Designation: D 3106 – 95a

Standard Test Method for Permanent Deformation of Elastomeric Yarns[1]

This standard is issued under the fixed designation D 3106; 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 determination of the permanent deformation of bare, continuous elastomeric monofilaments and filament yarns made from rubber, spandex, anidex, or other elastomers subjected to prolonged periods of tension. This test method is applicable to elastomeric yarns having a linear density in the range from 4 to 320 tex (36 to 2900 den.).

1.2 This test method is not applicable to covered, wrapped, core-spun yarns, or yarns spun from elastomeric staple.

1.3 This test method was developed using yarns in the "as-received" condition, but may be used for treated yarns provided the treatment is specified.

1.4 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

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:*

D 123 Terminology Relating to Textile Materials[2]

D 2433 Test Method for Rubber Thread[3]

3. Terminology

3.1 *Definitions*—For definitions of textile terms used in this test method, refer to Terminology D 123.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *breaking force*, *n*—the maximum force applied to a specimen in a tensile test carried to rupture.

3.2.1.1 *Discussion*—Force is commonly expressed in pounds-force (lbf), newtons (N), or millinewtons (mN). Newtons or millinewtons are preferred units.

3.2.2 *elastomeric yarn*, *n*—a nontextured yarn that can be stretched repeatedly at room temperature to at least twice its original length and which after removal of the tensile force will immediately and forcibly return to approximately its original length.

3.2.2.1 *Discussion*—The elastic properties of the yarn are produced by the use of filaments, or a core, made from polymers having a special chemical composition or molecular structure, for example, filaments made from spandex or from cut or extruded rubber.

3.2.3 *elongation*, *n*—the ratio of the extension of a material to the length of the material prior to stretching.

3.2.3.1 *Discussion*—In a tensile test of elastomeric yarns, the percent elongation is usually calculated on the basis of the nominal gage length of a pretensioned specimen.

3.2.4 *elongation at the break*, *n*—the elongation corresponding to the breaking force.

3.2.4.1 *Discussion*—Elongation at the breaking force is the change in length of the specimen which results from stretching the specimen to rupture.

3.2.5 *extension*, *n*—an increase in length or width.

3.2.6 *force*, *n*—a physical influence exerted by one body on another which produces acceleration of bodies that are not free to move.

3.2.7 *linear density*, *n*—mass per unit length; the quotient obtained by dividing the mass of a fiber or yarn by its length.

3.2.7.1 *Discussion*—The preferred units of measurement are grams per metre, or multiples or submultiples of these. The tex unit, grams per kilometre, is recommended for yarns.

3.2.8 *permanent deformation*, *n*—the net long-term change in a dimension of a specimen after deformation and relaxation under specified conditions.

3.2.8.1 *Discussion*—Permanent deformation is usually expressed as a percentage of the original dimension. Permanent deformation is also commonly referred to as "permanent set," "nonrecoverable deformation," and "nonrecoverable stretch."

4. Summary of Test Method

4.1 The nominal linear density of the sample is known or determined and the elongation at the breaking force is determined from representative specimens.

4.2 A specimen from the sample is placed in a pair of line-contact clamps and held at a selected elongation for a

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

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

[3] *Annual Book of ASTM Standards*, Vol 09.02.

specified period of time. The permanent deformation or non-recoverable stretch is measured after a specified recovery period.

5. Significance and Use

5.1 Test Method D 3106 for testing permanent deformation of elastomeric yarns is considered satisfactory for acceptance testing of commercial shipments when there is prior agreement as to the exact value of elongation to be used for testing, since current estimates of between-laboratory precision are acceptable.

5.1.1 In case of a dispute arising from differences in reported test results when using Test Method D 3106 for acceptance testing of commercial shipments, the purchaser and the supplier should conduct comparative tests to determine if there is a statistical bias between their laboratories. Competent statistical assistance is recommended for the investigation of bias. As a minimum, the two parties should take a group of test specimens that are as homogeneous as possible and that are from a lot of material of the type in question. The test specimens should then be randomly assigned in equal numbers to each laboratory for testing. The average results from the two laboratories should be compared using Student's *t*-test for unpaired data and an acceptable probability level chosen by the two parties before the testing is begun. If bias is found, either its cause must be found and corrected or the purchaser and the supplier must agree to interpret future test results in the light of the known bias.

5.2 Yarns are subjected to long periods of tension resulting in an appreciable amount of stretch during normal use. A portion of the induced stretch may be permanent. The amount of permanent deformation is influenced by the amount of tension, the time the yarn is under tension and the time available for recovery between successive uses.

5.3 For optimum processing of elastomeric yarns, the permanent deformation value should be low or zero.

6. Apparatus

6.1 *Line-Contact Clamps*, with one fixed clamp and one movable clamp, assembled as directed in Appendix X1, and as shown in Fig. 1.

6.2 *Tensioning Weights*, 10 mg to 3 g, to pretension the specimens before final clamping.

NOTE 1—Aluminum foil has been found to be suitable for use as tensioning weights; the foil may be attached to the yarn by folding it over the yarn.

6.3 *Stop Watch or Timer*.

7. Sampling

7.1 *Lot Sample*—As a lot sample for acceptance testing, take at random the number of shipping cartons of elastomeric yarn as directed in the applicable material specification or other agreement between the purchaser and supplier. Consider the material shipping carton to be the primary sampling unit.

7.2 *Laboratory Sample*—As a laboratory sample for acceptance testing, take at random the number of packages from each shipping carton in the lot sample as directed in the applicable material specification or other agreement between the purchaser and the supplier. If differing numbers and packages are to be taken from the shipping cartons in the lot sample, determine at random which shipping cartons are to have each number of packages drawn.

NOTE 2—An adequate specification or other agreement between the purchaser and the supplier requires taking into account the variability between shipping cartons, and the variability of the material within the shipping carton, to provide a sampling plan with a meaningful producer's risk, consumer's risk, acceptable quality level, and limiting quality level.

7.3 *Test Specimens*—From each package in the laboratory sample, take the number of specimens directed in Section 8. Inspect each package after withdrawing at least five layers of yarn from the outside of the package. If there is evidence of damage, continue to withdraw units of five layers and reinspect until there is no discernible damage. Withdraw yarn over the end of the package and cut specimens approximately 150 mm long. Discard specimens that are damaged during withdrawal or cutting. Withdraw at least 2 m of yarn between specimens from a single package.

8. Specimens Per Package

8.1 Take a number of specimens per package such that the user may expect at the 95 % probability level that the test result is no more than 0.55 percentage points above or below the true average of the package. Determine the number of specimens as follows:

8.1.1 *Reliable Estimate of s*—When there is a reliable estimate of s based on extensive past records for similar materials tested in the user's laboratory as directed in the test method, calculate the required number of specimens per package using (Eq 1):

$$n = (ts/E)^2 \quad (1)$$

where:

n = number of specimens per package (rounded upward to a whole number),

s = reliable estimate of the standard deviation of individual observations on similar materials in the user's laboratory under conditions of single-operator precision,

t = value of Student's t for two-sided limits, a 95 % probability level, and the degree of freedom associated with the estimate of s (see Table 1), and

E = 0.55 percentage points, the value of the allowable variation.

8.1.2 *No Reliable Estimate of s*—When there is no reliable estimate of s for the user's laboratory, (Eq 1) should not be used directly. Instead, specify the fixed number of ten specimens. This number of specimens is calculated using $s = 0.87$ percentage point, which is a somewhat larger value of s than is usually found in practice. When a reliable estimate of s for the user's laboratory becomes available, (Eq 1) will usually require fewer than ten specimens.

9. Conditioning

9.1 Condition the specimens in the standard atmosphere for testing textiles, 65 ± 2 % relative humidity and 21 ± 1°C (70 ± 2°F) temperature, in moving air for a minimum time of 16 h. Preconditioning is not necessary for the currently produced

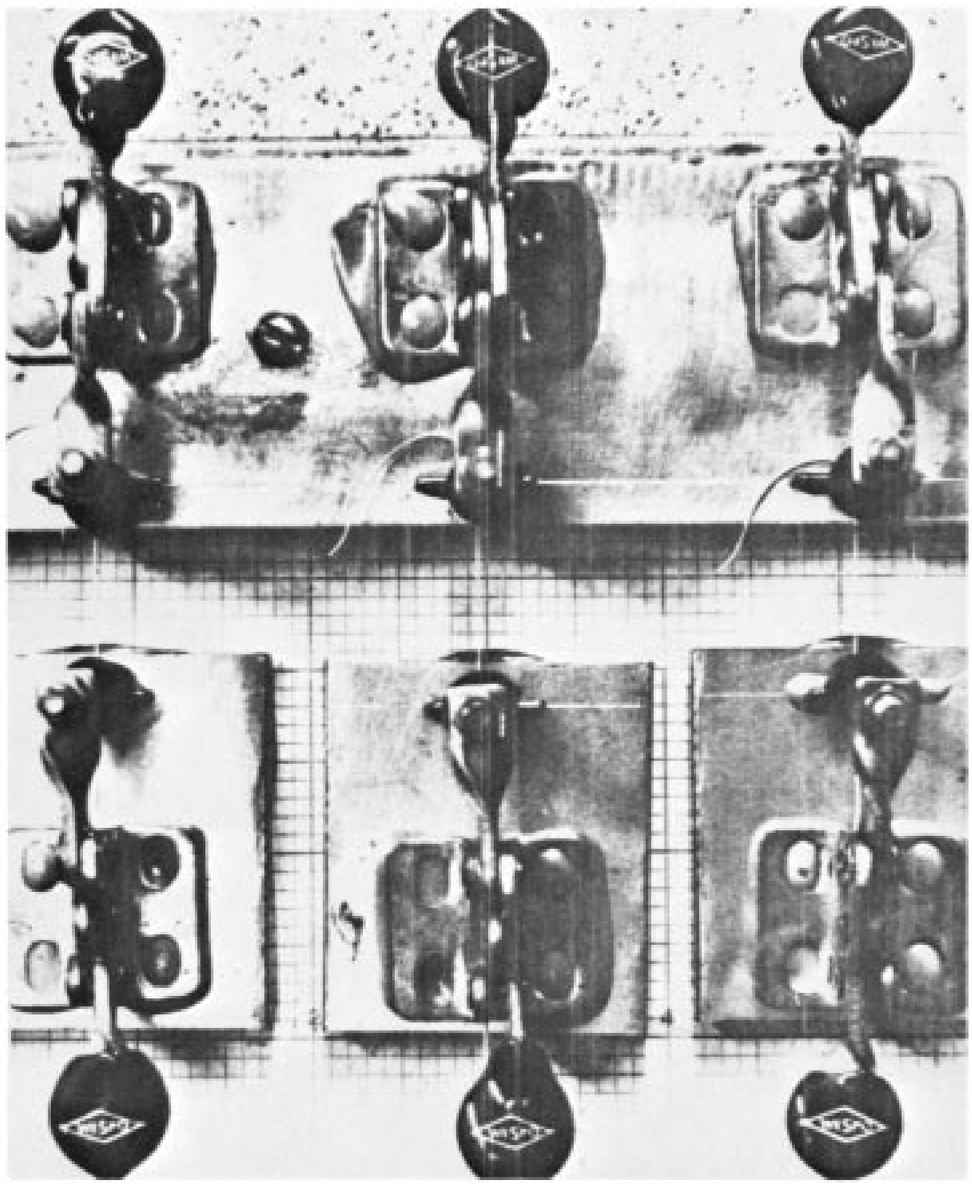

FIG. 1 Test Apparatus for Permanent Set

TABLE 1 Values of Student's t^A for One-Sided and Two-Sided Limits and the 95 % Probability Level

dF	One-sided	Two-sided	dF	One-sided	Two-sided	dF	One-sided	Two-sided
1	6.314	12.706	11	1.796	2.201	22	1.717	2.074
2	2.920	4.303	12	1.782	2.179	24	1.711	2.064
3	2.353	3.182	13	1.771	2.160	26	1.706	2.056
4	2.132	2.776	14	1.761	2.145	28	1.701	2.048
5	2.015	2.571	15	1.753	2.131	30	1.697	2.042
6	1.943	2.447	16	1.746	2.120	40	1.684	2.021
7	1.895	2.365	17	1.740	2.110	50	1.676	2.009
8	1.860	2.306	18	1.734	2.101	60	1.671	2.000
9	1.833	2.262	19	1.729	2.093	120	1.658	1.980
10	1.812	2.228	20	1.725	2.086	∞	1.645	1.960

[A] Values in this table were calculated using Hewlett Packard HP 67/97 Users' Library Programs 03848D, "One-sided and Two-sided Critical Values of Student's *t*" and 00350D," Improved Normal and Inverse Distribution." For values at other than the 95 % probability level, see published tables of critical values of Student's *t* in any standard statistical test (2), (3), (4), and (5).

rubber and other elastomers having a moisture regain below 1.0 % and low moisture hysteresis.

10. Procedure

10.1 Test all specimens in the standard atmosphere for testing textiles.

10.2 Determine the elongation at the breaking force for each specimen as directed in Test Method D 2433.

NOTE 3—When Test Method D 3106 is used for acceptance testing, the laboratory of the purchaser and the laboratory of the seller should agree on a specific value of the elongation at the breaking force.

10.3 Determine the linear density for the sample as directed in Test Method D 2433. The nominal linear density value may be used.

10.4 Adjust the line-contact clamps for a 100 mm nominal gage length (see Fig. 1). This is the original length of a specimen.

NOTE 4—A convenient method for checking the gage length is to place a piece of carbon paper and white paper in the clamps and close the clamps. The distance between the marks on the whitepaper (made by the carbon paper) is the nominal gage length. If the test apparatus is assembled as described in Appendix X1, the nominal gage length may be set directly.

10.5 Fasten one end of the specimen in the top clamp. Pass the other end of the specimen through the lower clamp faces and through the toggle clamp. Attach a tensioning mass equal to 0.03 mN/tex (0.3 ± 0.1 mgf/den.) to the yarn below the lower clamp, allowing the yarn to hang freely between the jaws of the lower clamp. Be sure the specimen remains in a vertical plane. Close the lower clamp and remove the tensioning mass. (See Note 1.)

10.6 Lower the movable clamp to stretch the specimen 60 % of the average breaking elongation calculated to the nearest 1 mm. Take about 5 s to lower the clamp and hold the specimen in this stretched condition for 10 ± 1 s.

10.7 After the 10-s holding period, raise the lower clamp until the specimen has a residual stretch of 20 % of the average breaking elongation calculated to the nearest 1 mm. This movement should take about 5 s. Hold the yarn in this position for 4 h ± 10 min.

NOTE 5—Results have been found to be dependent upon the time to stretch as well as the amount of stretch imparted to the yarn. It is recommended that prior to actual testing, the operator familiarize himself with the rate of stretch required to effect the total required stretch within the specified time limit.

10.8 At the end of the 4-h period, raise the lower clamp until the specimen has enough slack to prevent its coming under tension (becoming taut) as it recovers. Start the stop watch or timer and hold the specimen in this condition for 10 min ± 30 s.

10.9 At the end of the recovery period, lower the moveable clamp until the specimen is just straight without being stretched and measure the length of the specimen to the nearest 0.5 mm. The measured length is the stretched length of a specimen after a 10-min relaxation time.

10.10 Raise the lower clamp immediately after measuring the specimen, allowing enough slack to prevent the specimen from becoming taut due to recovery. Hold the specimen in this condition for 100 ± 5 min as measured by the stop watch or timer.

10.11 Remeasure the length of the specimen as directed in 10.9. This is the stretched length of a specimen after a 100–min relaxation time.

11. Calculation

11.1 Calculate the permanent deformation to the nearest 0.5 % using (Eq 2):

$$\text{Permanent deformation, \%} = [(S - L)/L] \times 100 \quad (2)$$

11.1.1 When L = 100 mm, (Eq 2) simplifies to the following:

$$\text{Permanent deformation, \%} = S - 100 \quad (3)$$

where:

S = stretched length of specimen at specified time, mm, and

L = original length of specimen, mm.

11.2 Calculate the average permanent deformation after 10-min and 100-min relaxation times.

11.3 Calculate the coefficient of variation, if requested.

12. Report

12.1 State that the specimens were tested as directed in Test Method D 3106. Describe the material or product sampled and the method of sampling used.

12.2 Report the following information:

12.2.1 The average breaking elongation,

12.2.2 The average permanent deformation at 10-min and 100–min relaxation times to the nearest 0.5 %.

12.2.3 The number of specimens tested, and

12.2.4 The coefficient of variation, if calculated.

13. Precision and Bias

13.1 *Summary*—In comparing two averages of five observations, the differences should not exceed .8 percentage points of the grand average of all of the observations in approximately 95 cases out of 100 when all of the observations are taken by the same well-trained operator using the same piece of test equipment and specimens drawn randomly from the same sample of material.

13.2 *Interlaboratory Test Data*—An interlaboratory test was run in 1969, in which two laboratories tested five specimens from each of three materials. Each laboratory used one operator to test each material. The within-laboratory precision and between-laboratory precision are expressed as standard deviations, as follows:

Single-operator component	0.62 percentage point
Between-laboratory component	1.00 percentage point

13.3 *Critical Differences*—For the components of variance reported in 13.1, two averages of observed values should be considered significantly different at the approximate 95 % probability level, if the difference equals or exceeds the critical difference listed as follows:

Critical Difference, Percentage Points, for the Condition Noted[A]

Number of Observations in Each Average	Single-Operator Precision	Between-Laboratory Precision
2	1.2	3.0
5	0.8	2.9
10	0.5	2.8

[A] The values for the critical differences were calculated using t = 1.960, which is based on infinite degrees of freedom.

NOTE 6—This is a general statement with respect to between-laboratory precision. Before a meaningful statement can be made regarding 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 specimens drawn randomly from one sample of material to be tested.

13.4 *Bias*—The true value of the permanent deformation of elastomeric yarns can be defined only in terms of a specific test method. Within this limitation, Test Method D 3106 for determining the percent deformation of elastomeric yarns has no known bias.

14. Keywords

14.1 deformation; elastomeric; yarn

APPENDIX

(Nonmandatory Information)

X1. SUGGESTED TEST APPARATUS

X1.1 *Apparatus and Materials:*

X1.1.1 *Toggle Clamps*, such as Wespo No. 03131,[4] two for each unit.

X1.1.2 *Permanent Magnet*, such as P-40, 410 Alnico I disk magnet, 39.69 mm (1 9⁄16 in.) diameter, 7.14 mm (9⁄32 in.) thick,[5] one for each unit.

X1.1.3 *Copper Wire*, No. 10.

X1.1.4 *Epoxy Cement*.

X1.1.5 *Aluminum Block*.

X1.1.6 *Sheet Metal*, approximately 750 mm long and sufficiently wide to accommodate the number of units.

X1.1.7 *Aluminum Sheet*.

X1.2 The upper or fixed clamp consists of one toggle clamp fastened to an aluminum block with epoxy cement. The aluminum block is fastened to a long sheet metal base. The thickness of the aluminum block should be the same thickness as the lower clamping assembly.

X1.3 The lower or moveable clamp consists of one toggle clamp fastened to an aluminum sheet with epoxy cement. The aluminum sheet is fastened to the permanent magnet with epoxy cement. The sides of the aluminum sheet are bent over the magnet to make the edges of the sheet even with the bottom of the magnet. During the test, this clamp will move up and down the sheet metal base and be held in place by the magnet.

NOTE X1.1—Experience has shown that the magnet will not slip with the yarns tested and at stretch conditions up to 400 %. Users of this apparatus are cautioned to check for possible slippage with the yarns and conditions being used.

X1.4 Both toggle clamps are converted to line-contact clamps by cementing a length of No. 10 copper wire on the aluminum bases. The wire should be fastened under the center of the top clamp faces. Index lines are scribed on the clamp mountings in line with the line-grip faces (copper wire). The scribe lines on the moveable clamp should extend down the sides of the sheet metal base.

X1.5 Centimetre chart paper is used to cover the entire sheet metal base (the lower clamp assembly will be positioned on top of the paper). This paper should be placed on the base to allow the scribe lines of clamps, set 100 mm apart, to align with the 0-mm and 100-mm chart lines, or some other pair of millimetre lines denoting a 100-mm difference. Then, stretch and recovery may be read directly with each millimetre line representing 1 %.

X1.6 The entire test apparatus must be mounted to position the yarn in such a manner that the yarn is in a vertical plane at all times.

[4] Wespo toggle clamps made by Wespo Division, Vlier Engineering Corp., 801 Burlington Ave., Dowers Grove, IL, have been found acceptable. Available from mill supply and tool and die supply distributors.

[5] Available from Edmund Scientific Co., Barrington, NJ.