper Quartile Length* (25 % *point*)—Starting with the longest group, add the weights until a sum is obtained that is equal to, or greater than, one fourth of the total weight of the array and note the lower limit of the array length group at or in which this partial sum occurs. As shown on the work sheet, determine by interpolation the increment of length to be added to the lower limit just noted.

11.1.2 *Mean Length and Coefficient of Length Variation*—Calculate the mean length and coefficient of length variation as shown in the sample in Fig. 2.

11.1.3 If desired, determine the percentage of fibers shorter than ½ in. (12 mm) by subtracting the percent longer than ½ in. (last column) from 100 %.

12. Report

12.1 State that the specimens were tested as directed in Test Method D1440. Describe the material or product sampled and the method of sampling used.

12.2 Report the following information:

12.2.1 Upper quartile length to two decimal places.

12.2.2 Mean length to two decimal places.

12.2.3 Coefficient of variation for length to the nearest 1.0 %.

12.2.4 Percent shorter than ½ in. (12 mm), if determined.

12.2.5 Number of specimens tested for each sample.

13. Precision and Bias

13.1 *Interlaboratory Test Data*[4]—An interlaboratory test was carried out in 1969 in which two operators in each of three laboratories performed fiber length tests by the array method. Both operators tested a specimen from each of five subsamples from each cotton to establish standard values for each of five different cottons. Each of the subsamples was coded with a different number and the results were decoded after the tests were completed. The operators performing these tests had better than average skill and extensive experience. The level of the results for the participating laboratories were controlled by the use of the same control cottons. The components of variance expressed as standard deviations are listed below:

Test Item	Single operator	Within-Laboratory	Between Laboratory
Upper quartile length, in.	0.01905	0.00140	0.00623
Mean length, in.	0.02196	0.00227	0.01307
Coefficient of variation, percent of average	1.450	0.361	1.173
Fibers shorter than ½ in., percentage points	1.441	0.033	1.162

13.2 *Precision*—For the components of variance reported in 13.1, the averages of observed values for both the three specimen and the two specimen tests should be considered significantly different at the 95 % probability level if the differences equal or exceed the critical differences below:

[4] ASTM Research Report No. D13-1007. A copy is available from ASTM Headquarters.

FIBER LENGTH—ARRAY METHOD (Work sheets may be prepared based upon metric units throughout).		Test: CHECK	
		Laboratory No.: 10	
Silver by: A.B.	Sampled by: M.B.	Weighed by: A.B.	Lot No.
Sorted by: R.B.	Checked by: M.B.	Calculated by: B.M.	Checked by: M.B.

Length, L	Lower Limits (in.)	Number of Pulls		Average	Group Weights, W	Length Squared, L^2	Fiber Distribution	
		Technician 1	Technician 2				Sum of Weights	Cumulative Percentage of Fibers
39	2.375					1,521		
37	2.250					1,369		
35	2.125					1,225		
33	2.000					1,089		
31	1.875					961		
29	1.750					841		
27	1.625					729		
25	1.500					625		
23	1.375	5	5	5	4.0	529	4.0	5.31
21	1.250	4-6	4-6	10	11.6	441	15.6	20.74
19	1.125	3-10-3	3-10-3	16	18.9	361	34.5	45.88
17	1.000	7-5	7-5	12	13.2	289	47.7	63.43
15	0.875	5-6	5-6	11	9.0	225	56.7	75.40
13	0.750	4-2	4-2	6	5.1	169	61.8	82.18
11	0.625	6	4	5	3.8	121	65.6	87.23
9	0.500	2-1	4-1	4	1.7	81	67.3	89.49
7	0.375	7	7	7	3.2	49	70.5	93.75
5	0.250	2-2	2-1	3	2.3	25	72.8	96.81
3	0.125	3	4	4	1.6	9	74.4	98.94
1	0.000	1	1	1	0.8	1	75.2	100.00
Neps						Totals		
Totals		84	84	84	75.2	Reciprocal:		

$\Sigma WL = 1217.0$ $\Sigma WL^2 = 21583.2$

CALCULATIONS

A. Upper Quartile Length (25 % Point):
1. Cumulative sum of longest group weights equal to or greater than quartile. = 34.5
2. Quartile = $\Sigma W/4$ ..... = 18.8
3. Difference (Line 1 minus Line 2) ..... = 15.7
4. Correction = Difference × 0.125/weight of group containing U.Q.L. = 15.7 × 0.125/18.9 = 0.1038 in.
5. Lower limit of group containing U.Q.L. ..... = 1.1250 in.
6. Upper quartile length (Line 4 plus Line 5) ..... = 1.2288 in.

B. Mean Length = $\Sigma WL/(\Sigma W \times 16) = \frac{1217.0}{\Sigma W \times 16} = \frac{1217.0}{1203.2} = 1.011469$ in.

C. Variance:
1. $\Sigma WL^2/(\Sigma W \times 256) = \frac{21583.2}{\Sigma W \times 256}$ = 1.121135 in.
2. $(\text{Mean Length})^2$ ..... = 1.023070 in.
3. Variance (Line 1 minus Line 2) ..... = 0.098065 in.

D. Standard deviation:
S.D. = $\sqrt{\text{Variance}}$ ..... = 0.313

E. Coefficient of variation:
$\frac{\text{S.D.} \times 100}{\text{mean length}}$ ..... = 30.95 %

F. Percentage of fibers shorter than ½ in. or other specified length groups, or both.
Example for ½ in.:
= 100 – Cumulative percentage of fibers in length group 9
= 100 – 89.49 = 10.51

G. Average for Array Test				
Specimen	U.Q.L. (in.)	Mean (in.)	C.V. (%)	Shorter Than ½ in. (%)
1	1.2288	1.0115	30.95	10.5
2	1.2369	1.0255	30.52	8.7
3	1.2172	1.0037	31.28	11.8
Average	1.2276	1.0136	30.92	10.3

FIG. 2 Form Suitable for Recording Original Observations and Calculating Various Statistics for Length by the Fiber Array Method

Number of Specimens in Test and Item[A]	Single-Operator	Within Laboratory	Between-Laboratory
Three-specimen test:			
Upper quartile length, in.	0.030	0.031	0.035
Mean length, in.	0.035	0.036	0.051
Coefficient of variation, percent of average	2.3	2.5	4.1
Fibers shorter than ½ in., percentage points	2.3	2.3	4.0
Two-specimen test:			
Upper quartile length, in.	0.037	0.038	0.041
Mean length, in.	0.043	0.043	0.057
Coefficient of variation, percent of average	2.8	3.0	4.4
Fibers shorter than ½ in., percentage points	2.8	2.8	4.3

[A] The values for the critical differences used above were calculated using $t = 1.960$ which is based on an infinite number of degrees of freedom. These values are applicable only when the tests are performed by skilled operators in laboratories which control the level of results by use of standard calibration cottons.

NOTE 3—The tabulated values for the critical differences should be considered to be a general statement particularly with respect to between-laboratory precision. Before a meaningful statement can be made about two specific laboratories, the amount of statistical bias, if any, between them must be established with each comparison being based on recent data obtained on randomized specimens from one sample of the material to be tested.

13.3 *Bias*—This array method Test Method D1440 for the determination of length and length distribution of cotton fibers is not subject to any known bias and is considered the most accurate method available, with the possible exception of the measurement of a very large number of single fibers. It is the standard by which the bias of the other methods is judged.

14. Keywords

14.1 cotton; length