**Designation: D 2259 – ~~96~~02**

# Standard Test Method for Shrinkage of Yarns[1]

This standard is issued under the fixed designation D 2259; 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] This test method is under the jurisdiction of Committee D~~-~~13 on Textiles and is the direct responsibility of Subcommittee D13.58 on Yarn Test Methods, General. Current edition approved ~~Oct.~~ Sept. 10, ~~1996.~~ 2002. Published ~~February 1997.~~ November 2002. Originally published as D 2259 – 64 T. Last previous edition D 2259 – 9~~1~~7.

## 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 D 4031.

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 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 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]
~~D 2259 Test Method for Shrinkage of Yarns[2]~~
~~D 4031 Test Method for Bulk Properties of Textured Yarns~~ 3888 Terminology Related to Open-End Spinning[3]
D 3990 Terminology Realting to Fabric Defects[3]
D 4031 Test Method for Bulk Properties of Textured Yarns[3]
D 4848 Terminology of Force, Deformation and Related Properties of Textiles[3]
D 4849 Terminology Relating to Fibers and Yarns[3]
E 145 Specification for Gravity-Convection and Forced-Ventilation Ovens[4]

## 3. Terminology

3.1 *Definitions:*

~~3.1.1 *extension, n*—the change in length~~
3.1.1 For definitions of ~~a material due to stretching.~~
~~3.1.1.1 *Discussion*—In yarn shrinkage testing, extension is usually expressed as a percentage of the length prior to exposure. For yarns~~ textile terms used in ~~skein form,~~ this ~~change is an increase in loop length. Extension is sometimes referred~~ test method: skein and skein loop-length, refer to ~~as "negative" shrinkage or growth.~~

[2] *Annual Book of ASTM Standards*, Vol 07.01.
[3] *Annual Book of ASTM Standards*, Vol 07.02.
[4] *Annual Book of ASTM Standards*, Vol 14.02.

3.1.2 *shrinkage, n*—a decrease in one or more dimensions Terminology D 4849.

3.1.2 For definition of an object or material.

3.1.2.1 *Discussion*—Shrinkage is usually expressed as a percentage of the length prior to exposure. For yarns term extension used in skein form this decrease is in loop length.

3.1.3 *skein loop-length, n*—the inside length of a coil of yarn mounted vertically as measured under a specified tension.

3.1.4 For definitions of test method, refer to Terminology D 4848.

3.1.3 For other textile terms used in this test method, refer to Terminology Standards, D 123, D 3888, D 3990,D 4848 and D 4849.

## 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 D 2259 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 In case of a dispute arising from

5.1.1 If there are differences of practical significance between reported test results when using Test Method D 2259 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 there is a statistical bias between their laboratories. Competent them, using competent statistical assistance is recommended for the investigation of bias. assistance. As a minimum, use the two parties should take a group of test specimens which samples for such comparative tests that are as homogeneous as possible and which are possible, drawn from the same lot of material of as the type samples that resulted in question. The test specimens should then be disparate results during initial testing and randomly assigned in equal numbers to each laboratory for testing. laboratory. The average test results from the two laboratories involved should be compared using appropriate a statistical analysis and an acceptable test for unpaired data, a probability level chosen by prior to the two parties before the testing began. 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.

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 1.0 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 E 145, 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 ± 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 ± 3°C or 149 ± 5°F, in which the yarn specimens are not exposed to direct radiation from the heating elements.

## 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 excercised 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 D 2258.

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 D 2258.

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.

**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 |

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 D 1776, 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 ± 2 % and at a temperature of 21 ± 1°C or 70± 2°F.

11.2 Determine the linear density of the yarn if unknown by using Test Method D 1907 or Test Method D 1059. In case of controversy, results obtained as directed in Test Method D 1907 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:

$$\text{Tension force, mN} = 5.0 \times N \times T \quad (1)$$

$$\text{Tension force, gf} = 0.5 \times N \times D \quad (2)$$

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 $5.0 \times 16 \times 160 = 1280$ cN = 12.8 N ($0.5 \times 16 \times 160 = 1280$ gf = 1.28 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 ± 3 s, measure the inside length of the skein to the nearest 1 mm or 1/16 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°C or 122°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 ± 3°C or 149 ± 5°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°C or 212°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. **Caution:** Perform this operation with extreme care to prevent burns from hot surfaces or steam.

14.7 Remove the specimens and allow them to cool and dry to room conditions. Recondition the specimens in the standard atmosphere for testing as directed in 10.1.

14.8 Continue as directed in Section 16.

## 15. Solvent Exposure

15.1 Wrap each skein carefully in cheesecloth and secure the cheesecloth (sewed, tied) to prevent entanglement of the yarn during the solvent exposure.

15.2 Fill the container to be used with selected solvent. The mass of the solvent to be used should be 40 times or more than that of the wrapped skeins.

NOTE 8—**Precaution:** Solvents should be handled with proper protective equipment such as gloves, eye shields, hoods, etc.

15.3 If the exposure is to be at room temperature, immerse the specimens in the solvent for the agreed upon time period. If the exposure is to be at elevated temperature immerse the specimens in the solvent at the agreed upon temperature for the agreed upon time period.

15.4 Decant the solvent from the specimens allowing as much of the solvent to drain from the yarns as possible.

15.5 Extract as much solvent as possible by squeezing and damp dry the wrapped skeins. (See 7.2.)

15.6 Dry wrapped skeins for 1 h in an explosion proof forced-draft oven at 65°C or 149°F maximum, or remove the skeins from the cheesecloth and dry them under a hood at room temperature under a hood vented to the outside.

NOTE 9—Drying temperature should not exceed that of the solvent exposure temperature.

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

## 16. Remeasurement of Skeins

16.1 Remeasure skeins as directed in 11.4. Record the measurement as the final length.

## 17. Calculation

17.1 Calculate the shrinkage of each skein to the nearest 0.1 % using Eq 3:

$$\text{Shrinkage, \%} = 100\,(A - B)/A \tag{3}$$

where:

$A$ = original loop-length of each skein, and
$B$ = final loop-length of each skein.

NOTE 10—When $B$ is greater than $A$ due to the elongation of the skein, the "negative" shrinkage is reported as extension.

17.2 Calculate the average for each package, laboratory sampling unit and for the lot.

17.3 Calculate the standard deviation for each laboratory sampling unit and for the entire lot.

## 18. Report

18.1 State that the specimens were tested as directed in Test Method D 2259. Describe the material(s) or product(s) tested and the method of sampling used.

18.2 Report the following information:
18.2.1 Exposure conditions,
18.2.2 Perimeter of the reel used,
18.2.3 Number of wraps in each skein, if not 80 turns,
18.2.4 Number of packages tested,
18.2.5 The average for each laboratory sampling unit and for the lot, and
18.2.6 Standard deviation values, if calculated.

## 19. Precision and Bias

19.1 *Interlaboratory Test Data*[5]—An interlaboratory test was run in 1977, in which randomly drawn samples of three materials (nylon filament, polyester filament, and acrylic filament) were tested in each of four laboratories. Additional laboratory tests run in 1979, combined with the 1977 tests in which randomly drawn samples of four materials (nylon, polyester, cotton, and rayon spun yarns) were tested in each of the same four laboratories. Each laboratory used two operators, each of whom tested two specimens of each of the seven materials. The media used were dry heat and boiling water. The components of variance expressed as standard deviations were calculated to be the values listed in Table 1.

19.2 *Precision*—For the components of variance listed in Table 1, 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 2.

NOTE 11—The tabulated values of the critical differences should be considered to be a general statement, particularly with respect to between-laboratory precision. 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 randomized specimens from one sample of the material to be tested.

19.3 *Bias*—The values for shrinkage of yarns can only be defined in terms of a test method. Within this limitation, the procedures in Test Method D 2259 for determining those properties have no known bias.

## 20. Keywords

20.1 dimensional change; shrinkage; yarn

[5] Supporting data are available from ASTM. Request RR: D13-1004.

**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 |
| | 10 | 0.28 | 1.69 | 2.39 |
| Nylon filament yarn | 1 | 0.55 | 2.18 | 3.09 |
| | 5 | 0.25 | 2.12 | 3.06 |
| | 10 | 0.18 | 2.11 | 3.04 |
| Polyester spun yarn | 1 | 0.89 | 1.23 | 1.43 |
| | 5 | 0.40 | 0.95 | 1.19 |
| | 10 | 0.28 | 0.90 | 1.16 |
| Polyester filament yarn | 1 | 0.30 | 0.94 | 1.17 |
| | 5 | 0.14 | 0.90 | 1.13 |
| | 10 | 0.10 | 0.89 | 1.13 |
| Acrylic filament yarn | 1 | 0.61 | 1.31 | 1.55 |
| | 5 | 0.27 | 1.20 | 1.46 |
| | 10 | 0.19 | 1.18 | 1.44 |
| Cotton yarn | 1 | 0.44 | 0.73 | 0.90 |
| | 5 | 0.20 | 0.61 | 0.81 |
| | 10 | 0.14 | 0.60 | 0.80 |
| Rayon spun yarn | 1 | 0.44 | 0.82 | 1.01 |
| | 5 | 0.20 | 0.72 | 0.93 |
| | 10 | 0.14 | 0.71 | 0.92 |
| Shrinkage, dry heat: | | | | |
| Nylon spun yarn at 150°C | 1 | 0.67 | 0.92 | 1.03 |
| | 5 | 0.30 | 0.70 | 0.85 |
| | 10 | 0.21 | 0.67 | 0.82 |
| Nylon filament yarn at 150°C | 1 | 0.55 | 1.62 | 2.15 |
| | 5 | 0.25 | 1.54 | 2.09 |
| | 10 | 0.18 | 1.53 | 2.09 |
| Polyester spun yarn at 190°C | 1 | 1.08 | 1.51 | 1.67 |
| | 5 | 0.48 | 1.16 | 1.36 |
| | 10 | 0.34 | 1.11 | 1.32 |
| Polyester filament yarn at 190°C | 1 | 0.42 | 1.85 | 2.58 |
| | 5 | 0.19 | 1.81 | 2.55 |
| | 10 | 0.13 | 1.81 | 2.55 |