Designation: D 2969 – 00$^{\epsilon 1}$

Standard Test Methods for Steel Tire Cords[1]

This standard is issued under the fixed designation D 2969; 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.

ϵ[1] NOTE—Editorial changes were made throughout in August 2001.

1. Scope

1.1 These test methods cover the testing of cords made from steel that are specifically designed for use in the reinforcement of pneumatic tires. By agreement, these test methods may be used to test similar cords or filaments used for reinforcing other rubber products. The steel cords may be wound on spools or beams. The steel cords may also be woven into fabric, in which case they must be removed from the fabric prior to testing.

NOTE 1—For other methods of testing tire cords and tire cord fabrics, refer to Methods D 885, Test Methods D 1871, Specifications D 122, and Test Methods D 2692 and D 2970. For tolerances on tire cords and tire cord fabrics, refer to Specifications D 122 and Methods D 885.

1.2 These test methods include test procedures only; they do not establish specifications or tolerances.

1.3 This test method includes the following sections:

Subject	Section
Adhesion of Steel Cords and Filaments to Elastomers	16
Brass Coating Composition and Mass	14, 15
Breaking Force (Strength)	10
Construction	12
Data Form for Reporting Test Results	Appendix X1
Elongation at Break	10
Elongation Between Defined Forces (EDF)	11
Flare	8
Lay	12
Linear Density	9
Visual Appearance	8
Nomenclature System	Annex A1
Residual Torsions	8
Straightness	8
Thickness and Out-of-Roundness	13

1.4 *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.* See 14.3 and Note 11.

1.5 This standard is written in SI units. No other units of measurement are included in this standard.

2. Referenced Documents

2.1 *ASTM Standards:*

D 76 Specification for Tensile Testing Machines for Textiles[2]

D 122 Specifications for Tire Fabrics Other Than Tire Cord Fabrics[3]

D 123 Terminology Relating to Textiles[2]

D 885 Methods of Testing Tire Cords, Tire Cord Fabrics, and Industrial Filament Yarns and Cords Made from Manufactured Organic-Based Fibers[2]

D 1777 Test Method for Thickness of Textile Materials[2]

D 1871 Test Methods for Adhesion of Single-Filament Steel Wire to Rubber[2]

D 2229 Test Method for Adhesion Between Steel Tire Cords and Rubber[2]

D 2692 Test Method for Air Wicking of Tire Fabrics, Tire Cord Fabrics, Tire Cord, and Yarns[2]

D 2904 Practice for Interlaboratory Testing of a Textile Test Method that Produces Normally Distributed Data[2]

D 2970 Methods of Testing Tire Cords, Tire Cord Fabrics and Industrial Yarns Made from Glass Filaments[2]

D 4393 Test Method for Strap Peel Adhesion of Reinforcing Cords or Fabrics to Rubber Compounds[4]

E 663 Practice for Flame Atomic Absorption Analysis[5]

2.2 *International Bureau for the Standardization of Man-Made Fibers (BISFA):*

Internationally Agreed Methods for Testing Steel Tire Cords[6]

3. Terminology

3.1 *Definitions:*

3.1.1 *core, n*—a filament or strand that serves as an extended axis about which other elements can be wound.

3.1.2 *direction of lay*—the helical disposition of the components of a strand or cord.

3.1.2.1 *Discussion*—The strand or cord has an "S" or left hand lay if, when held vertically, the spirals around the central

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

[3] Discontinued. See *1993 Annual Book of ASTM Standards*, Vol 07.01.

[4] *Annual Book of ASTM Standards*, Vol 07.02.

[5] Discontinued. See *1996 Annual Book of ASTM Standards*, Vol 03.06.

[6] Available from BISFA, Lauren Garten Strasse 12, PO Box, CH-4010 BASLE Switzerland.

axis of the strand or cord conform in direction of slope to the central portion of the letter" S"; and "Z," or righthand lay if the spirals conform in direction of slope to the central portion of the letter "Z."

3.1.3 **direction of twist**—See *direction of lay.*

3.1.4 *flare*, *n*—the spreading of the filament ends or the strand ends at the cut end of a steel tire cord, expressed as the unravelled length.

3.1.5 *high elongation*, *adj*—*in steel tire cord*, a cord with an elongation at break greater than 3.0 %.

3.1.6 *length of lay*, *n*—the axial distance required to make one complete revolution of any element of a strand or cord.

3.1.7 *residual torsion*, *n*—revolutions made by a specified length of steel tire cord when one end is held in a fixed position and the other is allowed to turn freely.

3.1.8 *steel cord*, *n*—a formed structure made of two or more steel filaments when used as an end product or a combination of strands or filaments and strands.

3.1.9 *steel cord wrap*, *n*—a steel filament wound helically around a steel cord.

3.1.10 *steel filament*, *n*—the individual element in a steel strand or cord.

3.1.11 *steel strand*, *n*—a group of steel filaments combined to form a unit product to be processed further.

3.1.11.1 *Discussion*—A strand may be considered a cord if it is the finished product for tire reinforcement or it may be an element in a more complex structure.

3.1.12 *straightness*, *n*—*in steel cord*, the property of a cord characterized by a lack of deviation from its central axis over short lengths of a cord.

3.1.13 *wildness*, *n*—obsolete term, previously used to describe a number of steel tire cord properties including flare, straightness, and residual torsion.

3.1.14 For definitions of other textile terms used in these test methods, refer to Terminology D 123.

4. Summary of Test Method

4.1 A summary of the test methods prescribed for the determination of specific properties is stated in each of the sections pertaining to the respective properties.

5. Significance and Use

5.1 The procedures in Test Methods D 2969 for the determination of the properties of steel tire cord and related materials are considered satisfactory for acceptance testing of commercial shipments of such products because the procedures are the best available and have been used extensively in the trade. When a purchaser frequently uses a specific supplier, it is recommended that the two parties investigate the methods to determine if there is any bias between their two laboratories as directed in .

5.1.1 In case of a dispute arising from differences in reported test results when using this test method 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. 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 the appropriate statistical analysis and an acceptable probability level chosen by the two parties before 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 with consideration to the known bias.

5.2 The significance and use of particular properties are discussed in the appropriate sections.

6. Sampling

6.1 *Lot Sample*—As a lot sample for acceptance testing, take at random the number of primary sampling units as directed in an applicable material specification or other agreement between the purchaser and the supplier. Consider cartons of cords or rolls of fabric as primary sampling units.

NOTE 2—A realistic specification or other agreement between the purchaser and the supplier requires taking into account the variability between cartons of cords and between spools or other packages within a carton, or the variability between and within rolls of fabric so as to provide a sampling plan with meaningful producer's risk, consumer's risk, acceptable quality level, and limiting quality level.

6.2 *Laboratory Sample*—As a laboratory sample for acceptance testing, proceed as follows:

6.2.1 For cords, take at random the number of spools or other packages per carton as directed in the applicable material specification or other agreement between the purchaser and the supplier.

6.2.2 For fabric, take a full-width swatch 1 m long from the end of each roll in the lot sample, after first discarding a minimum of 1 m of fabric from the outside layer of the roll (see 6.2.3).

6.2.3 Place each laboratory sampling unit in a moisture-proof container to protect it from atmospheric corrosion and contamination.

6.3 *Test Specimens*—Take the number of specimens from each laboratory sampling unit as directed in each specific test method.

6.4 *Specimen Preparation*—For cords, when practical, perform tests on specimens taken directly from the spools or other packages in the laboratory sample.

7. Conditioning

7.1 Conditioning of materials covered by these test methods has not been found necessary, except to maintain cleanliness.

8. Visual Appearance, Residual Torsion, Straightness, Flare

8.1 *Scope*—This test method covers the visual examination of steel cord for appearance and test procedures for residual torsion, straightness, and flare.

8.2 *Significance and Use*—Physical properties of steel tire cord may be affected by the methods of manufacturing and handling procedures. Cleanliness has a direct effect on the adhesion of steel tire cord to elastomers.

8.3 One specimen is taken from each laboratory sampling unit for residual torsion, flare, and straightness. Specimens for other tests may be used for visual appearance.

8.4 *Procedures*:

8.4.1 *Residual Torsion*—Determine residual torsion by removing at least 3 m of cord from the package, cutting it off, and discarding it. Make a right angle bend about 25 mm from the cord end on the package. Hold this bent end tightly so that it cannot turn while pulling out a specimen having a length of 6 ± 0.2 m. Pull the specimen from the package in such a manner that does not change the residual torsions of the specimen from that of the cord on the package. Release the free end of the cord and allow this end to rotate while the cord is free of external tension. Count and record the number of rotations of the cord end to the closest one-half rotation and, viewing the cord from the bent end toward the package, denote clockwise rotations as positive (+) and anti-clockwise rotations as negative (–).

8.4.1.1 Calculate the average residual torsion for the lot.

8.4.2 *Straightness*—Without cutting the specimen from the package, pull out a length of cord 6± 0.2 m and lay it on a smooth, hard surface and allow it to rotate freely. With no tension applied to the cord, place the cord specimen approximately equidistant from two straight parallel lines spaced at a distance of 75 ± 3 mm. If the specimen does not touch both lines consider the specimen straight. Record the observation.

NOTE 3—It is common practice to make residual torsion and straightness observations on the same specimen. Residual torsion is measured first, then straightness.

8.4.3 *Flare*—Cut a straight section of cord (not less than 100 mm) using cutters[7] held at right angles to the axis of the specimen and measure to the nearest 1 mm of the distance along the longitudinal axis that any filament or strand unravelled. Record this distance.

8.4.3.1 Calculate the average flare for the lot.

8.4.4 *Contamination*—Make a visual inspection of the specimen taken as directed in 8.4.1, 8.4.2, or 8.4.3 and record the presence of any dirt, rust, oil, or any other foreign material. Also look for and record any pitting, including rough spots. A visual inspection of the package and its integrity may be included, if appropriate.

8.5 *Report*—State that the inspection of visual appearance was made in accordance with Section 8 of Test Methods D 2969. Describe the material sampled and the method used for sampling and report the following information:

8.5.1 *Residual Torsion*, for each sampling unit and the lot.

8.5.2 *Straightness*, for each sampling unit and the lot.

8.5.3 *Flare*, for each sampling unit and the lot.

8.5.4 *Contamination*—Visual appearance observations for each laboratory sampling unit.

8.6 *Precision and Bias*—No justifiable statement can be made either on the precision or bias of the procedures in Test Methods D 2969 for the evaluation of visual appearance because the test results merely state conformance to the criteria for success specified in the procedures.

8.6.1 Twenty cord samples of 2X.30 HT construction were measured for residual torsion and flare in accordance with 8.4.1 and 8.4.2. A single operator in a single laboratory performed the testing. A statistical analysis was used to quantify intralaboratory variability for these properties. The property flare showed a strongly right-skewed distribution, with values between 0 and 65 mm; the median value was 3 mm. Repeatability was not calculated for flare because of its non-normal distribution. Results are shown in the following:

Property	Average	S_r	Repeatability	S_R	Reproducibility
Flare	8.6	16.3	-	NA	NA
Residual Torsion	1.45	0.22	0.62	NA	NA

S_r is the intra-laboratory standard deviation. S_R, the total standard deviation, is formed by taking the square root of the sum of intra-laboratory and interlaboratory variance components. S_R cannot be determined from these data.

Method repeatability is defined as the "maximum difference" that can "reasonably" be expected between two test results obtained on the same material when the test results are obtained in the same laboratory. Method reproducibility is defined as the "maximum difference" that can "reasonably" be expected between two test results obtained on the same material when the test results are obtained from different laboratories.

9. Linear Density

9.1 *Scope*—In this test method, a specified length of steel cord is weighed using an analytical balance and linear density is calculated as mass per unit length.

9.2 *Significance and Use*—The linear density of steel cord is used to calculate the expected mass of pneumatic tires and the various components used in their manufacture as a part of the process control procedure.

9.3 *Number and Preparation of Specimens*—Take a specimen having a minimum length of 1 m from each sample of cord (see Note 4 for high-elongation cords). For samples from fabric, use a sufficient number of ends to give a minimum length of 1 m of cord for each specimen. Measure the length of the specimen to within 0.1 % using a tension of 10 ± 1 N to keep the cord straight. Cut the specimen at the required length. Record the length.

NOTE 4—A proposed method for measuring the linear density of high-elongation cords is as follows:

(*1*) Clamp an extensometer onto the specimen that is straight, but under no tension; read the gage length L (0);

(*2*) Apply a tension of 1.5 ± 0.2 N to the cord and read the gage length, L (1);

(*3*) Calculate the extension factor, EF, as follows:

$$EF = (L(1) - L(0))/L(0) \tag{1}$$

(*4*) Calculate and report the linear density, as follows:

$$\text{Linear density, tex} = M/(L(0) \times (1 + EF)) \tag{2}$$

where:

M = mass, g,
L (0) = length, km, and
EF = extension factor.

9.4 *Procedure*—Determine the mass of the specimen of cord by weighing to the nearest 1 mg.

9.5 *Calculation*—Calculate the linear density to the nearest 10 tex using Eq 3:

[7] The sole source of supply of the apparatus known to the committee at this time is Felix Flisch Felco, 2206 Les Geneveys-s/Coffrane Switzerland or Loos and Co., 900 Industrial Blvd., Naples, FL 33942. 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, which you may attend.

$$\text{Linear density, tex} = M/L \quad (3)$$

where:
M = mass, g, and
L = length, km.

9.5.1 Calculate the average linear density for the lot.

9.6 *Report*—Report that the specimen was tested in accordance with Section 9 of Test Methods D 2969. Describe the material sampled and the method of sampling used. Report the linear density for each laboratory sampling unit and for the lot.

9.7 *Precision and Bias*:

9.7.1 *Summary*—In comparing two averages of four observations, the difference between averages should not exceed 10 tex in 95 out of 100 cases when all of the observations are taken by the same well-trained operator using the same piece of test equipment and the specimens are randomly drawn from the same sample. Larger differences are likely to occur under all other circumstances.

9.7.2 *Interlaboratory Test Data*[8]—An interlaboratory test was run in 1983 in which randomly drawn specimens of four materials were tested in sixteen laboratories in accordance with Practice D 2904. Each laboratory used two operators, each of whom tested specimens of each material on two different days. The components of variance expressed as standard deviations are listed in Table 1.

9.7.3 *Precision*—For the components of variance reported in Table 1, the averages of two 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 5—The values of the tabulated differences should be considered to be a general statement, particularly with respect to between-laboratory

[8] Supporting data are available from ASTM Headquarters. Request RR: D13-1072.

TABLE 1 Components of Variance as Standard Deviations[A]

Name of Property	Single-Operator Component	Within-Laboratory Component	Between-Laboratory Component
Linear Density, tex			
Single-material comparisons	4.96	3.31	1.28
Multi-material comparisons	0.00	3.31	3.15
Breaking Force, N[B]			
1 × 4 × 0.25	4.30	1.63	5.88
3 × 0.20 + 6 × 0.38	16.13	11.58	25.84
3 + 9 × 0.22 + 1 × 0.15	27.48	0.00	34.62
2 + 7 × 0.22 + 1 × 0.15	17.63	3.05	15.12
Elongation, %[B]			
1 × 4 × 0.25	0.07	0.00	0.00
3 × 0.20 + 6 × 0.38	0.15	0.00	0.00
3 + 9 × 0.22 + 1 × 0.15	0.12	0.00	0.00
2 + 7 × 0.22 + 1 × 0.15	0.11	0.00	0.00
Cord lay length (rubbing), mm			
Single-material comparisons	0.34	0.06	0.00
Multi-material comparisons	0.00	0.06	0.22
Strand lay length (rubbing), mm			
Single-material comparisons	0.14	0.00	0.00
Multi-material comparisons	0.05	0.00	0.04
Cord lay length (counter), mm			
Single-material comparisons	0.11	0.04	0.08
Multi-material comparisons	0.06	0.04	0.19
Strand lay length (counter), mm			
Single-material comparisons	0.06	0.02	0.06
Multi-material comparisons	0.01	0.02	0.08
Cord thickness, mm			
Single-material comparisons	0.009	0.004	0.033
Multi-material comparisons	0.004	0.004	0.061
Cord ovality, mm			
Single-material comparisons	0.013	0.006	0.009
Multi-material comparisons	0.010	0.006	0.009
Mass of Brass, g/kg[C]			
Single-material comparisons	0.197	0.084	0.136
Multi-material comparisons	0.000	0.084	0.152
Copper in Brass, %[C]			
Single-material comparisons	1.118	0.284	0.308
Multi-material comparisons	0.223	0.284	0.383
Mass of Brass, g/kg[D]			
Single-material comparisons	0.097	0.023	0.234
Multi-material comparisons	0.000	0.023	0.244
Copper in Brass, %[D]			
Single-material comparisons	0.310	0.000	0.190
Multi-material comparisons	0.152	0.000	0.308

[A] The square roots of the components of variance are listed so that variability is expressed in the appropriate units of measure rather than as the square of those units of measure.
[B] Breaking load and elongation were found to be dependent on cord construction during interlaboratory testing and no valid statement can be made about the components of variance for multi-material comparisons. The cord constructions noted were those tested in the 1983 interlaboratory test.
[C] By atomic absorption (Section 14).
[D] X-ray fluorescence (Section 15).

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 specimens taken from a lot of material of the type being evaluated so as to be as homogeneous as possible, and then randomly assigned in equal numbers to each of the laboratories.

9.7.4 *Bias*—The procedure in Test Methods D 2969 for determining the linear density of steel cord has not been checked against referenced materials but contains no known bias. The test method is accepted as a referee method.

9.7.4.1 The materials used in the 1983 interlaboratory test were:

1 × 4 × 0.25
3 × 0.20 + 6 × 0.38
3 + 9 × 0.22 + 1 × 0.15
2 + 7 × 0.22 + 1 × 0.15

Except as noted in the appropriate section, components of variance and critical differences were found to be independent of significant material effects. See Annex A1 for an explanation of cord constructions.

TABLE 2 Critical Differences for Conditions Noted

Name of Property	Number of Observations	Single-Operator Precision	Within-Laboratory Precision	Between-Laboratory Precision
Linear Density, tex		(single-material comparisons)		
	1	13.76	16.54	16.91
	2	9.73	13.37	13.84
	4	6.88	11.46	12.00
	8	4.86	10.38	10.97
	16	3.44	9.80	10.42
		(multi-material comparisons)		
	1	13.76	16.54	18.70
	2	9.73	13.37	15.97
	4	6.88	11.46	14.42
	8	4.86	10.38	13.57
	16	3.44	9.80	13.13
Breaking Force, N[A]		(single-material comparisons)		
1 × 4 × 0.25	1	11.91	12.73	20.63
	2	8.42	9.55	18.89
	4	5.95	7.47	17.93
	8	4.21	6.17	17.43
	16	2.98	5.41	17.17
		(single-material comparisons)		
3 × 0.20 + 6 × 0.38	1	44.69	55.03	90.31
	2	31.60	45.05	84.50
	4	22.35	39.12	81.59
	8	15.80	35.78	80.05
	16	11.17	33.99	79.27
		(single-material comparisons)		
3 + 9 × 0.22 + 1 × 0.15	1	76.16	76.16	122.50
	2	53.86	53.86	110.02
	4	33.08	38.08	103.22
	8	26.93	26.93	99.65
	16	19.04	19.04	97.81
		(single-material comparisons)		
2 + 7 × 0.22 + 1 × 0.15	1	48.87	49.60	64.93
	2	34.56	35.58	54.98
	4	24.44	25.86	49.25
	8	17.28	19.24	46.12
	16	12.22	14.86	44.47
EDF, %		(single-material comparisons)		
	1	0.01	0.01	0.02
	2	0.01	0.01	0.02
	4	0.01	0.01	0.02
	8	0.00	0.01	0.02
	16	0.00	0.02	0.02
		(multi-material comparisons)		
	1	0.01	0.02	0.02
	2	0.01	0.01	0.02
	4	0.01	0.01	0.02
	8	0.01	0.01	0.02
	16	0.01	0.01	0.02
Elongation, %[A]		(single-material comparisons)		
1 × 4 × 0.25	1	0.20	0.20	0.20
	2	0.14	0.14	0.14
	4	0.10	0.10	0.10
	8	0.07	0.07	0.07
	16	0.05	0.05	0.05
		(single-material comparisons)		
3 × 0.20 + 6 × 0.38	1	0.43	0.43	0.43

TABLE 2 *Continued*

Name of Property	Number of Observations	Single-Operator Precision	Within-Laboratory Precision	Between-Laboratory Precision
	2	0.30	0.30	0.30
	4	0.21	0.21	0.21
	8	0.15	0.15	0.15
	16	0.11	0.11	0.11
		(single-material comparisons)		
3 + 9 × 0.22 + 1 × 0.15	1	0.33	0.33	0.33
	2	0.23	0.23	0.23
	4	0.16	0.16	0.16
	8	0.12	0.12	0.12
	16	0.08	0.08	0.08
		(single-material comparisons)		
2 + 7 × 0.22 + 1 × 0.15	1	0.30	0.30	0.30
	2	0.22	0.22	0.22
	4	0.15	0.15	0.15
	8	0.11	0.11	0.11
	16	0.08	0.08	0.08
Cord lay length (rubbing), mm		(single-material comparisons)		
	1	0.95	0.97	0.97
	2	0.67	0.70	0.70
	4	0.48	0.51	0.51
	8	0.34	0.38	0.38
	16	0.24	0.30	0.30
		(multi-material comparisons)		
	1	0.95	0.97	1.14
	2	0.67	0.70	0.92
	4	0.48	0.51	0.79
	8	0.34	0.38	0.72
	16	0.24	0.30	0.68
Strand lay length (rubbing), mm		(single-material comparisons)		
	1	0.39	0.39	0.39
	2	0.28	0.28	0.28
	4	0.20	0.20	0.20
	8	0.14	0.14	0.14
	16	0.10	0.10	0.10
		(multi-material comparisons)		
	1	0.41	0.41	0.43
	2	0.30	0.30	0.33
	4	0.23	0.23	0.26
	8	0.19	0.19	0.22
	16	0.16	0.16	0.20
Cord lay length (counter), mm		(single-material comparisons)		
	1	0.31	0.33	0.40
	2	0.22	0.25	0.34
	4	0.15	0.19	0.30
	8	0.11	0.16	0.28
	16	0.08	0.14	0.27
		(multi-material comparisons)		
	1	0.35	0.37	0.64
	2	0.27	0.29	0.60
	4	0.22	0.25	0.58
	8	0.19	0.23	0.57
	16	0.18	0.21	0.57
Strand lay length (counter), mm		(single-material comparisons)		
	1	0.17	0.18	0.24
	2	0.12	0.13	0.21
	4	0.08	0.10	0.19
	8	0.06	0.08	0.18
	16	0.04	0.07	0.17
		(multi-material comparisons)		
	1	0.17	0.18	0.28
	2	0.12	0.13	0.25
	4	0.09	0.10	0.24
	8	0.06	0.09	0.23
	16	0.05	0.08	0.23
Cord thickness, mm		(single-material comparisons)		
	1	0.02	0.03	0.10
	2	0.02	0.02	0.10
	4	0.01	0.02	0.09
	8	0.01	0.02	0.09
	16	0.01	0.01	0.09
		(multi-material comparisons)		
	1	0.03	0.03	0.17
	2	0.02	0.02	0.17