Designation: D4031 – 07 (Reapproved 2012)

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

This standard is issued under the fixed designation D4031; 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 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:*[2]

D123 Terminology Relating to Textiles

D1059 Test Method for Yarn Number Based on Short-Length Specimens (Withdrawn 2010)[3]

D1776 Practice for Conditioning and Testing Textiles

D1907 Test Method for Linear Density of Yarn (Yarn Number) by the Skein Method

D2258 Practice for Sampling Yarn for Testing

D4849 Terminology Related to Yarns and Fibers

3. Terminology

3.1 For all terminology relating to D13.58, Yarns and Fibers, refer to Terminology D4849.

3.1.1 The following terms are relevant to this standard: bulk shrinkage, crimp contraction, crimp development medium, crimp recovery, skein shrinkage.

3.2 For all other terms are related to textiles, refer to Terminology D123.

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

[1] This test method is under the jurisdiction of ASTM Committee D13 on Textiles and is the direct responsibility of Subcommittee D13.58 on Yarns and Fibers.

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

[3] The last approved version of this historical standard is referenced on www.astm.org.

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 light	1	CCAD
C	light	light	2nd light light	2 or 3	BKS

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 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 may be calculated. When used to duplicate or to utilize suitable mechanical yarn handling devices,[4] 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 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 there 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[4]

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).

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.

[4] 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, [1] which you may attend.

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 D2258. 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 D2258.

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 D1776 (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 D1059 or Test Method D1907, 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.

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).

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

NOTE 2—When handling weights, use care not to let the weight drop, bounce, or otherwise stretch the yarn beyond its loading tension.

NOTE 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 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 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. 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. 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.

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

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

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

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

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

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 D4031. 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

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

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.

13.3 *Bias*—The procedures in this test method 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