Designation: D 4031 – 01

Standard Test Method for Bulk Properties of Textured Yarns[1]

This standard is issued under the fixed designation D 4031; 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 measurement of the change in length of a tensioned skein of textured yarn due to change in crimp characteristics brought about by exposure to wet or dry heat. The change in length, depending on procedure, is a measure of skein shrinkage, crimp contraction, bulk shrinkage, or crimp recovery.

1.2 This test method applies to crimped, continuous multifilament yarns ranging from 1.7 to 88.9 tex (15 to 800 denier).

1.3 Three conditions are provided for crimp development mediums, and loading routines are provided to be used on the yarn skeins to allow determination of yarn bulk by several different procedures.

1.4 The values stated in either SI units or inch-pound units are to be regarded as standard. Within the text, the inch-pound units are shown in parentheses. The values stated in each system are not exact equivalent; therefore, each system shall be used independently of the other. Combining values from the two systems may result in noncomformance 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:* [2]

D 123 Terminology Relating to Textiles

D 1059 Test Method for Yarn Number Based on Short-Length Specimens

D 1776 Practice for Conditioning and Testing Textiles

D 1907 Test Method for Linear Density ofYarn (Yarn Number) by the Skein Method

D 2258 Practice for Sampling Yarn for Testing

3. Terminology

3.1 *Definitions:*

3.1.1 *bulk shrinkage*, *n*—a measure of potential stretch and power of stretch yarns or a measure of bulk of textured-set yarns.

3.1.2 *crimp contraction*, *n*—an indicator of crimp capacity or a characterization of a yarn's ability to contract under tension.

3.1.3 *crimp development medium*, *n—for testing of textured yarn*, an environment that allows the temporary set of fiber crimp to be overcome and that allows the filaments to assume their permanently set configuration.

3.1.4 *crimp recovery*, *n*—a measure of the ability of a yarn to return to its original crimped state after being subjected to tension.

3.1.5 *skein shrinkage*, *n*—a measure of true or intrinsic yarn shrinkage not including crimp contraction.

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

4. Summary of Test Method

4.1 A skein of yarn of a prescribed size (linear density) is subjected to a crimp development medium using a specified loading routine. As the crimp is developed or shrinkage occurs in the yarn, the skein changes in length. The lengths of the skein under specified tension forces are used to calculate the value of bulk shrinkage, crimp contraction, skein shrinkage, or crimp recovery.

4.2 The test method offers three options for loading routine of the yarn skeins. Loading routines consist of using low-tension forces (light loads of 0.04 to 0.98 mN/tex (0.5 to 11 mgf/den)) that extend without removing crimp, and high-tension forces (heavy loads of 8.8 mN/tex (100 mgf/den)) that remove crimp without elongating the yarn. A list of weights to be used is given in Table 1. Weight option combinations are detailed in Table 2.

5. Significance and Use

5.1 The values obtained by this test method should not be used to predict similar properties in fabricated structures except in narrow well-defined comparisons, such as 16.7 tex (150-denier) polyester from the same feed yarn merge and textured on the same machine type. Attempts to relate yarn performance to fabric performance might result in poor correlations unless

[1] This test method is under the jurisdiction of ASTM Committee D13 on Textiles and is the direct responsibility of Subcommittee D13.58 on Yarn Test Methods, General.

Current edition approved Sept. 10, 2001. Published December 2001.. Originally published as D 4031 – 81. Last previous edition D 4031 – 95a.

[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.

TABLE 1 Tension Forces Used and Required Weights

Tension-mN/tex	mgf/den	Weight Required in Grams	
		1.7 to 44.4 tex[A] (15 to 400 den)	44.5 to 89.0 tex[B] (401 to 800 den)
For Options A, B, C:			
0.04	0.5	2.5	3.8
0.13	1.5	7.5	11.3
0.22	2.5	12.5	18.8
0.44	5.0	25.0	37.5
0.88	10.0	50.0	75.8
8.83	100.0	500.0	750.0
For Option B Only:			
0.10	1.1	2.5[C]	...
0.98	11.1	25.0[C]	...
9.82	11.1	250.0[C]	...
For Option C Only:			
0.13	1.5	[D]	

[A] 555.5-tex (5000-denier) skein.
[B] 833.3-tex (7500-denier) skein.
[C] For 250-tex (2250-denier) skein.
[D] Variable, see Eq 1.

TABLE 2 Weight Option Combinations

Option	Loading			Recommended Crimp Development Condition	Results Obtained
	Before Development	During Development	After Development		
A	light heavy	light	light heavy	1	CCBD, CCAD
B	...	none	light heavy	1	SS, CR CCAD
C	light	light	light 2nd light	2 or 3	BKS

other factors affecting bulk such as yarn shrinkage and fabric finishing are eliminated.

5.2 Elapsed time between processing and testing has a marked effect on the results of this test especially during the first 72 h. Therefore, specimens should only be compared if tested after the same elapsed time. This effect is caused by stress decay which is known to be minimal beyond the seventh day and after which time the sample remains relatively stable. Comparisons are preferably made after the seventh day.

5.3 In the case of yarns having a linear density near the upper limit of the skein size directed in Table 3, an error is introduced when rounding off to full revolutions. Therefore, the calculated values for crimp contraction, etc., should only be compared with other samples of yarn of the same linear density.

5.4 Option A used with crimp development Condition 1 (dry heat oven at 120°C (248°F)) and light loads of 0.04 mN/tex (0.5 mgf/den) and 0.44 mN/tex (5.0 mgf/den) are recommended for textured polyester yarns. All crimp parameters (3.1.1-3.1.4) may be calculated.

TABLE 3 Total Size (Linear Density) of Skein

Linear Density of Yarn	Linear Density of Skein[A]
Options A, B, C:	
1.7 to 44.4 tex (15 to 400 denier)	555.5 tex (5000 denier)
44.5 to 89.0 tex (401 to 800 denier)	833.5 tex (7500 denier)
Option B Only (for mechanical device):	
1.7 to 44.4 text (15 to 400 denier)	250 tex (2250 denier)
Option C Only:	
1.7 to 44.4 tex (15 to 400 denier)[B]	

[A] See Eq 2, and Note 1.
[B] 100 Revolutions, linear density of skein varies.

5.5 Option B may also be used with crimp development Condition 1 (dry heat) for textured polyester yarns. Crimp contraction (3.1.2) may be calculated. When used to duplicate or to utilize suitable mechanical yarn handling devices,[3] alternate skein size and weights may be used as described in 6.5.2 and 9.3.2.

5.6 Option C used with crimp development Condition 2 (water bath at 82°C (180°F)) and a light load of 0.13 mN/tex (1.5 mgf/den) is recommended for textured nylon yarns. For textured polyester yarns, Condition 3 (water bath at 97°C (206°F)) is recommended. Only bulk shrinkage (3.1.1) is calculated.

5.7 This test method for the measurement of bulk properties is not recommended for acceptance testing of commercial shipments because of lack of precision data.

5.7.1 If there are differences or practical significance between reported test results for two laboratories (or more), comparative tests should be performed to determine if their is a statistical bias between them, using competent statistical assistance. As a minimum, test samples that are as homogeneous as possible, drawn from the material from which the disparate test results were obtained, and randomly assigned in equal numbers to each laboratory for testing. The test results from the two laboratories should be compared using a statistical test for unpaired data, at a probability level chosen prior to the testing series. If a bias is found, either its cause must be found and corrected, or future test results for that material must be adjusted in consideration of the known bias.

6. Apparatus [3]

6.1 *Skein Reel*:

6.1.1 *General*—A hand or motor-driven reel having a specified perimeter. The reel shall be fitted with a traversing mechanism that will avoid bunching the successive wraps, and with an indicator of the length wound. A warning bell that will ring at a specified length is recommended. A collapsible arm is recommended for ease of removal of skeins. A revolution counter is also recommended.

6.1.2 *Reel Perimeter*—The perimeter shall be 1.0 m (1.09 yd) with a tolerance of ±2 %. By agreement between purchaser and supplier, reels may be used having any perimeter between 0.9 to 2.3 m (1 to 2.5 yd).

6.1.3 *Yarn Tensioning*—To minimize differences in yarn tensioning a motor driven unit with speeds at 150 ± 20 revolutions/min is recommended. Tensions should be as low as possible and no additional tensioning device is required for a motor driven reel. For a hand driven reel additional tensioning may be needed for yarn control. In no case should the tension exceed 13 mN/tex (0.15 gf/den).

[3] The sole source of supply of the Textured Yarn Apparatus known to the committee at this time is Lawson-Hemphill Sales, Inc., PO Drawer 6388, Spartanburg, SC 29304 or (International Sales) Lawson-Hemphill, Inc., 96 Hadwin Street, Central Falls, Rhode Island, 02863. 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, which you may attend.

6.2 *Measuring Stand*—A stand with a measuring scale, in mm, and a hook to position the skein vertically in line with the scale zero.

6.3 *Heating Rack*—A rack to support skeins during treatment and while cooling or drying. The rack and measuring stand may be combined in one piece.

6.4 *Mechanical Yarn Handling Device*.

6.5 *Weights*, which have a mass accurate to ±0.1 g, for tensioning skeins:

6.5.1 *For Options A, B, and C*, having mass dependent on yarn denier as shown below and listed in Table 1:

6.5.1.1 1.7 to 44.4 tex (15 to 400 denier): 2.5, 7.5, 12.5, 25.0, 50.0 and 500.0 g.

6.5.1.2 44.5 to 93.3 tex (401 to 840 denier): 3.8, 11.3, 18.8, 37.5, 75.0, and 750 g.

6.5.2 *For Option B only*, where suitable mechanical device is utilized or duplicated, a variation in skein size loading is used as shown in Table 1 and below.

6.5.2.1 1.7 to 44.4 tex (15 to 400 denier): 2.5, 27.5 and 250 g.

6.5.3 *For Option C*, calculate the mass required, using Eq 1.

$$W = (2 \times T)(L \times R) \quad (1)$$

where:

W = mass, g,
T = tension, mN/tex (gf/den),
L = yarn linear density, tex (denier), and
R = 100, the number of reel revolutions.

6.6 *Equipment for Developing Crimp by the Specified Condition*:

6.6.1 *Oven*—For crimp development Condition 1, an oven with temperature controls to maintain a temperature of 120 ± 2°C (250 ± 4°F) and large enough to hold skeins and attached weights vertically without the weights touching the oven floor.

6.6.2 *Waterbath*—For crimp development Conditions 2 and 3, a water bath capable of maintaining a water temperature of 82 ± 2°C (180 ± 4°F) or of 97 ± 2°C (206± 4°F), and large enough to hold skeins and attached weights vertically without the weights touching the tank bottom (see Sections 5 and 6).

6.7 *Stopwatch*, or suitable timer.

7. Sampling

7.1 *Lot Sample*—Take a lot sample of shipping containers as directed in an applicable specification, or as agreed upon between the purchaser and supplier. In the absence of an applicable specification or agreement, take a lot sample as directed in Practice D 2258. Consider shipping containers of yarn to be the primary sampling unit.

7.2 *Laboratory Sample*—As a laboratory sample for acceptance testing, from the combined number of primary sampling units, take four randomly selected packages from each container. Select the packages randomly from the containers in the lot sample as directed in Practice D 2258.

7.3 *Number of Specimens*—Test three specimens from each package of yarn in the laboratory sampling unit

8. Conditioning

8.1 Condition each package in the standard atmosphere for testing textiles which is 70 ± 2°F (21 ± 1°C) and 65 % ± 2 relative humidity as directed in Practice D 1776 (7.3 and 7.5), prior to winding skeins.

9. Preparation of Test Specimens

9.1 Determine linear density of yarn by either of Test Methods D 1059 or Test Method D 1907, unless known.

9.2 Strip approximately 30 m (30 yd) of yarn from each package and prepare skeins in the standard atmosphere for testing textiles as directed in 9.3.

9.3 *Skein Sizes*:

9.3.1 *Options A, B, and C*—Reel the skeins as directed in Table 3 (see Eq 2). The number of turns required for a skein size (linear density) of 555.5 tex (5000 denier) and yarn linear densities of 1.7 to 44.4 tex (15 to 400 denier) are given in Table 4. For higher tex up to 89.0 tex (800 denier), the number of wraps per skein is determined using Eq 2, raising any fractional wrap result to the next highest whole number.

$$R = S/2D \quad (2)$$

where:

R = number of reel revolutions required in the skein,
S = size (linear density) of the skein, tex (denier),
D = yarn linear density, tex (denier), and
2 = number of legs of skein.

NOTE 1—It is understood that the actual linear density of the reel skeins is not equal to the size (linear density) selected for the calculation of reel revolutions. The use of linear density to describe the total size of the skein is common in the textured yarn industry.

9.3.2 *Option B*—Where suitable mechanical device is utilized or duplicated for deniers 1.7 to 44.4 tex (15 to 400), a 250 tex (2250 total skein denier) may be used. Calculate the number of revolutions, using Eq 2.

9.3.3 *Option C*—In the case of a reel having a 1-m circumference where a skein of 100 m is used the number of revolutions will be 100. Where reels of other circumferences are used, a correction must be made for the number of revolutions by dividing by reel circumference in metres. Depending on linear density and reel circumference loading weights must be calculated in each case, using Eq 1.

10. Procedure

10.1 Make all length measurements in the standard atmosphere for testing textiles.

10.2 Test the skeins as directed in 10.3, 10.4, or 10.5.

10.3 *Option A*:

10.3.1 Crimp contraction before and after development (CCBD and CCAD) skein shrinkages (SS), bulk shrinkage (BKS), and crimp recovery (CR) may be calculated.

10.3.2 Select a crimp development condition from the options listed in Table 2 (see 5.4).

10.3.3 Select the weights from Table 1 based on selected tension forces to be used. A different set of specimens is required for each light load (see 5.4).

10.3.4 For each specimen make the following length measurements:

10.3.4.1 Length before development, under light load, label C_b.

10.3.4.2 Length before development, under heavy load, label L_b.