



Designation: D2259 – 21

# Standard Test Method for Shrinkage of Yarns<sup>1</sup>

This standard is issued under the fixed designation D2259; 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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This test method is used to determine the shrinkage of yarns in skein form when treated in boiling water, dry heat, saturated steam, or solvents. This test method is applicable to yarns made from any fiber or combination of fibers where the tex of the yarn is known or can be determined. This test method is not recommended for elastomeric yarns and those yarns that stretch more than 5 % under the tension loadings prescribed, although it has been used for the latter.

NOTE 1—Procedures for determining yarn shrinkage and bulk properties of textured yarns are covered in Test Method D4031.

1.2 This test method shows the values in both SI and inch-pound units. “SI” units is the technically correct name for the system of metric units known as the International System of Units. “Inch-pound” units is the technically correct name for the customary units used in the United States. The values stated in either SI units or in other units shall be regarded as standard. The values expressed in each system may not be exact equivalents; therefore each system must be used independently of the other without combining in any way.

1.3 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

## 2. Referenced Documents

2.1 *ASTM Standards:*<sup>2</sup>

D123 Terminology Relating to Textiles

<sup>1</sup> This test method is under the jurisdiction of Committee D13 on Textiles and is the direct responsibility of Subcommittee D13.58 on Yarns and Fibers.

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<sup>2</sup> 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.

D1059 Test Method for Yarn Number Based on Short-Length Specimens

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

D3888 Terminology for Yarn Spinning Systems

D3990 Terminology Relating to Fabric Defects

D4031 Test Method for Bulk Properties of Textured Yarns

D4848 Terminology Related to Force, Deformation and Related Properties of Textiles

D4849 Terminology Related to Yarns and Fibers

E145 Specification for Gravity-Convection and Forced-Ventilation Ovens

## 3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of textile terms used in this test method: skein and skein loop-length, refer to Terminology D4849.

3.1.2 For definition of the term extension used in this test method, refer to Terminology D4848.

3.1.3 For other textile terms used in this test method, refer to Terminology Standards, D123, D3888, D3990, D4848 and D4849.

## 4. Summary of Test Method

4.1 The loop length of a conditioned skein of yarn is measured under a specific tension, which is sufficient to straighten but not stretch the skein. The tension-free skein is then immersed in boiling water or exposed to dry heat or saturated steam or in the solvent reconditioned, and remeasured. The shrinkage (or in some cases, growth) is calculated as the change in length expressed as a percentage of the length before immersion or exposure.

## 5. Significance and Use

5.1 Test Method D2259 for testing yarn for shrinkage in boiling water, saturated steam, dry heat, or solvents is considered satisfactory for acceptance testing of commercial shipments of yarn because the test method has been used extensively in the trade for that purpose.

5.1.1 If there are differences of 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, use the samples for such comparative tests that are as homogeneous as possible, drawn from the same lot of material as the samples that resulted in disparate results during initial testing and randomly assigned in equal numbers to each laboratory. The test results from the laboratories involved should be compared using a statistical test for unpaired data, 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.

5.2 Results obtained by this test method can be used for the following purposes:

5.2.1 As an aid in predicting the dimensional stability of fabrics to wet processing,

5.2.2 As an aid in predicting the dimensional stability of fabrics during processing at elevated temperatures, and

5.2.3 As a control measure in the manufacture of some types of fibers.

5.3 The shrinkage medium to be used in the test depends on the requirements of the parties involved.

5.4 The procedure for shrinkage in boiling water is described in Section 12, for shrinkage in dry heat in Section 13, for shrinkage in saturated steam in Section 14, and for shrinkage in solvents in Section 15. A 30-min exposure time is prescribed for boiling water. In exposure to dry heat, saturated steam, or solvents, the extent of change in the length of yarn is dependent upon the fiber type and upon the time and temperature of the exposure. Fiber types differ in their reaction to elevated temperature as well as the nature of the specific solvent, and prior fiber history can have a great influence upon the heat and solvent shrinkage of a yarn. Therefore, the time and temperature conditions to be used to determine dry heat or saturated steam shrinkage must be agreed upon for the particular product involved. In addition, time and temperature conditions, and solvent to be used must be agreed upon for solvent shrinkage determination for the particular product involved.

## 6. Apparatus and Reagents

6.1 *Reel*—A hand or motor-driven reel having a nominal perimeter of 1 m, 1.5 yd, or 1.125 m (Note 2). The reel should have a traversing mechanism that will minimize bunching of ends on the reel, a yarn-tensioning device capable of maintaining tension below 1 cN/tex or 0.1 gf/den, and a yarn length or revolution indicator. A warning bell that will ring just prior to the specified number of reel revolutions is recommended. A collapsible arm is advisable for convenience in skein removal.

NOTE 2—By agreement, reels of other perimeters, between 1 and 2 m (1 and 2 yd) may be used.

6.2 *Measuring Scale*—A tape or scale accurate to 1 part in 1000 is recommended. Any scale length exceeding the reel diameter by 250 mm or 10 in. allowing for the extension of the skein is satisfactory. The scale should be mounted vertically. A top hook holds the skein and is mounted with support surface in line with the zero index of the scale.

6.3 *Metal Hook*—A hook designed to hang from the skein, shaped to receive the tensioning weights, and with a mass known to 1 part in 1000. The hook may have a pointer located and attached for ease in reading the measuring scale at a point level with the inside bottom of the skein.

6.4 *Tensioning Masses*—Accurate to 1 part in 1000.

6.5 *For Boiling Water:*

6.5.1 *Container*, of sufficient size for 40:1 mass ratio water bath.

6.5.2 *Roller Wringer or Centrifugal Extractor*.

6.5.3 *Heat Source*, for water bath.

6.5.4 *Distilled or Demineralized Water*.

6.5.5 *Nonionic Wetting Agent*.

6.6 *For Dry Heat:*

6.6.1 *Heating Oven*—A forced-draft oven capable of meeting the required temperature and that meets the temperature uniformity requirements for a Type IIB oven as described in Specification E145, Table 1. There must be a means of suspending the skeins in the oven. This may be accomplished with a rod with cup hooks from which to suspend skeins. The rod may be mounted on a stand for placement in the oven; skeins should not be allowed to touch the sides of the oven.

6.7 *For Saturated Steam:*

6.7.1 *Autoclave*—A pressure vessel capable of sustaining the temperatures and pressures required, and of such a size that the test skeins of yarn can be suspended without touching sides or bottom of the autoclave.

6.8 *For Solvents:*

6.8.1 *Hot Plate or Heated Block*—A temperature controlled hot plate or heated block which can maintain the temperature of the solvent in a container to  $\pm 2$  °C or 4 °F of the specified value.

6.8.2 *Container*, of sufficient size for a 40:1 mass ratio solvent bath.

6.9 *For Drying Wet Skeins:*

6.9.1 *Drying Oven*—A ventilated drying oven maintained at a temperature of  $65 \pm 3$  °C or  $149 \pm 5$  °F, in which the yarn specimens are not exposed to direct radiation from the heating elements.

**TABLE 1 Components of Variance as Standard Deviations, Percentage Points**

Properties	Single-Operator Component	Within-Laboratory Component	Between-Laboratory Component
Shrinkage, boiling water:			
Nylon spun yarn	0.32	0.60	0.61
Nylon filament yarn	0.20	0.76	0.79
Polyester spun yarn	0.32	0.31	0.26
Polyester filament yarn	0.11	0.32	0.25
Acrylic filament yarn	0.22	0.42	0.30
Cotton yarn	0.16	0.21	0.19
Rayon spun yarn	0.16	0.25	0.21
Shrinkage, dry heat:			
Nylon spun yarn at 150 °C	0.24	0.23	0.17
Nylon filament yarn at 150 °C	0.20	0.55	0.51
Polyester spun yarn at 190 °C	0.39	0.38	0.26
Polyester filament yarn at 190 °C	0.15	0.65	0.65

## 7. Hazards

7.1 Avoid physical contact with hot water and hot metal and especially saturated steam (Sections 12, 13, and 14).

7.2 Refer to manufacturer's safety data sheets (MSDS) on the operation of the autoclave. Care should be exercised in venting the autoclave so that physical contact is not made with the saturated steam (Section 14).

7.3 Refer to manufacturer's material safety data sheets (MSDS) for information on handling, storage, use, and disposal of any solvents used in this test method (Section 15).

## 8. Sampling

8.1 *Division into Lots*—For acceptance testing purposes, divide the material to be tested into lots as directed in Practice D2258.

8.2 *Lot Sample*—As a lot sample for acceptance testing, take at random the number of shipping containers directed in an applicable material specification or other agreement between the purchaser and the supplier, such as an agreement to use Practice D2258.

NOTE 3—Differences between shipping containers, between packages within a container, and between specimens within a package are all sources of variability in test results. A realistic specification or other agreement between the purchaser and the supplier requires a sampling plan that considers the relative effects of such sources of variability and which at the specified limits for shrinkage has a meaningful producer's risk, consumer's risk, acceptable quality level, and lot tolerance fraction defective.

8.3 *Laboratory Sample*—As a laboratory sample for acceptance testing, take a total of ten packages. Select the packages randomly from all the packages in the lot sampling units.

8.4 *Number of Specimens*—Test one skein from each package in the laboratory sample.

## 9. Preparation of Specimens

9.1 Reel and discard the outer 10 % or 100 m or 110 yd material from each package.

9.2 Reel an 80-wrap skein using a uniform tension of not over 1 cN/tex or 0.1 gf/den. Lay the yarn smoothly on the reel, overlap, and loosely tie the beginning and trailing ends of the skein. To reduce tangling, the skein may be laced loosely. The number of wraps may be increased or decreased for very fine or very coarse yarns by agreement of the interested parties.

9.3 Identify each skein separately.

## 10. Conditioning

10.1 Condition the prepared skeins for testing as directed in Practice D1776, except that preconditioning is not necessary. Consider equilibrium to have been reached when the change in mass of the specimen between successive weighings made at intervals of not less than 2 h does not exceed 0.1 % of the mass of the specimen.

10.2 Condition the prepared skeins for a minimum of 24 h which is sufficient time for yarn recovery from package winding tensions as well as to reach the moisture equilibrium conditions specified in 10.1.

## 11. Measurement of Skeins

11.1 Make all skein loop length measurements in the standard atmosphere for testing textiles which is air maintained at a relative humidity of  $65 \pm 2\%$  and at a temperature of  $21 \pm 1\text{ }^\circ\text{C}$  or  $70 \pm 2\text{ }^\circ\text{F}$ .

11.2 Determine the linear density of the yarn if unknown by using Test Method D1907 or Test Method D1059. In case of controversy, results obtained as directed in Test Method D1907 shall prevail.

11.3 Calculate a tension force corresponding to 0.5 cN/tex or 0.05 gf/den using Eq 1 or Eq 2:

$$\text{Tension force, cN} = 0.5 \times N \times T \quad (1)$$

$$\text{Tension force, gf} = 0.05 \times N \times D \quad (2)$$

where:

$N$  = number of ends; that is twice the number of wraps in the skein,

$T$  = yarn number, tex, and

$D$  = yarn number, denier.

NOTE 4—For example, an 80-wrap skein has 160 ends. For a 16 tex yarn, the tension force would be  $0.5 \times 16 \times 160 = 1280\text{ cN} = 12.8\text{ N}$  (tension force in gf would be  $0.05 \times 160 \times [(16 \times 0.9 \times 10)\text{ denier}] = 1152\text{ gf} = 1.152\text{ kgf}$ ).

11.4 Measure the loop-length of each conditioned skein.

11.4.1 Hang the conditioned skein from the hook at the top of the measuring scale with the inside of the top of the skein and the zero index of the scale.

11.4.2 Hang the hook described in 6.3 on the bottom of the untwisted skein and add sufficient mass (including the mass of the hook) to produce the force calculated in 11.3.

11.4.3 After  $30 \pm 3\text{ s}$ , measure the inside length of the skein to the nearest 1 mm or  $\frac{1}{16}\text{ in}$ .

11.4.4 Record the loop-length of each skein.

11.5 Twist each skein into a figure 8 and bring the ends together to form a two-coil loop. Repeat the procedure to form a four-coil loop.

11.6 Continue as directed in Section 12 for boiling water, Section 13 for dry heat, Section 14 for saturated steam, or Section 15 for solvent.

## 12. Boiling Water Exposure

12.1 Wrap each skein carefully in cheesecloth and secure the cheesecloth (sewed, tied) to prevent the entanglement of the yarn in actively boiling water.

12.2 Make up a distilled or demineralized water bath, which is 40 times the mass of the wrapped skeins, and contains a 0.05 % solution of wetting agent by weight.

12.3 Bring the bath to a continuously rolling boil and immerse the skeins for 30 min.

NOTE 5—A basket may be used to transfer the skeins to and from the bath.

12.4 Allow the bath to cool to at least  $50\text{ }^\circ\text{C}$  or  $122\text{ }^\circ\text{F}$  before decanting the solution from the specimens.

12.4.1 Do not cool the bath by overflowing or rinsing the specimens, because the wetting agent will serve as a lubricant for the strands in making the final length measurement.

NOTE 6—If a basket is used, lift it from the cooled bath, allow the water to drain until dripping stops and the specimens are cool enough to handle easily.

12.5 Use a centrifuge or roll wringer to damp dry the wrapped skeins.

12.6 Remove the skeins from the cheesecloth and complete drying them at room temperature or for 1 h in a drying oven at  $65 \pm 3 \text{ }^\circ\text{C}$  or  $149 \pm 5 \text{ }^\circ\text{F}$ .

12.7 Recondition each dried skein in the standard atmosphere for testing textiles as directed in 10.1.

12.8 Continue as directed in Section 16.

### 13. Dry-Heat Exposure

13.1 Preheat the oven to the selected temperature.

13.2 Shut-off the oven fan, quickly open the door, and suspend the measured skeins in the oven.

NOTE 7—Shutting off the oven fan when opening the door reduces the possibility of entanglement or damage to the skeins.

13.3 Hang the skeins to prevent their touching the bottom or sides of the oven. Close the door, and restart the oven fan. Keep the open door time to a minimum.

13.4 When the oven has returned to the selected temperature, begin measuring the agreed upon exposure time.

13.5 At the end of this period, shut off the oven fan and remove the skeins.

13.6 Recondition the skeins in the standard atmosphere for textile testing.

13.7 Continue as directed in Section 16.

### 14. Saturated Steam Exposure

14.1 Set up the autoclave to produce saturated steam, not superheated steam. Accomplish this by having a vessel in the autoclave with sufficient water to contain liquid water in the vessel throughout the test.

14.2 Suspend the specimens in the autoclave.

14.3 Heat the autoclave with the vent open, until a temperature of  $100 \text{ }^\circ\text{C}$  or  $212 \text{ }^\circ\text{F}$  is reached and live steam issues from the vent. Close the vent and allow the pressure to increase until the required pressure or temperature, or both, is reached.

14.4 Expose the specimens to the saturated steam for the agreed upon time. The shrinkage of a yarn will usually stabilize in a short time. An exposure time of 15 to 30 min after reaching the required pressure is recommended.

14.5 Turn off heat (or steam), allow autoclave to cool until the pressure is less than 20 kPa (3 psi). Then, vent the autoclave to atmospheric pressure.

14.6 Open the autoclave. (**Warning**—Perform this operation with extreme care to prevent burns from hot surfaces or steam.)

**TABLE 2 Critical Differences, Percentage Points for the Condition Noted**

Properties	Number of Observations in Each Average	Single-Operator Precision	Within-Laboratory Precision	Between-Laboratory Precision	
Shrinkage, boiling water:					
	Nylon spun yarn	1	0.89	1.88	2.53
		5	0.40	1.71	2.40
Nylon filament yarn		10	0.28	1.69	2.39
		1	0.55	2.18	3.09
		5	0.25	2.12	3.06
Polyester spun yarn		10	0.18	2.11	3.04
		1	0.89	1.23	1.43
		5	0.40	0.95	1.19
Polyester filament yarn		10	0.28	0.90	1.16
		1	0.30	0.94	1.17
		5	0.14	0.90	1.13
Acrylic filament yarn		10	0.10	0.89	1.13
		1	0.61	1.31	1.55
		5	0.27	1.20	1.46
Cotton yarn		10	0.19	1.18	1.44
		1	0.44	0.73	0.90
		5	0.20	0.61	0.81
Rayon spun yarn		10	0.14	0.60	0.80
		1	0.44	0.82	1.01
		5	0.20	0.72	0.93
Shrinkage, dry heat:		10	0.14	0.71	0.92
	Nylon spun yarn at $150 \text{ }^\circ\text{C}$	1	0.67	0.92	1.03
		5	0.30	0.70	0.85
Nylon filament yarn at $150 \text{ }^\circ\text{C}$		10	0.21	0.67	0.82
		1	0.55	1.62	2.15
		5	0.25	1.54	2.09
Polyester spun yarn at $190 \text{ }^\circ\text{C}$		10	0.18	1.53	2.09
		1	1.08	1.51	1.67
		5	0.48	1.16	1.36
Polyester filament yarn at $190 \text{ }^\circ\text{C}$		10	0.34	1.11	1.32
		1	0.42	1.85	2.58
		5	0.19	1.81	2.55
	10	0.13	1.81	2.55	