Designation: D 4031 – ~~95a~~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 ~~is limited~~ applies to crimped, continuous multifilament yarns ranging from 1.7 to 888.9 tex (15 to 8000 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 This standard provides the~~

1.4 The values ~~in both inch-pound units and SI units. Inch-pound units is the technically correct name for the customary units used in the United States. SI units is the technically correct name for the system of metric units known as the International System of Units. The values~~ stated in either ~~acceptable metric~~ SI units or ~~in other~~ inch-pound units ~~shall~~ are to be regarded ~~separately~~ as standard. Within the text, the inch-pound units are shown in parentheses. The values stated in each system ~~m~~ are not exact equivalent; therefore, each system shall be used independently of the ~~other, without combining~~ other. Combining values from the two systems may result in ~~any way.~~ 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:*

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[1] This test method is under the jurisdiction of ASTM Committee D-13 on Textiles and is the direct responsibility of Subcommittee D13.58 on Yarn Test Methods, General.

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D 123 Terminology Relating to Textiles[2]
D 1059 Test Method for Yarn Number Based on Short-Length Specimens[2]
D 1776 Practice for Conditioning ~~Textiles for~~ and Testing Textiles[2]
D 1907 Test Method for Linear Density of Yarn (Yarn Number) by the Skein Method[2]
D 2258 Practice for Sampling Yarn for Testing[2]

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 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.

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

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 SS, CR
B	...	none	light heavy	1	CCAD
C	light	light	light 2nd light	2 or 3	BKS

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 2.
[B] 100 Revolutions, linear density of skein varies.

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.

5.5 Option B may also be used with crimp development Condition 1 (dry heat) for textured polyester yarns. Crimp contraction (3.1.~~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 In the case of a dispute arising from~~

5.7.1 If there are differences or practical significance between reported test results ~~when using Test Method D 4031~~ for ~~acceptance testing of commercial shipments, the purchaser and the supplier should conduct~~ two laboratories (or more), comparative tests should be performed to determine if thei~~r~~e is a statistical bias between ~~their laboratories. Competent~~ them, using competent statistical ~~assistance is recommended for the investigation of bias.~~ assistance. As a minimum, ~~the two parties should take a group of~~ test ~~specimens~~ samples that are as homogeneous as ~~possible and that are~~ possible, drawn from ~~a lot of~~ the material ~~of~~ from which the ~~type in question. The~~ disparate test ~~specimens should then be~~ results were obtained, and randomly assigned in equal numbers to each laboratory for testing. The ~~average~~ test results from the two laboratories should be compared using ~~Student's *t*-test~~ a statistical test for unpaired ~~data and an acceptable~~ data, at a probability level chosen ~~by~~ prior to the ~~two parties before the~~ testing ~~is begun.~~ series. If a bias is found, either its cause must be found and corrected, or ~~the purchaser and the supplier must agree to interpret~~ future test results ~~with~~ for that material must be adjusted in consideration ~~to~~ 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 ~~seller,~~ supplier, reels may be used having any perimeter between 0.9 to 2.3 m (1 to 2.5 yd).

~~[3] Texturmat, available from~~

[3] The sole source of supply of the Textured Yarn Apparatus known to the committee at this time is Lawson-Hemphill Sales, Inc., ~~P. O.~~ PO Drawer 6388, Spartanburg, S~~.~~C~~.~~ 29304 or (International Sales) Lawson-Hemphill, Inc., 96 Hadwin Street, Central Falls, Rhode Island, 02863. If you are aware of alternative s~~b~~uppliers, please provide this infou~~r~~mation to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend.

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).

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.~~

~~NOTE 1—An adequate specification or other agreement between the purchaser and the supplier requires taking into account the variability between~~ D 2258. Consider shipping ~~units, between packages or ends within a shipping unit, and between specimens from a single package~~ containers of yarn to ~~provide a~~ be the primary sampling ~~plan with a meaningful producer's risk, consumer's risk, acceptable quality level, and limiting quality level.~~ unit.

7.2 *Laboratory Sample*—As a laboratory sample for acceptance testing, ~~take a total~~ from the combined number of primary sampling units, take four randomly selected packages from each ~~container into the lot sample.~~ 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 ~~sample.~~ 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.

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

TABLE 4 Skein Reel Revolutions Calculations[A]

Tex.	(Denier)	Number of Turns	Tex.	(Denier)	Number of Turns
4.40 to 4.44	39.7 to 40.3	63	8.30 to 8.54	75.8 to 78.1	33
4.45 to 4.51	40.4 to 40.9	62	8.55 to 8.81	78.2 to 80.6	32
4.52 to 4.59	41.0 to 41.6	61	8.82 to 9.10	80.7 to 83.3	31
4.60 to 4.66	41.7 to 42.3	60	9.11 to 9.41	83.4 to 86.2	30
4.67 to 4.74	42.4 to 43.0	59	9.42 to 9.74	86.3 to 89.2	29
4.75 to 4.83	43.1 to 43.8	58	9.75 to 10.1	89.3 to 92.5	28
4.84 to 4.91	43.9 to 44.6	57	10.2 to 10.4	92.6 to 96.1	27
4.92 to 5.00	44.7 to 45.4	56	10.5 to 10.8	96.2 to 99.9	26
5.01 to 5.09	45.5 to 46.2	55	10.9 to 11.3	100.0 to 104.1	25
5.10 to 5.19	46.3 to 47.1	54	11.4 to 11.8	104.2 to 108.6	24
5.20 to 5.29	47.2 to 48.0	53	11.9 to 12.3	108.7 to 113.6	23
5.30 to 5.39	48.1 to 49.0	52	12.4 to 12.9	113.7 to 119.0	22
5.40 to 5.50	49.1 to 49.9	51	13.0 to 13.5	119.1 to 124.8	21
5.51 to 5.61	50.0 to 51.0	50	13.6 to 14.2	125.0 to 131.5	20
5.62 to 5.72	51.1 to 52.0	49	14.3 to 15.0	131.6 to 138.8	19
5.73 to 5.84	52.1 to 53.1	48	15.1 to 15.8	138.9 to 147.0	18
5.85 to 5.97	53.2 to 54.3	47	15.9 to 16.8	147.1 to 156.2	17
5.98 to 6.10	55.4 to 55.5	46	16.9 to 17.9	156.3 to 166.6	16
6.11 to 6.24	55.6 to 56.8	45	18.0 to 19.1	166.7 to 178.5	15
6.25 to 6.38	56.9 to 58.1	44	19.2 to 20.5	178.6 to 192.3	14
6.39 to 6.53	58.2 to 59.1	43	20.6 to 22.2	192.4 to 208.3	13
6.54 to 6.69	59.2 to 60.9	42	22.3 to 24.1	208.4 to 227.2	12
6.70 to 6.85	61.0 to 62.4	41	24.2 to 26.4	227.3 to 249.9	11
6.86 to 7.03	62.5 to 64.0	40	26.5 to 29.2	250.0 to 277.7	10
7.04 to 7.21	64.1 to 65.7	39	29.3 to 32.6	277.8 to 312.4	9
7.22 to 7.40	65.8 to 67.5	38	32.7 to 37.0	312.5 to 357.1	8
7.41 to 7.61	67.6 to 69.4	37	37.1 to 42.7	357.2 to 384.9	7
7.62 to 7.82	69.5 to 71.4	36	42.8 to 44.4	385.0 to 400.0	6
7.83 to 8.05	71.5 to 73.5	35			
8.06 to 8.29	73.6 to 75.7	34			

[A] Sample calculation of reel revolutions required for a given yarn density expressed as tex (from 4.40 to 44.4 tex (40 to 400 den.) and for a 555.5-tex (5000-den) skein (see Eq 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 ~~2~~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.

10.3.4.3 Length after development with light load attached, label C_a.

10.3.4.4 Length after development with heavy load, label L_a.

10.3.4.5 Length with light load on a developed specimen after heavy load removed, label C_c.

10.3.5 Place a skein for each of the light loads to be tested on a separate hook on the measuring stand and apply the respective

light load (see Table 1 and Note ~~3).~~ 2). Immediately start the stop watch and after a minimum of 15 s, measure the length of each skein to ± 1 mm (Note ~~4).~~ 3). Record length as C_b for each skein. The light load will remain on the skein throughout the test.

NOTE ~~3~~2—When handling weights, use care not to let the weight drop, bounce, or otherwise stretch the yarn beyond its loading tension.
NOTE ~~4~~3—For convenience it is preferable to run a group of skeins at one time, measuring one skein after the other.

10.3.6 Add the heavy load (8.8 mN/tex (100 mgf/den)) to the skein without removing the light load. Start stop watch and after a minimum of 30 s measure length of each skein to ±1 mm (Note ~~3).~~ 2). Record length with heavy load as L_b for each skein.

10.3.7 Remove the heavy load from each skein and hang the low-tensioned skein on heating rack hook.

10.3.8 Transfer the skein on the rack to crimp development Condition selected. For Condition 1, expose for 5 min in oven stabilized at 120 ± 2°C (250 ± 4°F) but do not start timing until oven returns to temperature after closing door. Remove and allow to cool in standard atmosphere. For Conditions 2, 3, and 4, expose as directed in 10.5.5-10.5.7.

10.3.9 Remeasure the skeins as directed in 10.3.5 and record respective lengths as C_a. The light weight will have remained on the skein during crimp development.

10.3.10 Remeasure the skeins as directed in 10.3.6 and record length under 8.8 mN/tex load (100.0 mgf/den) as L_a.

10.3.11 Carefully remove 8.8 mN/tex load (100.0 mgf/den). After 30 s, remeasure skein and label the length to ±1 mm, as C_c under each respective load.

10.3.12 Test the remaining skeins as directed in 10.3.5-10.3.11.

10.4 *Option B*:

10.4.1 Crimp contraction before and after development (CCBD and CCAD) may be calculated.

10.4.2 Select a crimp development Condition from those offered as options in Table 2 (see 5.5).

10.4.3 Select the weight or weights from Table 1. Two light loads may be used for each specimen.

10.4.4 For each specimen, make the following length measurements:

10.4.4.1 Length after development with heavy load, L_a.

10.4.4.2 Length after development with light load(s), C_a.

10.4.5 Place each skein to be tested on a separate hook on the measuring board. Apply no weight.

10.4.6 For Condition 1, place skein in oven stabilized at 120 ± 2°C (250 ± 4°F) for 5 min. Do not start timing until oven returns to temperature. Remove and allow to cool in standard atmosphere. For Conditions 2 and 3, expose as directed in 10.5.6 to 10.5.8.

10.4.7 Apply the heavy weight (8.8 mN/tex (100 mgf/den) in the case of a 555.5 tex (5000 den) skein or 4.8 mN/tex (111.2 mgf/den) in case of a 250 tex (2250 denier) skein. Start stopwatch and after 30 s, measure length of each skein to ±1 mm. Record length as L_a. Remove load.

10.4.8 Apply the 2.5-g weight if selected. Start stopwatch and after 10 min, measure length of each skein to ±1 mm (Note ~~3).~~ 2). Record length as C_a and note load used.

10.4.9 Remove the 2.5-g weight, if used, and apply the 25-g weight, if selected (Note 2). Start stopwatch and after 10 s, measure length of each skein to ±1 ~~mm (Note 3).~~ mm. Record length as C_a at 25.0 g tension. Remove the 25-g weight.

10.4.10 Test the remaining skeins as directed in 10.4.5-10.4.9.

10.5 *Option C*:

10.5.1 Bulk shrinkage (BKS) may be calculated.

10.5.2 Select the light load from Table 1. Where the recommended load of 0.13 mN/tex (1.5 mgf/den) and fixed skein length of 100 skein reel revolutions are used, calculate the weight using Eq 1.

10.5.3 For each specimen make the following length measurements:

10.5.3.1 Length before development, under light load, C_b.

10.5.3.2 Length after development, under light load, C_a.

10.5.4 Attach the selected weight to the skein (Note 2). After 15 s, measure the length of skein to ±1 ~~mm (Note 3).~~ mm. Record this length as C_b.

10.5.5 For Condition 1 see 10.3.7 to 10.3.8. For Conditions 2 or 3, totally immerse weighted skein in water or steam at the appropriate temperature for 10 min.

10.5.6 Remove skein from crimp development medium and hang on measuring rack. Allow the excess water to drip off (60 s minimum). With the weight still in place, measure the length of the skein to ±1 mm. Record this length as C_a.

10.5.7 If dry readings are required for Conditions 2 and 3, dry the specimens in standard conditions overnight or in a circulating air dryer at 54°C (130°F). The dry measurement is then made as in 10.5.6 after conditioning in standard atmosphere for 1 h. Record this length as C_a and indicate dried sample on data sheet.

11. Calculation of Results

11.1 Calculate crimp contraction before development (CCBD) to 0.1 % for each load using Eq 3.

11.2 Calculate crimp contraction after development (CCAD) to 0.1 % for each load using Eq 4.

11.3 Calculate skein shrinkage (SS) to 0.1 % after development using Eq 5.

11.4 Calculate crimp recovery (CR) to 0.1 % for each load using Eq 6.

11.5 Calculate the bulk shrinkage (BKS) to 0.1 % using Eq 7.

$$\text{CCBD} = 100\,(L_b - C_b)\,/\,L_b \tag{3}$$

$$CCAD = 100\,(L_a - C_a)\,/\,L_a \quad (4)$$

$$SS = 100\,(L_b - L_a)\,/\,L_b \quad (5)$$

$$CR = 100\,(L_a - C_c)\,/\,(L_a - C_a) \quad (6)$$

$$BKS = 100\,(C_b - C_a)\,/\,C_b \quad (7)$$

where:

CCBD = crimp contraction before development, %,
CCAD = crimp contraction after development, %,
SS = skein shrinkage, %,
CR = crimp recovery, %,
BKS = bulk shrinkage, %,
L_b = length of skein under heavy load before heating, mm,
L_a = length of skein under heavy load after heating, mm,
C_b = length of skein under light load before heating, mm,
C_a = length of skein under light load after heating, mm, and
C_c = length of skein under light load after heating and removal of heavy load, mm,

11.6 Calculate the average (from three specimens) for each property of each laboratory sample and of the lot sample.

11.7 Calculate the standard deviations or coefficient of variations, or both, for each laboratory sample and for the lot, if required.

12. Report

12.1 State that the specimens were tested as directed in ASTM Test Method D 4031. State the material or product sampled and the method of sampling used.

12.2 Report the following information.

12.2.1 The lapsed time between material processing and testing, if known.

12.2.2 Circumference of reel used and total skein size.

12.2.3 The weights used and also the loading scheme (as per Load Option A, B, or C).

12.2.4 State the development medium used (as per Option A, B, or C).

12.2.5 For Option C, whether wet or dry mediums were used for C_a and skein length.

12.3 Report data for each specimen and average of each laboratory and lot sample for the following parameters:

12.3.1 Yarn number,

12.3.2 Crimp contraction before development,

12.3.3 Crimp contraction after development,

12.3.4 Skein shrinkage,

12.3.5 Crimp recovery,

12.3.6 Bulk skein shrinkage,

12.3.7 Report the standard deviations and coefficient of variations if calculated.

13. Precision and Bias

13.1 *Precision—Interlaboratory Test*—An interlaboratory test was conducted in 1994 involving randomly drawn samples of two materials which were tested in each of two laboratories. Two operators in each laboratory tested two specimens of each material. Option A was used to calculate all bulk properties with Condition 3 used as a crimp development medium. Skeins of 555.5 tex (5000 den) were run. A light load of 7.5 g. and a heavy load of 500.0 g. were used for loading forces. The components of variance for the properties listed in Table 5 are shown as standard deviations.

13.2 *Critical Differences*—For the components of variance listed in Table 5, two averages of observed values should be considered significantly different at the 95 % probability level if the difference equals or exceeds the critical differences listed in Table ~~6.~~ 6.

13.3 *Bias*—The procedures in Test Method D 4031 for measuring the bulk properties of textured yarns have no bias because the values of the properties can be defined only in terms of a test method.

14. Keywords

14.1 bulk; bulk properties; crimp; textured yarn; yarn

TABLE 5 Components of Variance

	Properties				
	CCBD	CCAD	SS	CR	BKS
Single-operator component	.324	1.50	.497	3.75	1.58
Within-laboratory component	.362	1.28	.235	2.68	1.41

TABLE 6 Critical Difference

Number of Observations in Each Average	Property	Single-Operator Precision	Between-Laboratory Precision
1	CCBD	1.16	1.75
	CCAD	5.41	7.10
	SS	1.79	1.98
	CR	13.5	16.6
	BKS	5.69	7.63
3	CCBD	.674	1.01
	CCAD	3.12	4.10
	SS	1.03	1.14
	CR	7.80	9.59
	BKS	3.29	4.41
10	CCBD	.370	.550
	CCAD	1.71	2.25
	SS	.570	.630
	CR	4.27	5.25
	BKS	1.80	2.41