Standard Test Method for Diameter of Wool and Other Animal Fibers by Microprojection[1]

This standard is issued under the fixed designation D 2130; 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 a procedure, using the microprojector, for the determination of the average fiber diameter and the fiber diameter variation on wool and other animal fibers, such as mohair, cashmere, alpaca, camel's hair, etc. (Note 1) in their various forms.

1.2 The values stated in inch-pound units are to be regarded as the standard. The metric equivalents of inch-pound units may be approximate.

NOTE 1—This test method may also be applied to any fibers having a round cross section and accordingly may be used many times for melt-spun man-made fibers such as polyamides, polyesters, and glass; also it may be applied to a limited number of polyacrylics and regenerated cellulose type fibers. The values given in Appendix X1 for density and correction factors, however, apply only to wool and should not be used for other fibers. For suitable values for the density of other fibers, see Table 5 in Test Methods D 629, Quantitative Analysis of Textiles.[2]

NOTE 2—In subsequent sections of this test method, the term "wool" also signifies mohair or other fibers if the circumstances are applicable.

NOTE 3—For fineness specifications for wool, wool top, mohair, mohair top, alpaca, and cashmere, refer to Specifications D 3991 and D 3992, Specification D 2252, Test Method D 2816.

1.3 *This standard does not purport to address 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:*

D 123 Terminology Relating to Textiles[2]

D 584 Test Method for Wool Content of Raw Wool—Laboratory Scale[2]

D 629 Test Methods for Quantitative Analysis of Textiles[2]

D 1060 Practice for Core Sampling of Raw Wool in Packages for Determination of Percentage of Clean Wool Fiber Present[2]

D 1776 Practice for Conditioning Textiles for Testing[2]

D 2252 Specification for Fineness of Types of Alpaca[2]

D 2258 Practice for Sampling Yarn for Testing[2]

D 2816 Test Method for Cashmere Coarse-Hair Content in Cashmere[2]

D 2968 Test Method for Med and Kemp Fibers in Wool and Other Animal Fibers by Microprojection[2]

D 3510 Test Method for Diameter of Wool and Other Animal Fibers by Image Analyzer[3]

D 3991 Specification for Fineness of Wool or Mohair and Assignment of Grade[4]

D 3992 Specification for Fineness of Wool Top or Mohair Top and Assignment of Grade[4]

E 380 Practice for Use of the International System of Units (SI) (the Modernized Metric System)[5]

2.2 *Other Standards:*

Federal Standard, Official Standard of the United States for Grades of Wool, Section 31.0, Measurement Method for Determining Grade of Wool, Section 31.204[6]

IWTO-8-66(E) Method of Determining Wool Fiber Diameter by the Projection Microscope[7]

3. Terminology

3.1 *Definitions:*

3.1.1 *average fiber diameter, n— in wool and other animal fibers*, the average width of a group of fibers when measured on a projected image.

3.1.2 *grade, n—in wool and mohair*, a numerical designation used in classifying wool and mohair in their raw, semiprocessed, and processed forms based on average fiber diameter and variation of fiber diameter.

3.1.3 For definitions of other textile terms used in this test method, refer to Terminology D 123.

4. Summary of Test Method

4.1 This test method describes procedures for sampling various forms of wool and other animal fibers, the reduction of the sample to small test specimens, and the measurement, at high magnification, of the diameter of a number of fibers from

[1] This test method is under the jurisdiction of ASTM Committee D13 on Textiles and is the direct responsibility of Subcommittee D13.13 on Wool and Wool Felt.

Current edition approved Jan. 26, 1990. Published May 1990. Originally published as D 2130 – 61. Last previous edition D 2130 – 88.

[2] *Annual Book of ASTM Standards*, Vol 07.01.

[3] Discontinued, see *1986 Annual Book of ASTM Standards*, Vol 07.02.

[4] *Annual Book of ASTM Standards*, Vol 07.02.

[5] *Annual Book of ASTM Standards*, Vol 14.02.

[6] *Service and Regulatory Announcement*, No. 135, U. S. Department of Agriculture, C & MS, April 1966.

[7] International Wool Textile Organization, International Wool Secretariat, Raw Wool Services, Valley Drive, Ilkley, Yorkshire LS29 8PB, England.

Copyright © ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, United States.

the test specimens. From the observed data, computations are made to obtain the average fiber diameter, a measure of variation of fiber diameter and the percentage of medullated and kemp fibers, if present, as directed in Test Method D 2968.

5. Significance and Use

5.1 This test method specifies a sampling and testing procedure for the measurement of average fiber diameter and variation in diameter of animal fibers as required in Test Method D 2968.

5.2 Test Method D 2130 for testing wool and other animal fibers for average fiber diameter is considered satisfactory for acceptance testing of commercial shipments since current estimates of between-laboratory precision are acceptable and the method has been used extensively in the trade for acceptance testing. In cases of disagreement arising from differences in values reported by the purchaser and the seller when using this method for acceptance testing, the statistical bias, if any, between the laboratory of the purchaser and the laboratory of the seller should be determined with each comparison being based on the testing of specimens randomly drawn from one sample of material of the type being evaluated.

6. Apparatus and Material

6.1 *Microprojector*[8]—The microscope shall be equipped with a fixed body tube, a focusable stage responsive to coarse and fine adjustments, a focusable substage with condenser and iris diaphragm, and a vertically installed adequate light source to give a precise magnification of 500×, that is, a 12.5× eyepiece and a 21×, 0.50 numerical aperture objective.

6.2 *Stage Micrometer* ,[9]—calibrated in intervals of 0.01 mm for accurate setting and control of the magnification.

6.3 *Fiber Sectioning Apparatus*:

6.3.1 *Heavy-Duty Sectioning Device*[10]—An instrument comprised of a metal plate with slot and compressing key and equipped with a propulsion mechanism by which the fiber bundle may be extruded for sectioning. The instrument (Fig. 1) is designed to hold a sliver of top or equivalent bulk of fibers, yarn, or fabric.

[8] Obtainable from R and B Instruments, Leeds, Wortly. Low Mills, 318 Whitehall Rd., Leeds L512 4RJ England.

[9] Obtainable from most scientific laboratory instrument supply companies.

[10] Obtainable from Joe Opheikens, 426 Adams, Ogden, UT 84404 and MICO Instruments, 1944 Main St. P.O. Box 451, Marshfield Hills, MA 02051-0451.

FIG. 1 Heavy-Duty Cross-Section Device

6.3.2 *Safety Razor Blades*—Single-edge or double-edge blades (if used with blade holder).

6.3.3 *FRL Fiber Cutter*[11]—A device comprised of two razor blades, a threaded pin and an assemblage that will hold the blades rigidly in position. The device (Fig. 2), which is operated by applying pressure vertically downward, cuts fibers approximately 250 µm (Note 4) in length.

NOTE 4—A description of the Swiss Fiber Cutting device described in earlier editions can be found in Part 25 of the *Annual Book of ASTM Standards*, issued in 1971 and previous volumes.

6.4 *Microscope Slides*, 1 by 3 in. (25 by 75 mm).

6.5 *Cover Glasses*, No. 1 thickness, 7⁄8 by 2 in. (22 by 50 mm).

6.6 *Mounting Medium*[12]—Colorless immersion oil with a refractive index of 1.480 ± 0.005 at 68°F (20°C), and a viscosity of 78.81 SUS at 100°F (37.8°C).

6.7 *Wedge Scale*[13]—Strips of heavy paper or Bristol board, imprinted with a wedge for use at a magnification of 500× (Fig. 3).

6.8 *Box for Compressing Loose Fibers*—A box 12 by 6 by 15 in. (300 by 150 by 375 mm) deep, inside dimensions, equipped with a floating top which has 16 randomly spaced holes 0.75 in. (20 mm) in diameter over its area. The wool may be firmly compressed by applying pressure on the top. The top is held in place by two rods extending through holes in the side of the box and over the top. The coring tube is thrust through the holes in the top to sample the wool.

6.9 *Pressure Coring Tube*[14]—A 1⁄2-in. (13-mm) inside-diameter metal tube, approximately 30 in. (760 mm) long, reamed and tapped on one end to hold a sharp 3⁄8 or 1⁄2-in. (10 or 13-mm) cutting tip. The tube is fitted with a "T" cross bar about 20 in. (500 mm) long.

6.10 *Core Extruder*— A 0.25-in. (6-mm) wood dowel or aluminum rod slightly longer than the coring tube to extrude wool from tube.

7. Sampling

7.1 *Loose Fibers*— The method of obtaining a representative sample of wool will differ according to circumstances. The sampling procedures and major circumstances encountered are as follows:

7.1.1 *Lots of Packaged, Grease, Pulled, or Scoured Wool*—Take core samples as directed in Practice D 1060. Clean or scour the raw wool sample as directed in Test Method D 584. If a representative portion of the scoured wool core sample resulting from the test for clean wool fiber present is available, it may be used for fiber diameter determination. If core sampling is not feasible, take at random, by hand, at least 50 handfuls of wool from not less than 10 % of the packages. The aggregate mass of the sample shall be at least 3 lb (1.5 kg).

[11] Obtainable from Albany International Research Co., 1000 Providence Highway, Dedham, MA 02026.

[12] Obtainable from YoCOM-McColl Testing Laboratories, Inc., 540 West Elk Place, Denver, CO 80216.

[13] Obtainable from E. J. Powers Press, 201 South St., Boston, MA 02111 and Visual Inspection Products, 50 High St., Lynn, MA 01902.

[14] Obtainable from YoCOM-McColl Testing Laboratories, Inc., 540 W. Elk Place, Denver, CO 80216 and Aero Associates, Inc., 163 Merrimac St., Woburn, MA 01801.

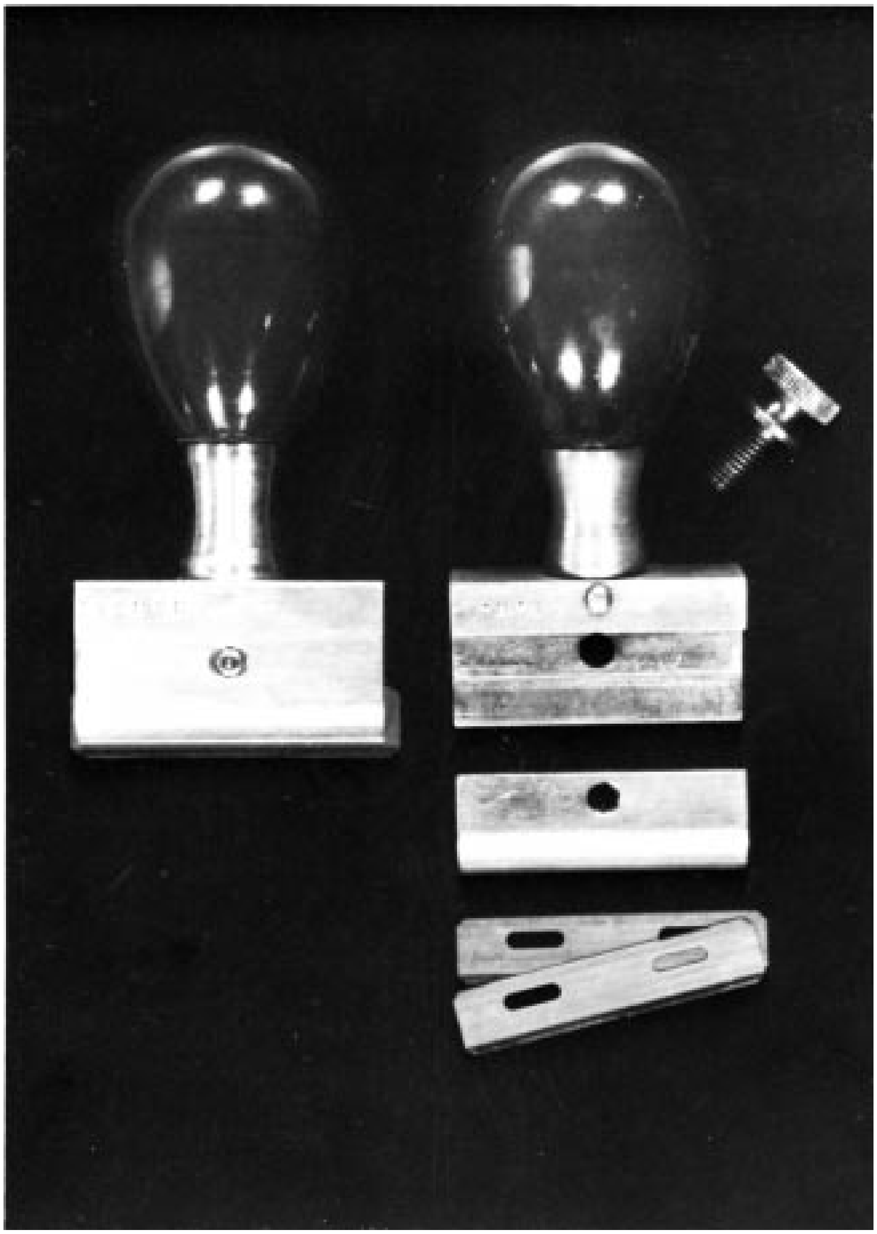


FIG. 2 FRL Fiber Cutter

7.1.2 *Major Sort*—Packaged grease wool in fleece form for which a diameter test is desired for only the major sort of the fleece, hand sample by drawing one or more handfuls of wool from the major sort portion of at least 50 fleeces taken at random from the lot. The aggregate mass of the sample shall be at least 3 lb (1.5 kg).

7.1.3 *Piles of Graded or Sorted Wool*—Sample piles of graded or sorted wool by taking from random locations in the pile at least 50 handfuls of wool, the aggregate mass of which shall be at least 3 lb (1.5 kg). If the wool is in fleece form and a test is desired for only the major sort, take the sample as directed in 7.1.2.

7.1.4 *Card Sliver*— Sample the wool card sliver by drawing at random from the lot, preferably during the carding operation, ten 2-ft (600-mm) lengths of sliver.

7.1.5 *Top*—Sample the top by drawing from each 20 000 lb (9072 kg) or fraction thereof, four sections of sliver, each of which shall be at least 1 yd (1 m) in length and taken from different balls of top selected at random. Take only one ball from any one bale or carton. For broken top, take an equivalent aggregate length of sliver at random.

7.2 *Yarns and Fabrics*—Take a yarn sample as directed in Practice D 2258. Cut an approximately 3-yd (3-m) length of yarn sample into at least 20 sections of woolen-spun yarn, or 50 sections if worsted-spun yarn. For fabric, take two samples at least 2 by 2 in. (50 by 50 mm) from areas at least 2 in. from a selvage and at a sufficient distance apart to represent filling yarn taken from at least two different bobbins. Remove 20 (if woolen-spun) or 50 (if worsted-spun) warp yarns from each sample. Remove 10 (if woolen-spun) and 25 (if worsted-spun) filling yarns from each sample.

8. Test Specimens

8.1 *Grease Wool, Pulled Wool, Scoured Wool*:

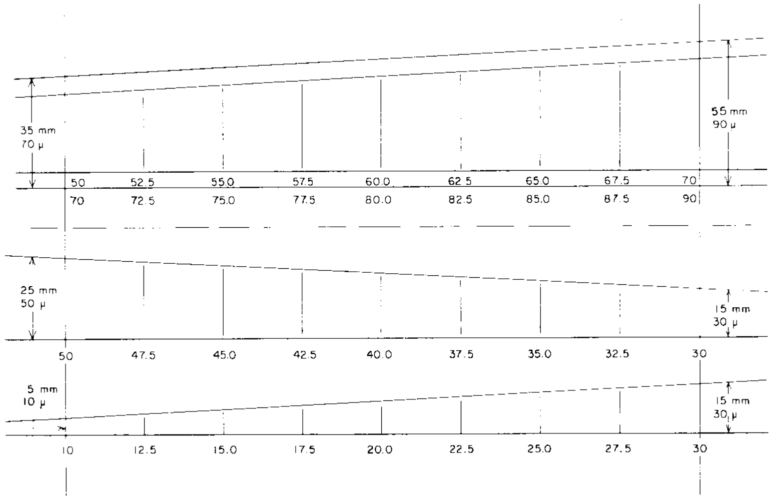


FIG. 3 Wedge Scale

8.1.1 *Sub-Coring*—Randomly pack the core or hand sample (see 7.1.1-7.1.3), into a suitable container (see 6.8) and compress to approximately 2 psi (14 kPa) by loading a weight of 150 lbf (667 N) on the floating top. By means of a ⅜ or ½-in. (10 or 13-mm) tube with sharp tip, extract a sufficient number of cores (at least five) to provide a test specimen of at least 20 g of scoured wool. Scour or otherwise clean the test specimen if it is grease wool or pulled wool as directed in Test Method D 584.

8.1.2 *Gridding*—Core Test Residue—If the sample comprises an adequate amount of scoured wool resulting from the core testing of a lot for clean fiber content (see 7.1.1), divide the sample into 40 portions of approximately equal size. From each portion, draw at random at least 0.5 g. Mix or blend these 40 portions to form the test specimen. Test specimens from samples obtained by means of 1.25 in. (30 mm) and larger coring tubes may be carded for homogenization; but do not card those from coring tubes smaller than 1.25 in. (30 mm) since loss of fiber may occur.

8.1.3 *Gridding and Machine Blending*—For samples other than those specified in 8.1.1 and 8.1.2, divide the sample into 40 portions of approximately equal size. From each portion draw at random a sufficient quantity of fiber to provide a test specimen of 20 g. Scour or otherwise clean the test specimen, of grease or pulled wool. Homogenize the clean specimen by carding 3 times, breaking the web, and feeding at right angles after the first and second passes; or by gilling 15 times, breaking, and combining the pieces of silver as required to maintain a convenient length.

8.2 *Card Sliver*— Strip off portions of each of the ten 2-ft (600-mm) lengths of sliver (see 7.1.4). Combine these portions to form a composite sliver about 2 ft in length. This constitutes the test specimen.

8.3 *Top*—Each of the four sections of sliver comprising the sample (see 7.1.5) constitutes a test specimen.

8.4 *Yarn*—The yarn sections (see 7.2) constitute the test specimen.

8.5 *Fabric*—The undisturbed piece of fabric or the teased out yarns of the fabric (see 7.2) constitute the test specimen.

9. Calibration of Microprojector

9.1 Adjust the microprojector to produce a magnification of 500× in the plane of the projected image. Do this by placing a stage micrometer on the stage of the microprojector and bringing the microscope into such adjustment that the lines of the micrometer are sharply focused in the center of the image plane. An interval of 0.20 mm on the stage micrometer will then measure 100 mm on the image plane, or 0.01 mm on the micrometer will measure 5 mm on the image plane. All measurements must be made with the specimen in a plane at the same distance from the stage as the lines on the stage micrometer.

10. Conditioning

10.1 Precondition all test specimens to approximate equilibrium in an atmosphere having a relative humidity of 10 to 25 % and a temperature of not over 122°F (50°C), then condition the samples for at least 4 h in the standard atmosphere for testing textiles, 65 ± 2 % relative humidity and 70 ± 2°F (21 ± 1°C), as directed in Practice D 1776.

11. Test Provisions

11.1 Separate observations shall be made by two operators.

11.2 Each operator shall independently prepare at least one slide for each test specimen.

12. Preparation of Slides by Use of Heavy-Duty Cross-Section Device

12.1 *Compacting Specimen*:

12.1.1 *Sliver Specimen*— At an area of the sliver, estimated to be a full fiber length or more from the end, place the specimen in the slot of the metal plate, compress with the key, and secure with the set screw.

12.1.2 *Bulk Specimen*— Draw small quantities of fiber at random, pack the assemblage of fibers into the slot, compress and secure as directed in 12.1.1.

12.1.3 *Yarn Specimen*— Pack the assemblage of yarn pieces into the slot, compress, and secure as directed in 12.1.1.

12.1.4 *Fabric Specimen*— Pack the assemblage of warp or filling yarn pieces or diagonal cuts of fabric into the slot, compress, and secure as directed in 12.1.1. If it is known that warp and filling yarns are identical, make a diagonal cut in each of the fabric samples. Segregate the warp and filling yarns when of different or unknown composition and when necessary to determine diameter and dispersion for each.

12.2 *Preliminary Sectioning of Specimen*—Cut off the gripped fibers at the upper and under surfaces of the plate. Extrude the fiber bundle about 0.50 mm to take up slack in the fibers and the propulsion mechanism. Moisten the projecting fibers with a few drops of mounting medium. With a sharp razor blade, cut off this projecting fiber bundle flush with the upper surface of the fiber-holding plate, and discard the section.

12.3 *Final Sectioning of Specimen*—Again extrude the fiber bundle approximately 0.25 mm (250 µm). With the razor blade, cut off the projecting fibers flush with the plate, leaving the fiber pieces adhering to the razor blade.

12.4 *Mounting the Fibers on the Slide*—Place a few drops of mounting medium on a clean glass slide. With a dissecting needle, scrape the fiber pieces from the blade onto the slide. Thoroughly disperse the fibers in the oil with the dissecting needle (Fig. 4), and cover the specimen with a cover glass.

NOTE 5—Use sufficient oil in the preparation of the slide to ensure thorough distribution of the fibers, but an excess must be avoided, as practically no oil should be permitted to flow out or be squeezed out beyond the borders of the cover glass. If the number of fibers is too great to permit proper distribution on the slide, or if an excess of oil has been used, wipe away a portion of the mixture after thorough dispersion of the fibers.

13. Preparation of Slides by Use of the FRL Fiber Cutter

13.1 *Cutting Specimens*:

13.1.1 *Fabric*—Using the equipment described in 6.3.3, with the razor blades in alignment and firmly secured, force the blades vertically downward into the warp fringe close to the edge of the fabric. Repeat the operation for the filling yarns. If the warp and filling yarns are the same, the cut may be made diagonally, sectioning the warp and filling yarns of the fabric at the same time. Make a duplicate cut at the opposite side of the fabric. The individual cuts should include between 1500 and 2000 fibers, approximately 250 µm long.

13.1.2 *Yarns and Other Fiber Assemblies*—Cut the prepared woolen or worsted yarn specimens with the pieces arrayed as a unit, or other specimens of yarn, roving, and the like, in a manner similar to the procedure described in 13.1.1.

13.2 *Release of Cut Sections*—Release the top plate of the device, then remove the blades, holding the ends between the thumb and forefinger of one hand. By careful separation of the blades, the fiber sections will adhere to the edge of either blade.

13.3 *Mounting the Fibers on the Slide*—See 12.4.

14. Procedure

14.1 Measure fibers the same day a slide is prepared.

14.2 Place the finished (prepared) slide on the microprojector stage with the cover glass toward the objective (see 9.1).

14.3 Plan the viewing traverses across the slide to ensure that all portions under the glass are selected (sampled) for fiber measurement.

14.4 To measure a fiber, bring the midlength area into sharp focus on the wedge scale. When correctly focused the fiber edges appear as fine lines, not as pronounced dark borders (Fig. 5). However, the two edges of the fiber may not be in focus at the same time. If both edges of the fiber are not uniformly in focus, adjust the focus so that one edge of the fiber appears as a fine line and the other edge shows as a bright line. Fiber image width is regarded as the distance between the fine lines of both edges when they are uniformly in focus, or the fine line of one edge and the inner side of the bright line at the other edge when they are not uniformly in focus.

14.4.1 At the midlength area of the fiber, measure the width of the image by marking the wedge at the point where the width of the wedge scale coincides with the width of the fiber image (Fig. 6). Position the wedge scale so the taper of the scale is opposite any taper in the fiber image.

14.5 In the planned traverses, measure all fibers whose midlength area comes within the field of a 4-in. (100-mm) diameter circle, centrally located in the projected area. Kemp

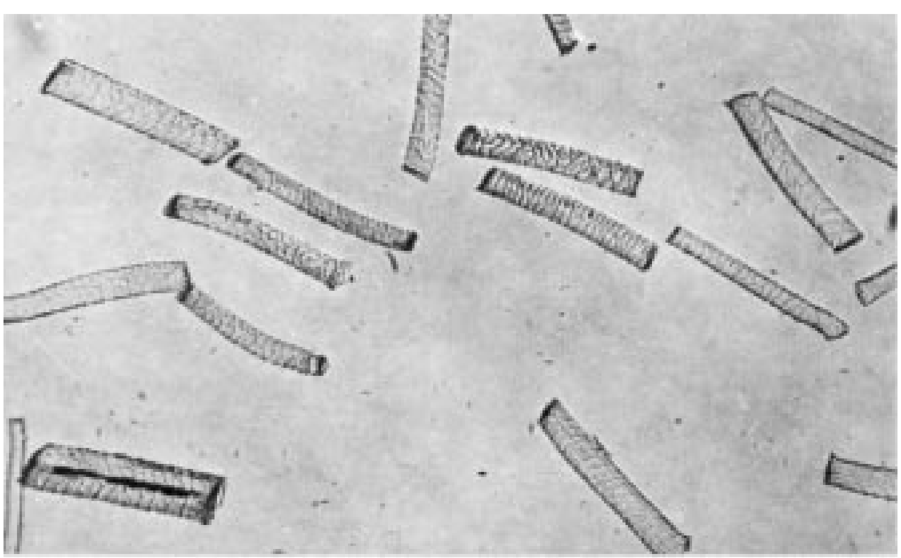
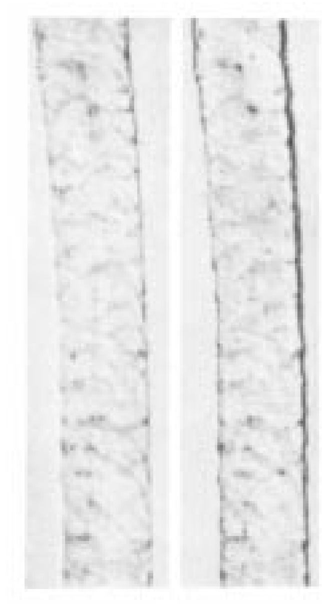


FIG. 4 Dispersion of Fibers on Slide



(*a*) Correct (*b*) Incorrect

FIG. 5 Correctly and Incorrectly Focused Fiber

FIG. 6 Point to Mark Wedge Scale: Where Wedge and Fiber Image Coincide

and med fibers which come within the field of measurement are to be measured for fiber diameter. Exclude from measurement fiber images shorter than 100 mm (200 µm fiber) or longer than 150 mm (300 µm fiber) and those having a distorted image. If the width of a fiber image is less than or greater than the limits of the wedge scale, project the fiber image onto the border of the wedge scale and draw lines which coincide with the edges of the midlength area. Measure the distance between the lines in millimetres and convert to micrometres; 1 mm is equal to 2 µm at a magnification of 500x.

15. Number of Fibers

15.1 The number of fibers to be measured depends on the variability of the fiber diameters and the required or desired precision of the average. Calculate the number by using Eq 1:

$$n = (t\sigma/E)^2 \quad (1)$$

where:

n = number of fibers to be measured,
σ = standard deviation of fiber diameters,
E = allowable variation of the mean, µm, and
t = 1.960, the value of Student's t for infinite degrees of freedom, two-sided limits, and a 95 % probability level, ($t^2 = 3.842$).

15.2 Estimates of standard deviation for the various grades of wool and wool top, mohair and mohair top, and alpaca are given in Tables A1.1-A1.3, together with the calculated number of fibers required for various confidence intervals of the mean at a statistical probability of 0.95.

16. Calculation

16.1 From the observations determined with the wedge scales calculate the pertinent information as shown in the example (Table A1.4).

17. Report

17.1 State that the specimens were tested as directed in ASTM Test Method D 2130 and state the type and number of samples taken and the kind of material that was tested.

17.2 Report the following information:

17.2.1 The average fiber diameter ($\bar{X}$) in µm.

17.2.2 The fiber diameter distribution, where applicable.

17.2.3 The standard deviation of fiber diameters, in µm.

17.2.4 The coefficient of variation of fiber diameters, %, *v*.

17.2.5 The 95 % confidence limits for the lot mean.

18. Precision and Bias

18.1 *Precision*—Estimates of standard deviation for the various grades of wool and wool top, mohair and mohair top, and alpaca are given in Tables A1.1-A1.3, together with the calculated number of fibers required for various confidence intervals of the mean at a 95 % probability level.

18.2 *Bias*—The procedure in Test Method D 2130 for measuring the diameter of wool fibers by microprojection is widely accepted in the trade as having no known bias and is generally used as a referee method.

19. Keywords

19.1 animal fibers (except wool); diameter; wool

ANNEX

(Mandatory Information)

A1. DATA FOR PRECISION OF MEASUREMENTS AND EXAMPLES OF CALCULATIONS

A1.1 The estimates of standard deviation for the various grades of wool for determination of the number of fibers to measure at selected confidence limits and examples of calculations listed in 15.1 and 15.2 are given in Tables A1.1-A1.4.

TABLE A1.1 Wool and Wool Top:[A] Number of Fibers to be Measured for Selected Confidence Limits of Mean in Micrometres, µm at a 95 % Probability Level, for Selected Standard Deviation Values

Wool or Wool Top Grade	Typical Average Standard Deviation, µm	Number of Fibers to be Measured for 95 % Confidence Limits of Lot Means		
		±0.2 µm	± 0.4 µm	± 0.5 µm
Finer than 80s	4.00	1 537	384	246
	4.00	1 537	384	246
80s	4.40	1 859	465	298
70s	5.00	2 401	600	385
64s	5.60	3 014	753	482
62s	6.10	3 574	893	572
60s	6.70	4 311	1 079	690
58s	7.20	4 979	1 245	796
56s	7.80	5 845	1 461	935
54s	8.00	6 146	1 537	983
50s	8.90	7 604	1 902	1 217
48s	9.00	7 779	1 945	1 245
46s	9.40	8 319	2 121	1 358
44s	9.90	9 413	2 353	1 506
40s	10.10	9 797	2 449	1 567
36s				
Coarser than 36s	—	—	—	—

[A] ASTM Research Report No. RR D-13-1024. A copy is available from ASTM Headquarters.

TABLE A1.2 Mohair and Mohair Top:[A] Number of Fibers to be Measured for Selected Confidence Limits of Mean in Micrometres, µm, at a 95 % Probability Level, for Selected Standard Deviation Values

Mohair or Mohair Top Grade	Typical Average Standard Deviation, µm	Number of Fibers to be Measured for 95 % Confidence Limits of Lot Means		
		±0.2 µm	± 0.4 µm	± 0.5 µm
Finer than 40s	7.2	4 979	1 245	796
40s	7.2	4 979	1 245	796
36s	7.4	5 259	1 315	841
32s	7.6	5 547	1 387	888
30s	8.0	6 146	1 537	983
28s	8.4	6 777	1 694	1 084
26s	8.8	7 437	1 859	1 190
24s	9.2	8 129	2 032	1 301
22s	10.2	9 992	2 498	1 598
20s	11.0	11 621	2 905	1 859
18s	11.2	12 046	3 012	1 928
Coarser than 18s	—	—	—	—

[A] ASTM Research Report No. RR D-13-1025. A copy is available from ASTM Headquarters.

TABLE A1.3 Alpaca: Number of Fibers to Measure for Selected Confidence Limits of Mean in Micrometres, µm, at a 95 % Probability Level, for Selected Standard Deviation Values

Alpaca Type	Typical Average Standard Deviation, µm	Number of Fibers to be Measured for 95 % Confidence Limits of Lot Means		
		±0.2 µm	± 0.4 µm	± 0.5 µm
T	6.6	4 184	1 046	669
X	6.6	4 184	1 046	669
AA	7.7	5 694	1 423	911
A	10.2	9 992	2 498	1 598

TABLE A1.4 Example of Calculations: Average Fiber Diameter, Standard Deviation, Coefficient of Variation, Distribution, and Confidence Limits of the Mean

Class Interval	*A*	Deviation in Class Interval from *A*, *x*	Observed Frequency, *f*	*fx*	fx²	Cumulative Frequency	Cumulative Percent
5.0 to 7.5	6.25	0	0	0	0	0	0
7.5 to 10.0	...	1	0	0	0	0	0
10.0 to 12.5	...	2	1	2	4	1	0.12
12.5 to 15.0	...	3	12	36	108	13	1.62
15.0 to 17.5	...	4	53	212	848	66	8.25
17.5 to 20.0	...	5	113	565	2 825	179	22.38
20.0 to 22.5	...	6	132	792	4 752	311	38.88
22.5 to 25.0	...	7	141	987	6 909	452	56.50
25.0 to 27.5	...	8	111	888	7 104	563	70.38
27.5 to 30.0	...	9	79	711	6 399	642	80.25
30.0 to 32.5	...	10	63	630	6 300	705	88.13
32.5 to 35.0	...	11	44	484	5 324	749	93.63
35.0 to 37.5	...	12	28	336	4 032	777	97.13
37.5 to 40.0	...	13	7	91	1 183	784	98.00
40.0 to 42.5	...	14	6	84	1 176	790	98.75
42.5 to 45.0	...	15	5	75	1 125	795	99.38
45.0 to 47.5	...	16	3	48	768	798	99.75
47.5 to 50.0	...	17	0	0	0	798	99.75
50.0 to 52.5	...	18	2	36	648	800	100.00
Totals			800	5 977	49 505		

n = number of observations = 800
A = 6.25 µm (midpoint of smallest class interval considered)
m = class interval = 2.5 µm
$E_1 = \Sigma fx/n = 5977/800 = 7.4712$
$E_2 = \Sigma fx^2/n = 49505/800 = 61.8812$
Average diameter = $\bar{X} = A + mE_1 = 6.25 + 2.5\ (7.4712) = 24.93$ µm[A]
Standard deviation = $\sigma = m\sqrt{E_2 - E_1^2} = 2.5\sqrt{61.8812 - 55.8188} = 2.5\ (2.4622) = 6.16$ µm[A]
Coefficient of variation = $v = 100\ \sigma/\bar{X} = 616/24.93 = 24.71$ %
Limits for the lot mean at the 95 % probability level = $\bar{X} \pm (1.96\ \sigma/\sqrt{n}) = 24.93 \pm 0.43$ µm
[A] Round off the calculated values of average fiber diameter, standard deviation, and coefficient of variation to two decimal places following the procedure set forth in Practice E 380, for Use of the International System of Units (SI) (The Modernized Metric System), *Annual Book of ASTM Standards*, Vol 14.02.

APPENDIX

(Nonmandatory Information)

X1. ESTIMATION OF LINEAR DENSITY OF WOOL FIBER IN TEX UNITS FROM MICROPROJECTION MEASUREMENTS OF THE FIBER DIAMETER

X1.1 *General Equation*—For any fiber of circular cross section, the fiber linear density in tex is related to the fiber diameter measurements obtained by microprojection as in Eq X1.1 or, alternatively, Eq X1.2.

$$\text{Fiber linear density, tex} = 0.00102\ p(\pi\bar{X}^2/4)[1 + (v/100)^2] \quad (X1.1)$$

$$= 0.00102\ p(\pi D^2/4) \quad (X1.2)$$

where:
$\bar{X}$ = average diameter by microprojection measurement, µm,
v = coefficient of variation of the diameter measurements, %,
p = density of the fiber, g/cm³, and
D = root mean square diameter (sometimes called gravimetric average diameter) $\bar{X}\sqrt{1 + (v/100)^2}$.

X1.2 *Equation for Wool*:

X1.2.1 Wool fibers are not perfectly round in cross section.[14] When cut into short sections for mounting on a slide, wool fibers tend to lie on the flat side so that the average fiber "diameter" and root mean square "diameter" determined by microprojection are too high. Furthermore, the equation for calculating the area of a circle is not applicable to the cross sections of such fibers. An empirical correction factor may be used to compensate for the effects of non-circularity, as shown in Eq X1.3:

$$\text{Wool fiber linear density, tex} = 0.00102\ pk^2(\pi\bar{X}^2/4)[1 + (v/100)^2] \quad (X1.3)$$

where k = empirical correction factor for wool.

X1.2.2 *Estimation of Empirical Factor, k*:

TABLE X1.1 Fiber Linear Density in Tex[A] Associated with Grades of Wool Top

Wool Top Grade	Minimum Average Fiber Diameter for Grade, µm[B]	Standard Deviation, µm[C]	Fiber Linear Density Tex	Approximate Tex Number of Worsted Yarn[D]		Approximate Worsted Count Number for Yarn	
				Number of Fibers per Cross Section			
				40	60	40	60
80s	18.10	3.70	0.341	13.6	20.5	64.9	43.3
70s	19.60	4.20	0.402	16.1	24.1	55.1	36.7
64s	21.10	4.80	0.468	18.7	28.1	47.3	31.5
62s	22.60	5.40	0.540	21.6	32.4	41.0	27.3
60s	24.10	6.00	0.617	24.7	37.0	35.9	23.9
58s	25.60	6.60	0.699	28.0	41.9	31.7	21.1
56s	27.10	7.00	0.783	31.3	47.0	28.3	18.9
54s	28.60	7.40	0.873	34.9	52.4	25.4	16.9
50s	30.10	7.90	0.968	38.7	58.1	22.9	15.3
48s	31.80	8.40	1.082	43.3	64.9	20.5	13.6
46s	33.50	8.80	1.200	48.0	72.0	18.5	12.3
44s	35.20	9.20	1.324	53.0	79.4	16.7	11.2
40s	37.10	9.70	1.470	58.8	88.2	15.1	10.0
36s	39.00	10.10	1.623	64.9	97.4	13.6	9.1

[A] Estimated using Eq X1.6.
[B] See Specification D 3992.
[C] Estimated from average value shown in Table A1.2.
[D] Calculated using Eq X1.8.

X1.2.2.1 It has been reported[15] that the deviation from perfect roundness (usually, but not necessarily, called ellipticity) should cause the root-mean-square diameter determined by microprojection of fiber 800 µm long to appear very close to 1 % higher than the true gravimetric average diameter. Experimentally, however, interlaboratory results have been obtained[16] showing about 1.2 % difference in the other direction. The WIRA method[17] of determining gravimetric diameter in these data[16] is expected to give results at least 1 % lower due to stretching. The difference in results was ascribed to difficulties in focusing. Other work[18] illustrates that the shorter the fiber is cut for mounting, the greater the freedom of the fiber to lie over on its flat side and appear fat; in this work fiber cut to 250 µm appeared to be about 3.6 % larger than fiber cut to 800 µm.

X1.2.2.2 From these comparisons an estimate of the empirical factor, k, is obtained as follows:

$$k = (100/103.6)(101.2/100)(100/99) = 0.987 \tag{X1.4}$$

X1.2.3 *Density of Wool, p*—The density of wool depends in part on factors such as the presence or absence of a medulla in the fiber and the level of moisture regain. The generally accepted value for the density of unmedullated wool under the test conditions prescribed in Test Method D 2130 is 1.31 g/cm.[3]

X1.2.4 Substitution of 1.31 for p and 0.987 for k, Eq X1.3 becomes:

$$\text{Wool fiber linear density, tex} = 0.00102\,\bar{X}^2[1 + (v/100)^2] \tag{X1.5}$$

or,

$$= 0.00102\,(\bar{X}^2 + s^2) \tag{X1.6}$$

where s = standard deviation of the diameter measurements, µm.

X1.2.4.1 The empirical Eq X1.5 and Eq X1.6 provide an estimate of fiber linear density in tex from microprojection measurement of unmedullated wool obtained as directed in Test Method D 2130.

X1.3 *Application to Wool Top Grades and to Wool Yarn*:

X1.3.1 *Tops*—For each fineness grade of wool top the range of average fiber diameter, in micrometres, is specified in Specification D 3992 and the typical average standard deviation, in micrometres, is shown in Table A1.1. Hence estimates of the fiber linear density in tex associated with grades of wool top may be calculated using Eq X1.6. Table X1.1 shows the calculated fiber linear density in tex corresponding to the minimum average fiber diameter of each grade of wool top of corresponding average variability.

X1.3.2 *Yarn*—If both the average fiber linear density and the number of fibers per cross section of yarn are known, the tex number and worsted count number for the yarn are readily calculated, as follows:

$$\text{Yarn tex number} = n \times \bar{F} \tag{X1.7}$$

$$\text{Worsted count number} = 885.8/(n \times \bar{F}) \tag{X1.8}$$

where:
n = number of fibers per cross section,
$\bar{F}$ = average linear density, tex, and
885.8 = factor relating worsted count number and tex.

X1.3.3 Two examples of the association of tex number and worsted count for yarn with grades of wool top also are shown in Table X1.1.

[15] Anderson, S. L., and Benson, F., "Fibre Ellipticity and Its Effect on Diameter Measurement," *Journal of the Textile Institute*, JTINA, Vol 44, 1953, pp. 98–104.
[16] Palmer, R. C., "Report of the 1948 Interlaboratory Diameter and Length Experiment; International Wool Textile Organization Technical Committee," *Journal of the Textile Institute*, JTINA, Vol 42, 1951, pp. 23–43.
[17] See Wool Industry Research Assn. (WIRA), "Gravimetric Determination of Root-Mean-Square Diameter," *Technical Committee Proceedings*, International Wool Textile Organization, Vol 2, 1948, pp. 13–18.
[18] Anderson, S. L., and Palmer, R. C., "The Effect of Non-Circular Cross-Section on Fibre Diameter Measurement of Wool by the Profile Method." *Journal of the Textile Institute*, JTINA, Vol 42, 1951, pp. 114–116.

The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, at the address shown below.

This standard is copyrighted by ASTM, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, United States. Individual reprints (single or multiple copies) of this standard may be obtained by contacting ASTM at the above address or at 610-832-9585 (phone), 610-832-9555 (fax), or service@astm.org (e-mail); or through the ASTM website (www.astm.org).