ASTM Designation: D 1577 – 96

Standard Test Methods for
Linear Density of Textile Fibers[1]

This standard is issued under the fixed designation D 1577; 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 These test methods cover the measurement of mass per unit length (linear density) of textile fibers and filaments. Direct weighing and vibroscope procedures with modifications for crimped and uncrimped fibers are included. The options and sections are listed below.

Option	Sections
A—Fiber Bundle Weighing	7-15
B—Single-Fiber Weighing	16-23
C—Vibroscope, General	24-30
	35 and 36
C1—Uncrimped Fibers	31 and 32
C2—Crimped Fibers	33 and 34
Precision and Bias	37 and 38

NOTE 1—For linear density of short lengths of yarn, refer to Test Method D 1059. For cotton linear density, refer to Test Methods D 1769, and D 2480. For measurement of wool diameter, refer to Test Methods D 1282, D 2130 and D 3510.

1.2 The crimp, taper and cross-sectional shape of the fiber may influence the linear density measured by single-fiber weighing and vibroscope.

1.3 These test methods measure the linear density of fibers with moisture in equilibrium with the standard atmosphere for testing textiles. The fiber moisture under these conditions is not necessarily the same as the commercial moisture regain for the fibers.

1.4 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system are not exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

1.5 *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:*

D 123 Terminology Relating to Textiles[2]
D 629 Test Methods for Quantitative Analysis of Textiles[2]
D 1059 Test Method for Yarn Number Based on Short-Length Specimens[2]
D 1282 Test Method for Resistance to Airflow as an Indication of Average Fiber Diameter of Wool Top, Card Sliver, and Scoured Wool[2]
D 1769 Test Method for Linear Density of Cotton Fibers (Array Sample)[2]
D 1776 Practice for Conditioning Textiles for Testing[2]
D 1907 Test Method for Yarn Number by the Skein Method[2]
D 2130 Test Method for Diameter of Wool and Other Animal Fibers by Microprojection[2]
D 2257 Test Method for Extractable Matter in Textiles[2]
D 2258 Practice for Sampling Yarn for Testing[2]
D 2480 Test Method for Maturity Index and Linear Density of Cotton Fibers by the Causticaire Method[2]
D 2904 Practice for Interlaboratory Testing of a Textile Test Method That Produces Normally Distributed Data[2]
D 3333 Practice for Sampling Man-Made Staple Fibers, Sliver, or Tow for Testing[3]
D 3510 Test Method for Diameter of Wool and Other Animal Fibers by Image Analyser[3]
D 3818 Test Method for Linear Density and Maturity Index of Cotton Fibers (IIC-Shirley Fineness/Maturity Tester)[3]
D 5103 Test Method for Length and Length Distribution of Man-Made Staple Fibers (Single-Fiber Test)[3]
2.2 ASTM Adjuncts:
TEX-PAC[4]

3. Terminology

3.1 *Definitions:*

3.1.1 *effective fiber length—in the vibroscope test for linear density*, that portion of the fiber free to vibrate between fixed supports.

3.1.2 *fundamental resonant frequency—in linear density testing*, the lowest frequency at which free oscillations can exist in a fiber tensioned between two fixed points.

3.1.3 *linear density*, n—mass per unit length.

3.1.3.1 *Discussion*—The preferred units of measurement

are grams and metres, or multiples or submultiples of these. The tex unit, grams per kilometre, is recommended for yarns. In these methods the linear density of the fibers is calculated in decitex (dtex) units; which are tex units multiplied by 1000 millitex (mtex).

3.1.4 *tex*—the unit of linear density; equal to the mass in grams of 1000 meters of fiber, yarn, or other textile strand, that is used in a direct yarn numbering system.

3.1.5 For definitions of other textile terms used in these methods, refer to Terminology D 123.

4. Significance and Use

4.1 Option A for bundle weighing of Test Method D 1577 is used in the trade for acceptance testing of commercial shipments. Option B for single-fiber weighing and Option C for the vibroscope may be used for acceptance testing (see Section 37); however, caution is advised when using Option B or Option C because between-laboratory precision information is incomplete. Comparative tests as directed in 4.1.1 may be advisable.

4.1.1 In case of dispute arising from differences in reported test results when using Test Method D 1577 for acceptance testing of commercial shipments, the purchaser and the supplier should conduct comparative tests to determine if there is a statistical bias between their laboratories. Competent statistical assistance is recommended for the investigation of bias. As a minimum, the two parties should take a group of samples that are as homogeneous as possible and that are from a lot of material of the type in question. These samples should then be randomly assigned in equal numbers to each laboratory for testing. The average results from the two laboratories should be compared using the appropriate statistical analysis and a probability level chosen by the two parties before testing is begun. If a bias is found, either the cause must be found and corrected or the purchaser and the supplier must agree to interpret future test results with consideration to the known bias.

4.2 Option A for bundle weighing is generally considered to be the referee procedure for acceptance testing.

4.3 Option A is not recommended for measurement of linear density of blends of production fibers having different nominal linear densities.

4.4 The accuracy of the linear density values obtained by Options A and B is dependent upon the accuracy with which the fibers can be cut and weighed.

NOTE 2—On short staple fiber, an accuracy in cutting of 1.0 % is difficult to obtain. This problem is further complicated if crimp is present in the fibers.

4.4.1 The accuracy of weighing can be controlled by the number of fibers composing the bundle. However, with short fiber of low linear density the number of fibers to be counted becomes prohibitive unless the bundle mass is kept low.

4.5 Options A and B are fundamental procedures which are used to standardize the vibroscope equipment used in Options C1 and C2.

4.6 Test Method Options B and C are most useful for the measurement of linear density of single fibers when further tests upon the same test specimen are required, for example,

tension tests and adjustment of the data obtained for the linear density of the test specimen. These options offer advantages in accuracy and ease of operations over calculation from specific gravity and microscopically measured cross-sectional area.

4.7 Additional information specific to Option C is in Section 26.

5. Sampling

5.1 *Lot Sampling*—As a lot sample for acceptance testing, take at random the number of shipping containers directed in the applicable material specification or other agreement between the purchaser and supplier, such as an agreement to use Practice D 3333 or Practice D 2258, as applicable. Consider shipping containers to be the primary sampling units.

NOTE 3—An adequate specification or other agreement between the purchaser or supplier requires taking into account the variability between shipping units, between packages, ends or other laboratory sampling unit within a shipping unit if applicable, and within specimens from a single package, end or other laboratory sampling unit to provide a sampling plan with a meaningful producer's risk, consumer's risk, acceptable quality level, and limiting quantity level.

5.2 *Laboratory Sample*—As a laboratory sample for acceptance testing, take at random from each shipping container in the lot sample the number of laboratory sampling units as directed in an applicable material specification or other agreement between purchaser and supplier such as an agreement to use Practice D 3333 or Practice D 2258, as applicable. Preferably, the same number of laboratory sampling units are taken from each shipping container in the lot sample. If differing numbers of laboratory sampling units are to be taken from shipping containers in the lot sample, determine at random which shipping containers are to have each number of laboratory units drawn.

5.2.1 *For staple fiber*—Take 50-g samples from laboratory sampling units.

5.2.2 *For sliver (or top) or tow*—Take a metre (yard) from the leading end which has a clean, uniform appearance.

5.2.3 *For yarns*—Prepare at least a 50-m (50-yd) skein from each package.

6. Conditioning

6.1 Condition the laboratory samples as directed in Practice D 1776.

OPTION A—FIBER BUNDLE WEIGHING

7. Scope

7.1 This test method option covers the measurement of the average linear density of textile fibers by cutting and weighing.

8. Summary of Test Method

8.1 Average linear density, in tex or denier units, of single fibers in a bundle is calculated from mass and length measurements on the bundle and the number of single fibers in the bundle.

9. Apparatus

9.1 *Balance*, having a capacity of 15 mg and sensitivity of at least 0.005 mg.

9.2 *Metal Template, Die, or Mechanical Cutting Device*, having a precision of ±1 % and designed to permit cutting fibers of a specified length while under tension sufficient to remove crimp.

9.2.1 For fibers less than 50 mm in length, a template or die 25 mm in width for measurements in tex units (22.5 mm in width for measurements in denier units) has been found satisfactory.

9.2.2 For fibers more than 50 mm in length, a mechanical cutting device, for example, a cutting board having two clamps at a greater distance apart than the selected length and having two central clamps for fixing specimens to the board during cutting, each with a side adjacent to the path of one of a pair of traversing blades positioned the selected length apart. Templates or dies of the type described in 9.2.1 can be made with appropriate widths for use on longer fibers.

9.3 *Weights*, for preloading crimped fibers.

9.4 *Forceps or Clamps*, having gripping surfaces padded with fiber board, cork, or rubber, and wide enough to hold a bundle of fibers firmly.

9.5 *Stationary Coarse Comb,*[5] approximately 63 mm in width and having needles approximately 12.5 mm in length and spaced 19 needles to the centimetre.

9.6 *Cathetometer.*

10. Verification of Equipment Parameters

10.1 Determine that the length defined by the templates or the cutting edges of dies and mechanical cutting devices is correct within 1 % by accurate measurement of these devices with a cathetometer.

10.2 Determine that the balance and pretension weights are correct within ±0.5 % by comparison with standard weights.

11. Test Specimens

11.1 From each laboratory sampling unit in a container, take five specimens at random. If the standard deviation determined for the container from which the laboratory sampling units were taken is more than a value agreed upon between the purchaser and supplier, continue testing in groups of five specimens from the same laboratory sampling units in the container until the standard deviation for all specimens tested for the container is not more than the agreed-to value or stop with a specified number testing by agreement.

11.2 Select tufts or bundles of fibers containing a sufficient number of fibers to weigh between 0.5 and 7.5 mg when cut to the specified length. If fibers from yarns are to be tested, carefully remove twist before taking specimens.

Note 4—A tuft of fibers less than 50 mm in length and below 1 tex (9 denier) in nominal linear density will contain 500 to 1000 fibers. The number of longer or coarser fibers required in a tuft will be proportionately fewer.

12. Preparation of Specimens

12.1 If linear density of finish-free fiber is requested, remove the finish after cutting the specimen and before

weighing. Refer to Test Method D 1907, Test Method D 2257, or the Non-fibrous Material Section of Test Methods D 629 for procedures on the removal of finish.

Note 5—Hot-water or hot solvent may cause considerable shrinkage and consequent changes in linear density, and should not be used.

12.2 The specimens chosen from staple fiber may require combing to align the fibers and remove short ends. Because fibers are easily stretched, combing must be done with extra care. Comb the specimen as follows:

12.2.1 Grip the specimen at one end in suitable clamp or tweezers. Ease the specimen onto the stationary coarse comb needles 3 to 5 mm on the clamp side of the center of the tuft. Draw the specimen gently toward the center.

12.2.2 Lift the specimen off the comb. Replace the specimen on the needles 3 to 5 mm closer to the clamp than the last position. Draw the specimen gently to the center as before.

12.2.3 Continue to comb the specimen as directed in 12.2.2 until the clamp is reached and all unclamped fibers are drawn to the center.

12.2.4 Reverse the specimen. Clamp it in the combed segment approximately 3 to 5 mm from the uncombed segment, near the center. Comb the other end of the specimen, progressing from tip to center in 3 to 5 mm increments. Discard the combings.

12.3 Arrange fibers from filament yarn or tows in parallel alignment.

13. Procedure

13.1 Test the specimens in the standard atmosphere for testing textiles, which is 21 ± 1°C (70 ± 2°F) and 65± 2 % relative humidity.

13.2 Place the bundle of fibers prepared as directed in 12.2 or 12.3 in a cutting device or on a flat cutting surface. Make certain the fibers are in parallel alignment.

13.3 If crimp is present, remove it by pretensioning the specimen under a tension determined as directed in X1.1 of the Appendix.

Note 6—Upon visual examination, if crimp does not appear to be completely removed even at greater pretensioning than the minimum determined, note this in the report.

13.4 Cut the specimen to the selected length using template, die, or cutting device.

13.5 Weigh the specimen to the nearest 0.005 mg.

13.6 Count the number of fibers in the bundle.

Note 7—Counting of fine fibers is facilitated by using some magnification and shuffling the specimen on a short pile surface of contrasting color to separate the fibers.

14. Calculation

14.1 Calculate the average fiber linear density for each specimen to the nearest 0.1 dtex (0.01 denier), using Eq 1 or Eq 2:

$$T = 100\ W/(L \times N) \tag{1}$$

$$D = 9000\ W/(L \times N) \tag{2}$$

where:
T = average fiber linear density, dtex,

[5] Combs meeting these requirements may be obtained from the Alfred Suter Co., Prell Plaza, Orangeburg, NY 10962.

D = average fiber linear density, denier,
W = mass of bundle specimen, mg,
L = length of bundle specimen, mm, and
N = number of fibers in the bundle specimen.

14.2 Calculate the mean of the average linear density for each laboratory sampling unit and for the lot sample.

14.3 If requested, calculate the standard deviation, coefficient of variation or both.

15. Report

15.1 State that the specimens were tested as directed in Test Methods D 1577, Option A, for linear density by fiber bundle weighing. Describe the material(s) or product(s) sampled, whether the fibers were crimped or uncrimped, and the method of sampling.

15.2 Report the following information:

15.2.1 Average linear density of each specimen,

15.2.2 Average fiber linear density values for each laboratory sampling unit and the lot.

15.2.3 The standard deviation, coefficient of variation, or both, if calculated, and

15.2.4 Tension to remove crimp, if used.

OPTION B—SINGLE-FIBER WEIGHING

16. Scope

16.1 This test method option covers the measurement of the linear density of single fibers. This option is not recommended for fibers shorter than 30 mm.

17. Summary of Test Method Option

17.1 The length of a single fiber, is measured and the fiber is weighed. The linear density of the fiber is then calculated in dtex or denier units.

18. Apparatus

18.1 *Balance*, having a sensitivity of at least 0.0001 mg.

18.2 *Forceps*.

18.3 *Specimen Board*, of contrasting-color, and with short pile for use in measuring fiber lengths and storing specimens.

18.4 *Measuring Scale*, with divisions in 0.5 mm increments.

19. Test Specimens

19.1 From each laboratory sampling unit, take ten specimens at random. If the standard deviation determined for the ten specimens is more than a value agreed upon between the purchaser and supplier, continue testing in groups of ten specimens from the same laboratory sampling unit until the standard deviation for all specimens tested is not more than the agreed-to value or stop testing with a specified number by agreement.

19.2 If fibers from yarns are to be tested, carefully remove twist before taking specimens. Using forceps and grasping the specimens at the ends, gently remove the required number of specimens from the laboratory sampling units for testing. In some cases, it may be advisable to place the specimens on an identified short-pile of plush surface for storage until ready to test. Take care to guard against the tendency to select the more readily visible, hence coarser, fibers as well as the tendency to

compensate for this by selecting finer fibers. Avoid fibers with sharp bends or apparent damage.

20. Preparation of Test Specimens

20.1 If linear density of finish-free fiber is requested, remove the finish as directed in Test Methods D 1907, D 2257, or the Nonfibrous Materials Section of Test Methods D 629. See Note 5.

21. Procedure

21.1 Test the specimens in the standard atmosphere for testing textiles, that is 21 ± 1°C (70 ± 2°F) and 65± 2 % relative humidity.

21.2 Cut any filaments to measurable lengths. Measure the length of each fiber to the nearest estimated 0.1 mm using Test Method D 5103. Record the length.

21.3 Weigh each fiber to the nearest 0.0001 mg. Record the mass.

22. Calculation

22.1 Calculate the linear density of each fiber to the nearest 0.1 dtex (0.01 denier), using Eq 1 or Eq 2 with N = 1.

22.2 Calculate the average linear density for each laboratory sampling unit and for the lot sample.

22.3 If requested, calculate the standard deviation, coefficient of variation, or both, for each laboratory sampling unit and for the lot.

23. Report

23.1 State that the specimens were tested as directed in Option B of this test method, for linear density by single-fiber weighing. Describe the material(s) or product(s) sampled, and the method of sampling.

23.2 Report the following information:

23.2.1 The linear density of each specimen,

23.2.2 The average linear density for each laboratory sampling unit and for the lot sample, and

23.2.3 The standard deviation, the coefficient of variation, or both, if calculated.

OPTION C—VIBROSCOPE

24. Scope

24.1 These test methods options cover procedures for measuring the linear density of single fibers using the vibroscope. These options are particularly applicable to staple fibers with linear density below 10 dtex (9 denier). Option C-1 is for uncrimped fibers and Option C-2 is for crimped fibers.

25. Summary of Test Method Options

25.1 These test methods are based on the vibrating string principle. The linear density, or mass per unit length, can be calculated from the fundamental resonant frequency of transverse vibration of a fiber measured under known conditions of length and tension. Eq 3 and 4 expressing this relationship are as follows:

$$\text{Linear density, g/cm} = t/4L^2f_1^2 \qquad (3)$$

$$\text{Linear density, tex units} = t/4L^2f_1^2 \times 10^5 \qquad (4)$$

where:
t = fiber tension, dynes,
L = effective fiber length, (distance between fiber contact points), mm, and
f_1 = fundamental resonant frequency, Hz.

26. Significance and Use

26.1 Eq 3 and 4 assume a perfectly flexible fiber, but in practice a fiber will have a finite bending stiffness. For very precise work, it may be necessary to apply a correction factor to Eq 3 and 4 based on cross-sectional shape, the dimensions, and the initial modulus of the fiber (**1, 2**).[6] For fibers with linear density under 1 tex, the bending stiffness correction will be no greater than 3 % and may be included in the correction factor K calculated for any particular combination of vibroscope and fiber as described in 29.4.3.

26.2 Test instruments arranged to provide data that satisfy the requirements of Eq 3 and 4 in the manner described in 26.2.1 and 26.2.2 have been found satisfactory in use.

26.2.1 *Type 1*—A fiber of known length under known tension is driven at varying frequency until the fundamental resonant frequency of vibration is attained (**3, 4, 5, 6**).

26.2.2 *Type 2*—A fiber of fixed length is driven at fixed frequency while tension is varied until the fundamental resonant frequency of vibration is attained (**7, 8, 9**). Instruments of this type have not been marketed commercially.

27. Apparatus

27.1 *Vibroscope*, consisting of the following components:

27.1.1 A source of sinusoidally alternating energy with provision for its application to the fiber to cause the fiber to vibrate transversely.

27.1.2 Means for applying tension in the range of 3.0-5.0 mN/tex (0.03 to 0.05 g/fpden) to the fiber, with an accuracy of ±0.5 %, for example, clips, tabs (with cement), or a chain-loading device.

27.1.3 Means for fixing or defining the test length of the fiber to the nearest 0.5 %.

27.1.4 Means for determining or controlling the fundamental resonant frequency of vibration developed by the fiber.

27.1.5 Means for viewing or otherwise detecting the vibration of the fiber at its fundamental resonant frequency.

27.2 *Cathetometer*.

27.3 *Tabs and Adhesive Cement*, for mounting specimens on vibroscope, if needed.

27.4 *Forceps*.

28. Test Specimens

28.1 From each laboratory sampling unit, take ten specimens at random. If the standard deviation determined for the ten specimens is more than a value agreed upon between the purchaser and supplier, continue testing in groups of ten specimens from the same laboratory sampling unit until the standard deviation for all specimens tested is not more than the agreed-to value or stop testing with a specified number by agreement.

28.2 If fibers from yarns are to be tested, carefully remove twist before taking specimens. Using forceps and grasping the specimens at the ends, gently remove the required number of specimens from the laboratory sampling units for testing. In some cases, it may be adviseable to place the specimens on an identified short-pile of plush surface for storage until ready to test. Take care to guard against the tendency to select the more readily visible, hence coarser, fibers as well as the tendency to compensate for this by selecting finer fibers. Avoid fibers with sharp bends or apparent damage.

29. Calibration

29.1 Determine that the effective fiber length is correct within ±0.5 % by accurate measurement between the points of termination with a cathetometer.

29.2 Determine that the means for applying tension is correct within ±0.5 % by comparison with standard weights.

29.3 Calibrate variable frequency oscillators against a tuning fork oscillator or against a crystal-controlled frequency counter according to the directions of the manufacturer.

29.4 Calibrate the vibroscope operating as a unit by comparing the linear density obtained by the vibroscope with the linear density obtained by direct weighing by one of the following procedures:

29.4.1 Using Option B, take one filament, at least 2.5 m (3 yd) long, from a filament yarn having an initial modulus no greater than 4.0 N/tex (45 gf/den), determine the mass and length of the filament accurately to 0.5 %, and calculate the linear density. Cut the filament into a minimum of 25 segments. Determine the linear density of each segment using the vibroscope. Average the linear density for the 25 segments. Then, adjust the vibroscope components to give the same linear density as that obtained for the single filament.

29.4.2 Alternatively, use Option A with a sufficient number of fibers having a nominal linear density in the range 3 to 5 dtex (3.0 to 4.5 denier), an initial modulus no greater than 4.0 N/tex (45 gf/d), no crimp and of specified length to allow determination of bundle mass accurate to 0.5 %. After weighing the bundle, determine the linear density of each fiber in the bundle on the vibroscope. Then, adjust the vibroscope components to give the same linear density as that obtained for the bundle.

29.4.3 Where it is not possible to adjust the vibroscope components to compensate for the compounding of small errors in frequency, length, and tension, calculate a correction factor K using Eq 5:

$$K = m_o / m_u \qquad (5)$$

where:
m_o = average linear density by weighing as determined in 29.4.1 or 29.4.2, and
m_u = average linear density by vibroscope.

29.4.4 The factor K may be determined for fibers where it is necessary to make a correction for bending stiffness. In this case, a bundle of fibers having the same nominal linear density and cross-sectional shape as the fibers to be tested should be weighed. Using this bundle mass, calculate the average linear density in tex units as directed in Section 14; then calculate the factor K by Eq 5. The factor K so determined will then include

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[6] The boldface numbers in parentheses refer to the list of references appended to these methods.

a correction for bending stiffness as well as compensation for the compounding of small errors in frequency, length, and tension in the vibroscope.

30. Preparation of Specimens

30.1 If linear density of finish-free fiber is requested, remove the finish as directed in Test Method D 1907, Test Method D 2257 or the Nonfibrous Materials Section of Test Methods D 629. See Note 5.

30.2 If the vibroscope in use requires the attachment of tabs to the fiber with cement, take care in the mounting process that the cement does not coat the fiber within the effective test length. If such tabs form all or part of the tensioning device, take the mass of the cement into consideration in the overall mass of the tab.

C-1 Uncrimped Fibers

31. Scope

31.1 The following procedures are suitable for use on uncrimped fibers or on fibers from which the crimp is removed by the tension applied in the test. Choice of the appropriate procedure is determined by the arrangement of the components comprising the vibroscope apparatus.

32. Procedure

32.1 Test the specimens in the standard atmosphere for testing textiles, which is 21 ± 1°C (70 ± 2°F) and 65± 2 % relative humidity, and as directed in 32.2 or 32.3.

32.2 *Variable Frequency, Fixed Tension, and Fixed Length*:

32.2.1 Attach a suitable tensioning weight in the range 3.0 to 5.0 mN/tex (0.03 to 0.05 gf/d) to the fiber. The weight must not stretch the fiber more than 0.5 % and must be suitable for the instrument. Transfer the fiber to the vibroscope without jerking it. The fiber must contact the activating and length-defining devices correctly. Vary the oscillator frequency, starting at a point considerably lower than the fundamental resonant frequency to be expected from consideration of the nominal fiber linear density. Increase the frequency gradually, while observing the amplitude of vibration. When maximum amplitude is approached, attenuate the oscillator signal until vibration is just evident and readjust the oscillator frequency to the point of maximum amplitude of vibration (Note 7). Repeat the location of resonance by slightly displacing the oscillator frequency toward both lower and higher values and relocating the point of maximum amplitude. Record the frequency of the oscillator each time and calculate the average frequency.

NOTE 8—Since it is possible in observing for maximum amplitude of vibration to confuse the lowest or fundamental mode with the third harmonic (Fig. 1(b) and (d)), make certain that the fiber is vibrating at the fundamental resonant frequency.

32.2.2 If the instrument **(4, 5, 6)** incorporates in its design means for automatically and essentially instantaneously bringing the fiber to resonance, read and record the resonant frequency, or if the instrument is calibrated to read directly in units of linear density, read and record the linear density value.

32.2.3 If the instrument in use has variable and measurable test length rather than a fixed test length, determine and record the test length before activating the fiber.

32.3 *Type 2 Vibroscopes—Variable Tension, Fixed Length, and Frequency*:

32.3.1 Fasten the upper end of the fiber in the vibroscope. Attach the variable tensioning device to the free, lower end. Do not jerk the fiber in attaching the weighting device. The fiber must contact the activating and length devices correctly and be aligned vertically for proper tension application. Adjust the oscillator for a moderate signal output and gradually increase the tension on the fiber while observing the amplitude of vibration. When maximum amplitude is approached, attenuate the oscillator signal until vibration is just evident and readjust the tension to the point of maximum amplitude (Note 7). Repeat the location of resonance by slightly displacing the tension toward both lower and higher values, and relocating the point of maximum amplitude of vibration. Record the tension each time and calculate the average tension.

32.3.2 If the instrument is calibrated to read directly in units of linear density, read and record the linear density value.

C-2 Crimped Fibers

33. Scope

33.1 Since the presence of crimp leads to falsely high linear density values, it must be removed by the use of sufficiently heavy tensioning weights. This requirement limits the type of
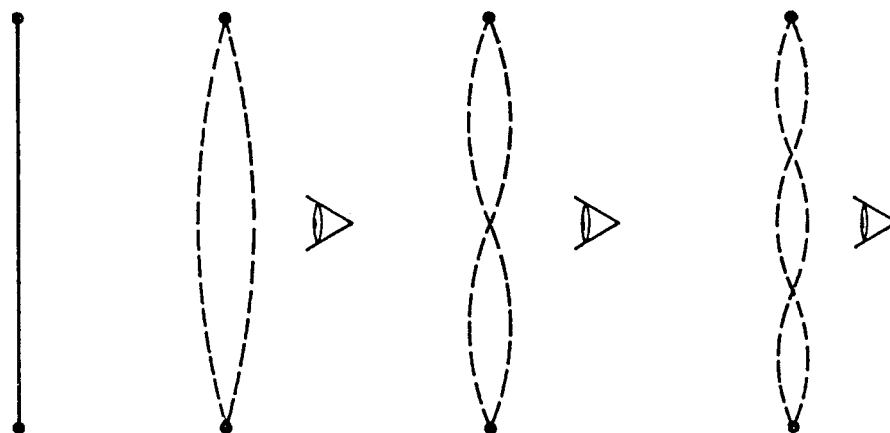

FIG. 1   Modes of Vibration

vibroscope which may be used to a variable frequency unit with adequate range to allow for the measurement of the fundamental frequency of vibration of short lengths of fiber under the tension required.

NOTE 9—When tension normally applied by the equipment used in the procedure described in 32.3 is adequate to remove crimp, this procedure may be used with lightly crimped fibers.

34. Procedure

34.1 Determine the tensioning force required to remove crimp in the type of fiber to be tested by one of the procedures given in the appendix.

34.2 Test the specimens in the standard atmosphere for testing textiles which is $21 \pm 1°C$ ($70 \pm 2°F$) and $65 \pm 2\%$ relative humidity.

34.3 Apply the predetermined tension to the fiber by means of a suitable tab or spring weight and proceed as directed in 32.2.

35. Calculation

35.1 When the observations are in terms of frequency or tension, calculate the linear density of each fiber, in decitex, (denier) to three significant digits using Eq 6 or Eq 7:

$$T = K \times [(W \times 980 \times 10^6)/4L^2f_1^2]10^5 \qquad (6)$$

$$D = K \times [(W \times 980 \times 9 \times 10^6)/4L^2f_1^2] \qquad (7)$$

where:
T = linear density, dtex,
D = linear density, denier,
K = correction factor (see 29.4.3 and 29.4.4),
W = tensioning mass, mg,
L = effective fiber length (distance between fiber contact points), mm, and
f_1 = fundamental resonant frequency, Hz.

35.2 Calculate the average linear density for each laboratory sampling unit and for the lot sample.

35.3 Calculate the standard deviation or coefficient of variation or both for the observations of linear density of the individual fibers, if requested.

36. Report

36.1 Report that the specimens were tested as directed in Test Method D 1577, Option C-1 or C-2 for linear density by vibroscope. Describe the material(s) or product(s) sampled, whether the fibers were crimped or uncrimped, and the method of sampling.

36.2 Report the following information:

36.2.1 Effective fiber length, tension used, fundamental frequency, if observed, and linear density for each specimen tested,

36.2.2 Fiber linear density for each laboratory sampling unit and for the lot,

36.2.3 Standard deviation or coefficient of variation or both, if calculated,

36.2.4 Value of correction factor, K, and

36.2.5 Option used, C-1 or C-2.

37. Precision and Bias

37.1 *Summary*—Based on limited information from one

laboratory, the single-operator and within-laboratory components of variance and critical differences shown in Tables 1 and 2 are approximate. These tables are constructed to illustrate what one laboratory found when all the observations were taken by the same well-trained operator using the same apparatus and specimens randomly drawn from the sample of material. For this laboratory, in comparing two averages, the differences should not exceed the single-operator precision values shown in Table 2 for the respective number of tests in 95 out of 100 cases. Differences for other laboratories may be larger of smaller. The number of laboratories available to perform the procedures in this test method has diminished over the last few years. If additional laboratories are identified to perform these tests, between-laboratory precision will be established.

37.2 *Single-Laboratory Test Data*—A single-laboratory test was run in 1995 in which randomly-drawn samples of four materials, two packages per material, were tested. Two operators in the laboratory each tested twenty specimens from each package of each material using Options A, B and C1 of Test Method D 1577. Ten fibers of each set of twenty were tested on one day and the remaining ten fibers on a second day. Data was analyzed using ASTM's "Tex-Pac" (adjunct to Practice D 2904). The components of variance for linear density, expressed as standard deviations, are given in Table 1. The four materials were:

Method AB—Cellulose Acetate, Crimped Tow, 18 gf/d initial modulus, 1.29 gf/d breaking tenacity
Method CD—Cellulose Acetate, Filament Yarn, 28 gf/d initial modulus, 1.34 gf/d breaking tenacity
Material EF—Polyester, Staple, 41 gf/d initial modulus, 5.42 gf/d breaking tenacity
Method GH—Polyester, Filament Yarn, 77 gf/d initial modulus, 4.28 gf/d breaking tenacity

TABLE 1 Linear Density as Denier—Average Components of Variance, Expressed as Standard Deviations[A]

Option and Material	Cellulose Acetate		Polyester	
	Crimped Tow	Filament Yarn	Staple	Yarn
Option A, Fiber Bundle Weighing Grand Average	2.21	3.70	1.52	4.48
Component of Variance				
Single-Operator Component	0.02	0.11	0.02	0.06
Within-Laboratory Component	0.01	0.04	0.00	0.00
Option B, Single-Fiber Weighing Grand Average	2.15	3.75	1.46	4.41
Component of Variance				
Single-Operator Component	0.17	0.75	0.23	0.21
Within-Laboratory Component	0.06	0.28	0.00	0.00
Option C1, Vibroscope Grand Average	2.14	3.82	1.54	4.48
Component of Variance				
Single-Operator Component	0.14	0.72	0.18	0.18
Within-Laboratory Component	0.04	0.00	0.00	0.03

[A] The square roots of the components of variance (standard deviations) are reported to express the variability in denier units of measure rather than the squares of the units of measure.

TABLE 2 Critical Differences^A in Denier Units

Option and Material	Number of Observations in Each, Average	Precision	
		Single-Operator	Within-Laboratory
Option A, Fiber Bundle Weighing			
Cellulose Acetate	1	0.06	0.07
Crimped Tow	2	0.04	0.05
	5	0.03	0.04
	10	0.02	0.04
Cellulose Acetate	1	0.29	0.31
Filament Yarn	2	0.21	0.23
	5	0.13	0.17
	10	0.09	0.14
Polyester Staple	1	0.06	0.06
	2	0.05	0.05
	5	0.03	0.03
	10	0.02	0.02
Polyester Yarn	1	0.17	0.17
	2	0.12	0.12
	5	0.08	0.08
	10	0.05	0.05
Option B, Single-Fiber Weighing			
Cellulose Acetate	1	0.46	0.48
Crimped Tow	2	0.32	0.35
	5	0.20	0.24
	10	0.14	0.19
Cellulose Acetate	1	2.08	2.22
Filament Yarn	2	1.47	1.66
	5	0.93	1.21
	10	0.66	1.02
Polyester Staple	1	0.65	0.65
	2	0.46	0.46
	5	0.29	0.29
	10	0.21	0.21
Polyester Yarn	1	0.59	0.63
	2	0.42	0.48
	5	0.26	0.35
	10	0.19	0.30
Option C1, Vibroscope			
Cellulose Acetate	1	0.38	0.39
Crimped Tow	2	0.27	0.29
	5	0.17	0.20
	10	0.12	0.16
Cellulose Acetate	1	2.00	2.00
Filament Yarn	2	1.42	1.42
	5	0.90	0.90
	10	0.63	0.63
Polyester Staple	1	0.50	0.50
	2	0.35	0.35
	5	0.22	0.22
	10	0.16	0.16
Polyester Yarn	1	0.49	0.49
	2	0.34	0.35
	5	0.22	0.23
	10	0.15	0.17
Option C1, Vibroscope			
Cellulose Acetate	1	0.38	0.39
Crimped Tow	2	0.27	0.29
	5	0.17	0.20
	10	0.12	0.16
Cellulose Acetate	1	2.00	2.00
Filament Yarn	2	1.42	1.42
	5	0.90	0.90
	10	0.63	0.63
Polyester Staple	1	0.50	0.50
	2	0.35	0.35
	5	0.22	0.22
	10	0.16	0.16
Polyester Yarn	1	0.49	0.49
	2	0.34	0.35
	5	0.22	0.23
	10	0.15	0.17

^{A} The critical differences were calculated using $t = 1.960$, that is based on infinite degrees of freedom.

37.3 *Precision*—Since tests were conducted in only one laboratory, estimates of between-laboratory precision may be underestimated or overestimated to a considerable extent and should be used with special caution. 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 samples taken from a lot of material of the type being evaluated to be as nearly homogeneous as possible and then randomly assigned in equal numbers to each of the laboratories. However, when agreed upon between the contractual parties, for the approximate components of variance reported in Table 1, two averages of observed values may be considered significantly different at the 95 % probability level if the difference equals, or exceeds, the critical differences listed in Table 2. There were sufficient differences related to the material type and structure to warrant listing the components of variance and the critical differences separately. Consequently no multi-material comparisons were made.

37.4 *Bias*—The value for linear density of textile fibers can only be defined in terms of a test method. Within this limitation, this test method no bias. However, failure to remove crimp, or stretching of fibers, will adversely affect precision and bias of measurements.

38. Keywords

38.1 linear density; textile fibers

APPENDIX

(Nonmandatory Information)

X1. DETERMINATION OF TENSIONING WEIGHT ON FIBERS OF UNKNOWN CRIMP CHARACTERISTICS

X1.1 Determine the tensioning force required for crimp removal by one of the following procedures:

X1.1.1 Examine the uncrimping portion of the force-elongation curve and choose a suitable force.

X1.1.2 Measure the linear density under increasing increments of tension until the force required to remove crimp is indicated by a minimum dependence of linear density on changing tension. Using a variable frequency vibroscope and a representative sample of the unknown fiber, measure the linear density of successive fibers in the sample under tension increased by fixed increments starting with a tension of approximately 200 mN/tex (2.2 gf/d). As the tensioning force is increased, the linear density measurement will decrease, pass through a region of essentially no change with increasing tension, and then again decrease. Discontinue tensioning when the second decrease occurs. Plot tension in mN/tex (gf/d) versus the average linear density for the sample at each tension (Fig. X1.1). The flat region *a–b* on this curve represents the range of tension which will essentially remove crimp without stretching the fiber. Choose a tension at the mid-point of this region.

X1.1.3 Determine the tension required to extend the fiber a fixed true extension by calculation from the initial modulus of the fiber. An extension of 0.5 % has been found safe for most fibers. Calculate the tension corresponding to 0.5 % extension using Eq X1.1:
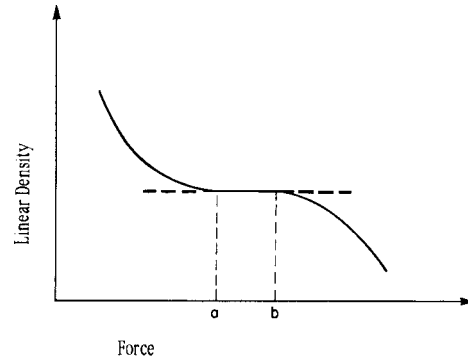

FIG. X1.1   Curve Showing the Change in Linear Density with Increase in Tension

$$W = 0.005 \times A \times M \qquad (X1.1)$$

where:
W = tensioning force, g,
A = nominal linear density of the fiber, dtex (denier), and
M = approximate initial modulus of the fiber, cN/tex (gf/d).

Note X1.1—This technique results in force levels considerably higher than those resulting from the procedure stated in X1.1.2 and, therefore, should effectively remove crimp. However, the force may also be outside the range of many vibroscopes.

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