Designation: D 2969 – 00ε1

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
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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

[1] These test methods are under the jurisdiction of ASTM Committee D13 on Textiles and are the direct responsibility of Subcommittee D13.19 on Tire Cord and Fabrics.

Current edition approved April 10, 2000. Published July 2000. Originally published as D 2969 – 71 T. Last previous edition D 2969 – 92.

[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:

$$EF = (L(1) - L(0))/L(0) \quad (1)$$

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

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

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

TABLE 2 *Continued*

Name of Property	Number of Observations	Single-Operator Precision	Within-Laboratory Precision	Between-Laboratory Precision
	4	0.02	0.02	0.17
	8	0.01	0.02	0.17
	16	0.01	0.02	0.17
Cord out-of-roundness		(single-material comparisons)		
	1	0.04	0.04	0.05
	2	0.03	0.03	0.04
	4	0.02	0.02	0.03
	8	0.01	0.02	0.03
	16	0.01	0.02	0.02
		(multi-material comparisons)		
	1	0.05	0.05	0.05
	2	0.04	0.04	0.05
	4	0.03	0.04	0.04
	8	0.03	0.03	0.04
	16	0.03	0.03	0.04
Mass of brass, g/kg[B]		(single-material comparisons)		
	1	0.546	0.594	0.703
	2	0.386	0.451	0.588
	4	0.273	0.359	0.520
	8	0.193	0.302	0.483
	16	0.136	0.270	0.464
		(multi-material comparisons)		
	1	0.546	0.594	0.728
	2	0.386	0.451	0.617
	4	0.273	0.359	0.553
	8	0.193	0.302	0.519
	16	0.136	0.270	0.500
Copper in brass, %[B]		(single-material comparisons)		
	1	3.10	3.20	3.31
	2	2.19	2.33	2.48
	4	1.55	1.74	1.94
	8	1.10	1.35	1.60
	16	0.77	1.10	1.40
		(multi-material comparisons)		
	1	3.16	3.26	3.42
	2	2.28	2.41	2.63
	4	1.67	1.84	2.13
	8	1.26	1.48	1.82
	16	0.99	1.27	1.65
Mass of brass, g/kg[C]		(single-material comparisons)		
	1	0.27	0.28	0.71
	2	0.19	0.20	0.68
	4	0.14	0.15	0.67
	8	0.10	0.12	0.66
	16	0.07	0.09	0.66
		(multi-material comparisons)		
	1	0.27	0.28	0.73
	2	0.19	0.20	0.71
	4	0.14	0.15	0.69
	8	0.10	0.12	0.69
	16	0.07	0.09	0.68
Copper in brass, %[C]		(single-material comparisons)		
	1	0.86	0.86	1.01
	2	0.61	0.61	0.80
	4	0.43	0.43	0.68
	8	0.30	0.30	0.61
	16	0.22	0.22	0.57
		(multi-material comparisons)		
	1	0.96	0.96	1.28
	2	0.74	0.74	1.13
	4	0.60	0.60	1.05
	8	0.52	0.52	1.00
	16	0.47	0.47	0.98

[A]Breaking force and elongation were found to be dependent on cord construction during interlaboratory testing and no valid statement can be made concerning least critical differences for multi-material comparisons. The cord constructions noted were those tested in the 1983 interlaboratory test.

[B]By atomic absorption (Section 14).

[C]By X-ray fluorescence (Section 15).

10. Tensile Properties or Cord Breaking Force (Strength) and Elongation at Break

10.1 *Scope*—The two ends of a specimen are clamped in a tensile testing machine and an increasing force is applied until the specimen breaks. The change in the force measured versus the increase in the separation of the specimen clamps to form

a force-extension curve. Breaking force and nominal extension at break are read directly from the curve. Elongation at break is calculated using the extension and specimen length.

10.2 *Significance and Use*—The levels of tensile properties obtained when testing specimens are affected by the rate of loading, the type of clamps, and the gage length of the specimen. The clamps used to grip the specimen have the most influence on the test results. Elongation at break is difficult to determine by the procedure in 10.6. For greater accuracy in determining elongation at break, see 10.3.2 and Note 6. A pretension of 1 % of full-scale force is required for all cords, except as indicated in Note 4.

10.3 *Apparatus*:

10.3.1 *Tensile Testing Machine*—A constant rate of extension (CRE) type with an autographic force-extension recorder, digital readout, or automated data logger that conforms to the requirements of Specification D 76 is recommended.

NOTE 6—The accuracy of the determination of elongation can be improved by the use of an extensometer in all cases where the gripping mechanism permits some movement of the specimen. Improvement can also be effected by using a longer gage length with gripping mechanisms that do not permit movement of the specimen in the grips.

10.3.2 *Extensometer (Optional)*—This may be any device that can be attached to the specimen and that permits recording of the specimen elongation during loading.

10.3.3 *Clamps*—Any clamp that does not cause failure of the specimen at the gripping point or in contact with the clamp. Instron pneumatic grips 2714-004, 2714-006, and Scott 400 clamps for finer cords have been found suitable. A smooth jaw surface or one similar to file cut is preferred over a diamond-type serration. If breaking force only is desired, a spool-type clamp may be used. The diameter of the capstan should be increased as the specimen thickness is increased to avoid a bending radius that will damage the filaments where they contact the capstan. The clamps must be of sufficient capacity and design to prevent specimen slippage without causing specimen breaks at the gripping point within the clamps or in contact with the clamp.

10.3.4 *Abrasive Cloth*, 180 or 240 grit.

10.4 *Number and Preparation of Specimens*:

10.4.1 Test five specimens from each laboratory sampling unit.

10.4.2 Remove the spiral wrap, if present, from the length of the specimen in contact with the clamps.

10.4.3 Tape the sample at convenient intervals equivalent to the required length of the specimen to be used, and cut through the sample where it has been taped to secure the needed number of specimens.

10.4.4 For some constructions where flare or unraveling is not a problem, it may be convenient to remove the spiral wrap completely and omit taping.

10.5 *Procedure*:

10.5.1 Select a force scale based on the estimated breaking force of the specimen so that the testing machine will be operating in the range from 10 to 90 % of its full-scale force.

10.5.2 Adjust the distance between the clamps on the testing machine so that the nominal gage length of the specimen equals the distance from nip to nip of the jaws in the clamps or between the axes of the capstan clamps. Jaw design and distance from nip to nip may vary. Gage length should be 500 ± 5 mm.

10.5.3 Operate the testing machine at a cross-head movement that gives a rate of extension between 5 and 10 % of the nominal gage length per minute. Testing at a rate in the lower end of a specified range is recommended when improved accuracy of elongation is needed. Graphic records of extension as a proportion of tester cross-head movement are permissible when the relationship of the record to the actual specimen extension is known and the correct elongation can be calculated.

10.5.4 Secure the specimen in the top clamp, exerting enough pressure to prevent the cord from slipping when loaded. Place the other end of the specimen between the jaws of the bottom clamp. Apply a pretension of 1 % of full scale to keep the specimen taut. Tighten the bottom clamp.

10.5.5 If failure at the jaws is a problem, insert an abrasive cloth as a jaw liner between the specimen and the jaw surface. Insert the abrasive cloth to cover the full jaw gripping surface, with the abrasive cloth extending beyond the leading edge of the jaw to protect the specimen where it is clamped. The abrasive side of the cloth should contact the specimen. If slippage occurs, it may be the result of a build up of residual wire drawing lubricant on the jaw surfaces and can be remedied by cleaning.

10.5.6 Start the testing machine, break the specimen, and note the highest force to three significant digits.

NOTE 7—In some constructions, it is possible for one or more strands or filaments to rupture prior to the others so that a drop in load-carrying ability may be indicated prior to complete rupture.

10.5.7 If the highest force for any specimen is less than the specified minimum and the specimen fractures at the gripping point (jaw break) or on the clamp surface, discard that result and test another specimen. If the highest force attained meets the specified minimum, retain the result whether or not the specimen breaks at the gripping points or on the clamp surface.

10.5.8 Determine the elongation at break of each specimen when determining its breaking force. Read the extension at the point of maximum force from the autographic recorder chart or by electronic means. If the force-extension curve exhibits an initial nonlinear portion, extrapolate from the initial straight line portion of the curve to the base line. This intersection is the point of origin for determining extension.

NOTE 8—The extrapolation procedure is not applicable to high-elongation cords.

NOTE 9—If capstan clamps are used, the elongation at the capstan might be less than in the free part. The difference can be calculated by determining the elongation at break at two gage lengths.

10.6 *Calculations*:

10.6.1 Calculate the average breaking strength of the sample to three significant digits from the observed breaking forces of the specimens tested. Calculate breaking strength for the lot.

10.6.2 Calculate the elongation at break for each specimen to the nearest 0.1 % using Eq 4:

$$E = 100\,L/G \tag{4}$$

where:
E = elongation at break, %,
L = extension of the specimen, mm, and
G = gage length (10.5.2), mm.

10.6.3 Calculate the elongation at break for each laboratory sampling unit and for the lot.

10.7 *Report*:

10.7.1 Report that the specimens were tested as directed in Section 10 of Test Methods D 2969. Describe the material sampled and the method of sampling used.

10.7.2 Report the following information:

10.7.2.1 Breaking strength for each laboratory sampling unit and for the lot.

10.7.2.2 Elongation at break for each laboratory sampling unit and for the lot.

10.8 *Precision and Bias*:

10.8.1 *Summary*—Interlaboratory test data have shown that the variance in breaking force testing is dependent upon the construction of the steel cord; therefore, no general statement can be made concerning least critical differences. The following data were generated during the interlaboratory test and are presented for reference. In comparing two averages of four observations, the difference between the averages should not exceed the following values 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 specimens are randomly drawn from the same sample of the steel cord construction indicated:

Steel Cord Construction	Breaking Force, N	Elongation at Break, %
1 × 4 × 0.25	6	0.10
3 × 0.20 + 6 × 0.38	22	0.21
3 + 9 × 0.22 + 1 × 0.15	38	0.16
2 + 7 × 0.22 + 1 × 0.15	24	0.15

Larger differences are likely to occur under all other circumstances. The procedure for determining breaking force and elongation at break has no known bias and is considered a referee method.

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

10.8.3 *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 (see Note 5).

10.8.4 *Bias*—The procedures in Test Methods D 2969 for determining breaking force and elongation at break of steel cord have not been checked against accepted reference materials but contain no known bias. These test methods are accepted as referee methods (see 9.7.4.1).

11. Elongation Between Defined Forces (EDF)

11.1 *Scope*—A specimen is mounted between the clamps of a tensile testing machine (usually with a specified pretension) and then elongated until the force on the specimen has reached a given value, usually less than 50 % of the nominal breaking force of the specimen. The change in force is measured as a function of the increase in the separation of the clamps of the tensile testing machine to define a force-extension curve. The extension between two specified force points is read directly from the curve or determined by electronic means or with an on-line computer. Recommended force points are 2.5 N and 20 N or 2.5 N and 50 N. Calculate the EDF using the extension between the two forces and the gage length.

11.2 *Significance and Use*:

11.2.1 The characteristic of elongation at relatively low force relates to steel cord processability or rubber penetration, or both.

11.2.1.1 Test results may be affected by the rate of application of the force, the type of clamps, the amount of pretension, the method of obtaining the sample, and the gage length of the specimen. The overall condition of the test equipment may also affect results because of the small forces and small crosshead movements used in this test.

11.2.2 Simplified methods, using portable testing equipment, are sometimes used by the producing plants for control of production. Such methods and equipment should be compared to this test method for possible bias. The simplified methods are not considered suitable for acceptance testing.

11.3 *Apparatus*:

11.3.1 *Tensile Testing Machine*—A constant rate of extension (CRE) type capable of low crosshead speeds (5 mm/min) and equipped with an automatic force-extension recorder, digital read-out, or automatic data logger that conforms to the requirements of Specification D 76 is recommended.

11.3.2 *Clamps*—Any clamp featuring smooth jaws which prevents slippage without causing specimen breakage. Instron pneumatic grips 2712-002, 2712-003, and 2712-005 have been found suitable.

11.4 *Number and Preparation of Specimen*:

11.4.1 Test five specimens from each laboratory sampling unit.

11.4.2 Remove the sample from the spool without subjecting the sample to any tension, rotation, or sharp bends that would kink the sample or otherwise distort the normal configuration. If the cord construction being tested includes a wrap wire, do not remove the wrap wire.

11.4.3 Mark the sample in intervals to give specimens at least 1.5 m apart to prevent the cut ends from influencing the test results, and simultaneously cut and fuse the cut ends.

11.4.4 Alternatively, preserve specimen integrity by taping the sample at specimen length intervals and cutting through the tape.

11.5 *Procedure*:

11.5.1 Calibrate the tester and recording instruments according to the manufacturer's recommendations.

11.5.2 Select a force range such that the two force points between which the elongation is to be measured fall within the range (from 2.5 to 20 N or from 2.5 to 50 N). A force measuring device, commonly referred to as a load cell, with a maximum capacity of no more than 100 N is recommended.

11.5.3 Set the crosshead speed at 5 mm/min.

11.5.4 If using a force-extension recorder, set the chart

speed fast enough to enhance accuracy of measurement and simplify calculation of elongation. A multiple of 100 times the crosshead speed (500 mm/min) is recommended. When using an automatic data logger, use a maximum signal sampling rate compatible with the equipment.

11.5.5 Adjust the distance between the clamps on the tensile testing machine so that the nominal gage length of the specimen, measured from nip to nip of the jaws of the clamps, is 500 mm, ±1 %.

11.5.6 Secure the specimen in the top clamp, exerting enough pressure to prevent the cord from slipping when force is applied. Place the other end of the specimen between the jaws of the bottom clamp. Use light hand tension (less than 1 N) to straighten and center the specimen. Close the bottom clamp. Start the test machine. Stop the crosshead when a force at least 5 N greater than the selected maximum force has been reached.

11.5.7 If specimen slippage has occurred during the test, discard the results and repeat the test using a new specimen.

11.5.8 Repeat the test until 5 valid determinations are obtained for each sample.

11.6 *Calculation*:

11.6.1 Calculate the elongation between the two chosen force points to the nearest 0.01 %. When measuring extension from a recorder chart, calculate EDF as follows in Eq 5:

$$\text{EDF} = \frac{(E_F - E_O)}{L} \times R \times 100 \quad (5)$$

where:

EDF = elongation between defined forces, %,
E_O = extension (in mm on the chart) at initial force (in N)
E_F = extension (in mm on the chart) at final force (in N)
L = gage length, in mm
R = ratio of crosshead speed/chart speed.

11.6.2 Calculate the EDF for each laboratory sampling unit and for the lot.

11.7 *Report*:

11.7.1 State that the specimens were tested as directed in Section 11 of Test Methods D 2969. Describe the material sampled and the method of sampling used.

11.7.2 Report the following information:

11.7.2.1 The EDF for each laboratory sampling unit and for the lot.

11.7.2.2 The two force points used to determine the elongation.

11.7.2.3 The gage length of the specimen used if different than specified in this test method.

11.7.2.4 Any modification to this test method.

11.8 *Precision and Bias*:

11.8.1 *Summary*—In comparing two averages of five observations the difference between averages should not exceed 0.005 % in 95 out of 100 cases when all of the observations are taken by the same well-trained operator using the same equipment and specimens are randomly drawn from the same sample of material. The procedures described in this method for determining the elongation between defined forces have no known bias and are considered referee methods.

11.8.2 *Interlaboratory Test Data*[9]—An interlaboratory evaluation coordinated by BISFA was conducted in 1991 in which randomly drawn samples of six constructions of steel tire cord were tested in six laboratories in accordance with Practice D 2904. Each laboratory used two operators, each of whom tested the six materials on two separate days. In analyzing the data, the results from one laboratory were discarded because there was evidence that the procedure was improperly applied in that laboratory.

11.8.3 *Precision*—Two test results should be considered significantly different at the 95 % probability level if the critical difference equals or exceeds the critical differences listed in Table 2 (see Note 5).

11.8.4 *Bias*—The procedures contained in Test Methods D 2969 for determining elongation between defined forces contain no known bias because EDF is only defined in terms of this test method.

12. Construction

12.1 *Scope*—A specimen is separated into its components, and the direction of lay and number of strands and filaments determined. Conventional construction nomenclature is given in Annex A1.

12.2 *Significance and Use*—Physical properties of steel cords are influenced by the direction of lay, length of lay, and number of strands and filaments. Certain special constructions may exist where the length of lay cannot be measured by this test method.

12.3 *Materials*:

12.3.1 *Masking Tape*, 20 mm wide.

12.3.2 *White Paper or Carbon Paper and Graphite Pencil*.

12.4 *Procedure*:

12.4.1 Tape one specimen from each laboratory sampling unit at two places approximately 250 mm apart and cut through the tape and specimen. Remove the spiral wrap, if one is present; however, if the lay of this wrap is required, determine the lay before removing the wrap.

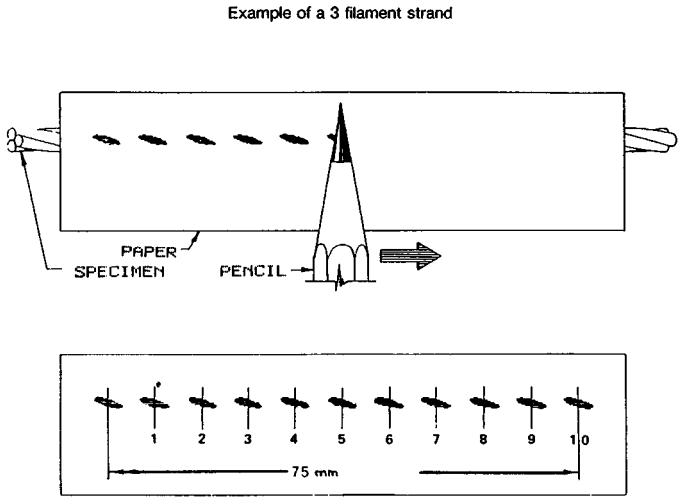
12.4.2 *Direction of Lay*—Note and record the direction of lay as “S” or “Z,” as defined in 3.1.2.

12.4.3 *Length of Lay*—Place a sheet of white paper or carbon paper over a straight-length section of the specimen and rub the paper with a pencil to form a relief impression. Count the number of nodes in the impression for a specified length (not shorter than five times the specified lay length) measured between the center of nodes (see Fig. 1). Using the number of strands from 12.4.4, calculate the length of lay of the cord as directed in 12.5.

12.4.4 *Number of Strands*—Separate the outermost components making up the specimen by unwinding the surface layer. Note and record the number of components in this surface layer. The outermost components may be single filaments or strands.

12.4.5 If the outermost component is comprised of more than one filament, unwind a strand from the cord and determine the direction of lay and the length of lay as directed in 12.4.2 and 12.4.3. Use the number of filaments determined as directed

[9] Supporting data are available from ASTM Headquarters. Request RR:13-1064.



Length of lay = (length marked/number of nodes) × the number of filaments in the strand (see 12.4.6) For the three-filament strand illustrated, Length of lay, mm = (75/10) × 3 = 22.5 mm

FIG. 1 Diagram Illustrating the Determination of the "Length of Lay"

in 12.4.6 and in Eq 6 of 12.5 to calculate the length of lay of the strands.

12.4.6 *Number of Filaments*—Separate the strand by unwinding and count the number of filaments in the strand.

12.4.7 Repeat the procedures in 12.4.2-12.4.6 for the core, if present. The core is the innermost component of a construction that remains in the center and does not extend to the surface layer. It can be a single filament or a strand.

12.4.8 An alternative method for determining the length of lay is the untwisting method, as covered in the section on Twist in Method D 885. A modified twist counter, such as a hand-driven torsion testing machine, is required to untwist the cord due to the stiffness of the cord. Untwist the cord first, then untwist the strands when more than one strand is present. The length of lay is calculated by dividing the initial specimen length as measured between the clamps by the number of turns required to untwist the cord or the strand. For high-elongation cords, apply 0.5 mN/tex pretension during the clamping.

12.5 *Calculation*—Calculate the length of lay to the nearest 0.2 mm using Eq 6 as follows:

$$\text{Length of Lay, mm} = (L/N) \times S \quad (6)$$

where:

L = length over which the number of nodes are counted, mm,
S = number of strands or filaments in the surface layer, and
N = number of nodes.

12.5.1 Calculate the length of lay for the lot.

12.6 *Report*:

12.6.1 State that the specimens were tested as directed in Section 12 of Test Methods D 2969. Describe the material sampled and the method of sampling used.

12.6.2 Report the following information for each cord part:

12.6.2.1 Direction of lay,

12.6.2.2 Length of lay for each laboratory sampling unit and for the lot. and

12.6.2.3 Number of strands or filaments, or both.

12.7 *Precision and Bias*:

12.7.1 *Summary*—In comparing two averages of four observations the difference between averages should not exceed the following amounts in 95 out of 100 cases when all of the observations are taken by the same well-trained operator using the same piece of equipment and specimens are randomly drawn from the same sample.

Rubbing Method	
Cord Lay Length	0.48 mm
Strand Lay Length	0.20 mm
Twist Counter Method	
Cord Lay Length	0.15 mm
Strand Lay Length	0.08 mm

Larger differences are likely to occur under all other circumstances.

12.7.2 *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. Ten laboratories used the rubbing method and six laboratories used the twist counter method. Each laboratory used two operators, each of whom tested two specimens of each material on different days. The components of variance expressed as standard deviations are listed in Table 1 (see 9.7.2.1).

12.7.3 *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 difference listed in Table 2 (see Note 5).

12.7.4 *Bias*—The procedures in Test Methods D 2969 for determining the cord and strand lay lengths of steel cord have not been checked against accepted reference materials but contain no known bias. These methods are accepted as referee methods (see 9.7.2.1).

13. Thickness of Cord

13.1 *Scope*—A minimum length specimen of strand or cord is held between two parallel circular-faced anvils of a micrometer. The movable anvil is closed gradually and gently until it is in contact with the specimen. The thickness is

determined by reading the micrometer gage. The out-of-roundness is determined from the minimum and maximum thickness measurements.

NOTE 10—Alternative methods of determining thickness are described in Methods D 885. Optical or non-contact methods for thickness measurements, especially of easily deformed cords, are under study.

13.2 *Significance and Use*—Thickness is one of the basic physical properties of strand and cord needed in many industrial applications. Tire dimensions and calendered fabric thickness are dependent on knowing cord thickness. Production techniques in calendering are also affected by the degree of out-of-roundness of the cord.

13.3 *Apparatus*:

13.3.1 *Precision Micrometer*, with a vernier to provide measurement to the nearest 0.01 mm. The anvils shall be plane and parallel within 0.015 mm. The dimensions of the anvils should be greater than one lay length. The force on the anvils shall be 1.5± 0.2 N.

13.4 *Number and Preparation of Specimens*:

13.4.1 Test one specimen from each laboratory sampling unit.

13.4.2 Remove a 150-mm specimen from the spool by burning or cutting. The section to be measured may not be bent or kinked.

13.5 *Procedure*:

13.5.1 Verify that the measuring instrument reads 0.000 when the anvils are closed.

13.5.2 Carefully make a right-angle bend in the cord without bending or kinking the section to be measured, so as to assist in rotating the cord between measurements and judging the amount of rotation. Determine the maximum and minimum thicknesses at each of three locations approximately 100 mm apart along the cord. Read and record each measurement to the nearest 0.01 mm.

13.6 *Calculations*:

13.6.1 Calculate the thickness, to the nearest 0.01 mm, as the average of the three maximum and three minimum measurements for each laboratory sampling unit and for the lot.

13.6.2 Calculate the difference between each pair of minimum and maximum readings for each specimen. The out-of-roundness for the specimen is the maximum difference determined.

13.6.2.1 Calculate the average out-of-roundness for the lot.

13.7 *Report*:

13.7.1 Report that the specimens were tested as directed in Section 13 of Test Methods D 2969. Describe the material sampled and the method of sampling used.

13.7.2 Report the following information:

13.7.2.1 Cord thickness for each laboratory sampling unit and for the lot, and

13.7.2.2 Out-of-roundness for each laboratory sampling unit and for the lot.

13.8 *Precision and Bias*:

13.8.1 *Summary*—In comparing two averages of four observations, the difference between averages should not exceed the following amounts in 95 out of 100 cases when all the observations are taken by the same well-trained operator using the same piece of test equipment and specimens are randomly drawn from the same sample:

Cord Thickness	0.01 mm
Cord Out-of-Roundness	0.02 mm

Larger differences are likely to occur under all other circumstances. The procedures for determining cord thickness and out-of-roundness have no known bias and are considered referee methods.

13.8.2 *Interlaboratory Test Data*[8]—An interlaboratory test was run in 1983 in which randomly drawn specimens of four materials were tested in fifteen laboratories in accordance with Practice D 2904. Each laboratory used two operators, each of whom tested two specimens of each material on different days. The components of variance expressed as standard deviations are listed in Table 1 (see 9.7.2.1).

13.8.3 *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 (see Note 5).

13.8.4 *Bias*—The procedures in Test Methods D 2969 for determining thickness and out-of-roundness of steel cord have not been checked against accepted reference materials but contain no known bias. These methods are accepted as referee methods (see 9.7.2.1).

14. Brass Coating Analysis by Atomic Absorption (AA)

14.1 *Scope*—The brass coating is stripped from the steel cord using nitric acid, and the composition is determined using flame atomic absorption analysis as in Practice E 663. The mass of the brass (coating weight) is expressed as the ratio of the total mass of the copper and zinc to the specimen mass prior to stripping.

14.2 *Significance and Use*—The adhesive properties of the cord depend in part on the composition and mass of the brass coating.

14.3 *Apparatus and Reagents*:

14.3.1 *Atomic Absorption Spectrophotometer*—A spectrophotometer capable of being operated in accordance with Practice E 663 with the following instrument operating parameters:

	Copper	Zinc
Wavelength	324.7 nm	213.9 nm
Fuel/oxidant	acetylene/air	
Flame	oxidizing	
Slit width	(per operating manual)	

14.3.2 *Calibration Solutions*—The following standard solutions may be used (fewer may be used based on the operating manual for the specific flame atomic absorption equipment used):

Solution A—1 ppm Cu, 0.5 ppm Zn, 5 % HNO_3(by volume).
Solution B—2 ppm Cu, 1.0 ppm Zn, 5 % HNO_3(by volume).
Solution C—3 ppm Cu, 1.5 ppm Zn, 5 % HNO_3(by volume).
Solution D—4 ppm Cu, 2.0 ppm Zn, 5 % HNO_3(by volume).
Solution E—5 ppm Cu, 2.5 ppm Zn, 5 % HNO_3(by volume).

14.3.3 *Reference Solution*—The reference solution used should be 5 % (by volume) nitric acid in distilled water.

14.3.4 *Chloroform*, technical grade.

14.3.5 *Toluene*, technical grade.

14.3.6 *Nitric Acid*, reagent grade, 69 to 71 % by weight.

14.4 *Number of Specimens*—Take one specimen per subunit

in the laboratory sample.

14.5 Hazards

14.5.1 Refer to the manufacturer's material safety data sheet (MSDS) for information on handling, use, storage, and disposal of chemicals used in this standard.

14.5.2 Precaution- In addition to other precautions, safety precautions should be followed when using any of the listed reagents. The reagents should be used only with adequate ventilation (in a hood) and with eye protection. Personnel should be familiar with current emergency first aid procedures for each reagent and should obtain medical attention immediately upon accidental contact.

14.5.3 Warning- Chloroform acts as a narcotic and anesthetic at high concentrations, and is toxic by ingestion.

14.5.4 Warning-Toluene is a local irritant, may be narcotic in high concentration, and is harmful or fatal if swallowed.

14.5.5 Warning- Nitric acid is corrosive and may cause sever burns of the skin eyes. the vapor is irritating to the mucous membranes.

14.6 *Procedure*:

14.6.1 Cut a length of cord to yield a specimen mass between 0.2 and 0.4 g without wrap wire.

14.6.2 Cut specimens into lengths of approximately 30-mm, untwist, and place individual filaments in a suitable test tube. If wrap wire is present, discard and do not include in the analysis. Rinse specimen with a 50:50 mixture of chloroform and toluene. Drain and dry for 30 min in a vented oven at 100 to 105°C. Remove and place in a desiccator and cool to room temperature.

14.6.3 Weigh the specimen to the nearest 0.1 mg and place in a dry 200-mL volumetric flask. Strip coating by covering wires with 5 mL of nitric acid and magnet stir for 30 s. Draw and hold the specimen in the neck of the flask using a magnet, rinse with 5 mL of nitric acid. While retaining the specimen in the neck of the flask with a magnet, rinse the specimen several times with distilled water, then carefully remove the specimen using the magnet.

14.6.4 Dilute to volume with distilled water and mix.

14.6.5 Analyze this solution and applicable calibration solutions in accordance with the specific flame atomic absorption spectrophotometer manual and Practice E 663.

14.7 *Calculation*:

14.7.1 Calculate the copper content to the nearest 0.01 g of copper/kg of cord, using Eq 7:

$$\text{Copper in brass, \%} = 100 \times \text{ppm Cu}/(\text{ppm Cu} + \text{ppm Zn}) \quad (7)$$

14.7.1.1 Calculate the copper content for the lot.

14.7.2 Calculate the zinc content to the nearest 0.01 g of zinc/kg of cord, using Eq 8:

$$\text{Zinc in brass, \%} = 100 \times \text{ppm Zn}/(\text{ppm Cu} + \text{ppm Zn}) \quad (8)$$

14.7.2.1 Calculate the zinc content for the lot.

14.7.3 Calculate the mass of brass (coating weight) to the nearest 0.01 g/kg using Eq 9:

$$\text{Mass of brass, g/kg} = 0.2 \times (\text{ppm Cu} + \text{ppm Zn})/W \quad (9)$$

where:

W = specimen mass, g.

14.7.4 Calculate the brass thickness to the nearest 10 nm, using Eq 10:

$$\text{Thickness, mm} = 0.234 \times F \times \text{mass of brass} \times 100 \quad (10)$$

where:

F = diameter of filament, mm.

14.7.4.1 Calculate the brass thickness for the lot.

14.8 *Report*:

14.8.1 Report that the specimens were tested as directed in Section 14 of Test Methods D 2969. Describe the material sampled and the method of sampling used.

14.8.2 Report the following information:

14.8.2.1 Copper content for each laboratory sampling unit and for the lot.

14.8.2.2 Zinc content for each laboratory sampling unit and for the lot.

14.8.2.3 Mass of brass (coating weight) for each laboratory sampling unit and for the lot.

14.8.2.4 Thickness of brass for each laboratory sampling unit and for the lot.

14.9 *Precision and Bias*:

14.9.1 *Summary*—In comparing two averages of four observations, the differences between averages should not exceed the following amounts 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 specimens drawn randomly from the same sample of material:

Mass of brass	0.27 g/kg
Copper in brass	1.55 %

Larger differences are likely to occur under all other circumstances. The procedures for determining mass of brass and copper in brass have no known bias and are considered referee methods.

14.9.2 *Interlaboratory Test Data*[10]—An interlaboratory test was run in 1981 in which randomly drawn specimens of nine materials were tested in twenty-two laboratories in accordance with Practice D 2904. Each laboratory used two operators, each of whom tested two specimens of each material. In analyzing the data, the results from two laboratories were discarded because there was evidence that the procedure was improperly applied in those two laboratories due to inexperienced operators. The components of variance, expressed as standard deviations, are listed in Table 1.

14.9.2.1 The materials used in both the 1981 and the 1983 interlaboratory tests for brass analysis were $(1 \times 4) + (6 \times 4) \times 0.175 + 1 \times 0.15$ construction with the nominal properties of:

Copper Percentages in Coating—63, 67.5, 72

Mass of Brass (g/kg)—3.66, 5.12, 6.59 in all possible combinations

14.9.3 *Precision*—For the components of variance reported in Table 1, two averages should be considered significantly different at the 95 % probability level if the difference equals or exceeds the critical differences listed in Table 2 (see Note 5).

14.9.4 *Bias*—The procedures in Test Methods D 2969 for

[10] Supporting data are available from ASTM Headquarters, 100 Barr Harbor Drive, West Conshohocken, PA 19428. Request RR: D13-1064.

determining mass of brass and copper in brass on filaments, strands, cords, and fabric made from steel cords have not been checked against accepted reference materials but contain no known bias. These procedures are accepted as referee methods.

15. Brass Coating Analysis by X-Ray Emission or Fluorescence Spectroscopy (XRF)

15.1 *Scope*—Steel cord specimens 38 mm long are placed side by side on a holder and irradiated with X-rays. The resultant emissions are used to calculate the mass of brass and the copper content in the brass.

15.2 *Significance and Use*—The adhesion properties of steel cord depend in part on the mass of brass and the brass composition.

15.3 *Apparatus*:

15.3.1 *X-ray Spectrometer*, with fine slit (see Note 11).

15.3.2 *Calibration Standards*—Brass standards from the National Institute for Standards and Technology (NIST)[11] should be used to confirm proper apparatus operation based on procedures specified for the particular spectrometer being used. Recommended standards taken and the percent copper in brass is calculated to the nearest 0.01 % using Eq 11:

$$\text{Cu, \%} = (\text{CuK}_\alpha \text{ Intensity} \times 100)/(\text{CuK}_\alpha + \text{ZnK}_\alpha \text{ Intensities}) \quad (11)$$

where:

CuK_α = number of intensity counts at the CuK_α wavelength, and

ZnK_α = number of intensity counts at the ZnK_α wavelength.

This value must fall within ±0.5 % of the nominal copper value for the NBS standard.

NOTE 11—**Precaution:** In addition to other precautions, observe occupational health and safety standards[12] on ionizing radiation at all X-ray emission spectrometer installations. X-ray equipment should be used only under the guidance and supervision of a responsible, qualified person.

15.3.3 Suitable monitoring devices, either film badges or dosimeters, shall be worn by all personnel using the equipment. Periodic radiation surveys of the equipment for leaks and excessive scattered radiation shall be made by a qualified person using an ionization chamber detector in accordance with local, state, and national radiation standards. The personal film badge survey record, the radiation survey record, and a maintenance record shall be available upon request.

15.3.4 Special precautions for the operator shall be posted.

15.3.5 X-ray caution signs shall be posted near the X-ray equipment and at all entrances to the radiation area.

15.3.6 Fail-safe "X-Ray On" warning lights shall be used in the immediate area of the equipment.

15.4 *Number of Specimens*—Unless otherwise agreed upon, take one specimen per subunit in the laboratory sample.

15.5 *Procedure*:

15.5.1 *Calibration Curves*—Due to the effect of specimen geometry, separate calibration curves must be established for each steel cord construction to be analyzed. The brass composition and mass of brass of the specimens used to establish the calibration curves must encompass the expected values of the material to be analyzed. Equipment operating conditions during establishment of calibration curves must be the same as those to be utilized during subsequent analysis.

15.5.1.1 Using a series of specimens drawn from samples whose brass composition and mass of brass have been previously determined in accordance with Section 14, the copper to brass ratio and the brass to iron ratio as defined by Eq 12 and Eq 13 are plotted versus the previously determined copper content and mass of brass values for those same samples.

$$R_1 = (\text{CuK}_\alpha \text{ intensity})/(\text{CuK}_\alpha \text{ intensity} + \text{ZnK}_\alpha \text{ intensity}) \quad (12)$$

$$R_2 = (\text{CuK}_\alpha \text{ intensity} + \text{ZnK}_\alpha \text{ intensity})/(\text{FeK}_\beta \text{ intensity}) \quad (13)$$

where:

FeK_β = number of intensity counts at the FeK_β wavelength,

R_1 = ratio to be plotted versus the known percentage copper, and

R_2 = ratio to be plotted versus the known mass of brass.

Data collection must be in accordance with the recommended operating procedure of the spectrometer. Analyze duplicate specimens. If results are not within 0.4 % for copper and 0.1 g/kg for mass of brass, analyze a third specimen.

15.5.2 Cut 40 specimens each 38 mm long. Place specimens side by side in a coplanar configuration and tape both ends. These are now ready for analysis in accordance with the operating procedures for the spectrometer.

15.5.3 Analyze the specimens in accordance with the operating procedures for the spectrometer. Record intensity values for CuK_α, ZnK_α, and FeK_β.

15.6 *Calculations*:

15.6.1 Compute ratios as directed in 14.7 and determine the percent copper and mass of brass from the calibration curves established in accordance with 14.7.

15.6.2 Determine zinc content by subtracting percent copper from 100 %.

15.6.3 Calculate the brass coating thickness to the nearest 10 nm using Eq 14:

$$\text{Thickness, mm} = 0.234 \times F \times \text{mass of brass} \times 1000 \quad (14)$$

where:

F = diameter of filament, mm.

15.7 *Report*:

15.7.1 Report that the specimens were tested as directed in Section 15 of Test Methods D 2969. Describe the material sampled and the method of sampling used.

15.7.2 Report the following information:

15.7.2.1 Mass of brass (coating weight) for each laboratory sampling unit and for the lot.

15.7.2.2 Copper content for each laboratory sampling unit and for the lot.

15.7.2.3 Zinc content for each laboratory sampling unit and for the lot.

[11] Calibration standards may be obtained through the National Institute for Standards and Technology, U.S. Department of Commerce, Washington, DC 20234.

[12] *Federal Register*, Vol 36, No. 105. May 29, 1971, Sec 1910.96 or of latest issue of Subpart G; Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20025; National Bureau of Standards Handbook 111, ANSI N43.2-1971.

15.7.2.4 Thickness of brass for each laboratory sampling unit and for the lot.

15.8 *Precision and Bias*:

15.8.1 *Summary*—In comparing two averages of four observations the difference between averages should not exceed the following amounts 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 specimens drawn from the same sample:

Mass of brass	0.14 g/kg
Copper in brass	0.43 %

Larger differences are likely to occur under all other circumstances. The procedures for determining mass of brass and copper in brass as directed in Section 15 have no known bias.

15.8.2 *Interlaboratory Test Data*[13]—An interlaboratory test was run in 1983 in which randomly drawn samples of nine materials were tested in six laboratories in accordance with Practice D 2904. Each laboratory used two operators, each of whom tested two specimens of each material on different days. The components of variance expressed as standard deviations are listed in Table 1. The samples used in this interlaboratory test were drawn from the same group of samples used in the interlaboratory test discussed in 14.9.2 (see 14.9.2.1).

15.8.3 *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 (see Note 5).

15.8.4 *Bias*—The procedures in Section 15, Test Methods D 2969, for determining the mass of brass and the copper in brass on filaments, strands, cords, and fabrics made from steel have not been checked against accepted reference materials but contain no known bias. The procedure in Section 15 is not an accepted referee method.

16. Static Adhesion of Filaments, Strands, and Cords to Elastomers

16.1 Determine the adhesion of strands and cords to elastomers as directed in Test Method D 2229.

16.2 Determine the adhesion of filaments to elastomers as directed in Test Methods D 1871.

16.3 Determine the peel adhesion of cords or filaments as directed in Test Method D 4393.

17. Keywords

17.1 adhesion; brass coating; direction of lay; elongation; linear density; steel cord; strength, breaking; thickness; visual appearance

[13] Supporting data are available from ASTM Headquarters. Request RR: D13-1071.

ANNEX

(Mandatory Information)

A1. NOMENCLATURE SYSTEM FOR STEEL CORDS

A1.1 *Format*:

$$(S \times F) \times D + (S \times F) \times D + (S \times F) \times D + F \times D$$

A1.2 *Sections*—The sections of the format are listed in order of sequence of manufacture of the cord structure:

(innermost) (intermediate) (outermost) (wrap)

A1.3 *Components*:

S = number of strands,
F = number of filaments, and
D = nominal diameter of filaments, 0.001 mm.

A1.4 *General Rules*:

A1.4.1 Start with the innermost part and proceed outward.

A1.4.2 Separate each part by a plus (+) sign.

A1.4.3 Parentheses are used for clarity to differentiate a part that consists of more than one component. Filaments and strands enclosed in parentheses form a part, the center of which is not the center of the cord.

A1.4.4 When S or F = 1, omit S or F in the format A1.1 to obtain short form of nomenclature.

A1.4.5 If the diameter is the same for two or more parts, omit the diameter except for the last part before the change. The filament diameter of the last part before the spiral wrap and the filament diameter of the spiral wrap should always be written out.

A1.4.6 The lay and direction of lay may also be indicated with the construction as in the following example:

(1 × 3)	+	(6 × 4)	×	0.20	+	1 × 0.15	construction
10	/	10	/	14	/	3.5 /	
S	/	*S*	/	*Z*	/	*S* /	
core	/	outer strand	/	cord	/	spiral wrap	

More commonly identified as 7 × 4 × 0.20 + 1 × 0.15.

A1.5 *Special Constructions*—There may be special cord constructions that are nonsymmetric or that contain nonhelicoidal elements and cannot be adequately described under this nomenclature system. In these instances a clear understanding must be established between the producer and user as to the geometry of each such cord construction.

NOTE A1.1—It is difficult to measure the diameter of the filament with a micrometer after it has been combined with other filaments to form a strand or cord due to undulations in the wire. The diameter of the filament may be measured using optical instruments or blade anvils in a micrometer. For identification of filaments in the nomenclature system, the nominal diameter of the filaments before forming as given by the supplier is used.

NOTE A1.2—The nomenclature system describes the steel cord construction as manufactured by the producer. Various abbreviated methods have been derived from this system. All of these can be expressed in the above format.

APPENDIX

(Nonmandatory Information)

X1. SUGGESTED DATA FORM FOR REPORTING TEST RESULTS

X1.1 To facilitate the reporting of test results for a lot of steel tire cord, especially when the data is to be transmitted electronically or recorded on tapes or diskettes designed to be read electronically, the data form in Table X1.1 is recommended.

X1.2 The key element in the suggested form is that neither the characteristic nor the lot identification associated with each line sequence number be violated. As an example, if data on linear density is required, then it must be preceded by the line sequence number 10. If data on a certain characteristic is not required, then no adjustment should be made in the line sequence numbers for the subsequent characteristics; simply do not utilize the line sequence number shown for the characteristic for which no data is required.

X1.3 It is suggested that line sequence numbers of 30 or greater be used for characteristics that are not the subject of an ASTM standard. This procedure will facilitate the possible future expansion of ASTM standards.

X1.4 Addition, deletion, or reordering of columns within the form should be only by mutual agreement between the purchaser and the supplier.

X1.5 Restrictions on the values of entries within a row, between rows, and between groups of rows should be by mutual agreement between the purchaser and the supplier.

TABLE X1.1 Data Form for Test Results from Lots of Steel Tire Cord[A]

Line Sequence No.	*Lot Identification*							
01	Supplier code: NNN					Supplier category: N		
02	Purchaser specification number: 'AAAAAAAAAAAAAAA'					Purchaser plant code: NN		
03	Date shipped: 'YYMMDD'	Purchase order No: 'AAAAAAAAAA'				Date tested: 'YYMMDD'		
04	Steelcord construction: 'AAAAA'	Supplier lot No: 'AAAAAAAA'				Brass analysis method: 'AAA'		
05	Type spool: 'AAAAAAA'	Number of spools: NNNN						
	Characteristic	Samples	Average	Standard Deviation	Minimum	Maximum	CPK	Limit
06	Cord thickness	NN	N.NNN	N.NNN	N.NNN	N.NNN	NN.NN	'A'
07	Breaking force:	NN	NNNNN.	NNNN.N	NNNNN.	NNNNN.	NN.NN	'A'
08	Adhesion force:	NN	NNNN.	NNNN.N	NNNN.	NNNN.	NN.NN	'A'
09	Adhesion coverage:	NN	NNN.N	NN.N	NNN	NNN	NN.NN	'A'
10	Linear density	NN	NNNNN.	NNNN.N	NNNNN.	NNNNN.	NN.NN	'A'
11	Percent copper:	NN	NN.N	NN.N	NN.N	NN.N	NN.NN	'A'
12	Plating mass:	NN	N.NN	N.NN	N.NN	N.NN	NN.NN	'A'
13	Residual torsions:	NNNN	NN.NN	NN.NN	NN.NN	NN.NN	NN.NN	'A'
14	Elongation at break:	NN	NN.NN	NN.NN	NN.NN	NN.NN	NN.NN	'A'

Residual Torsions:	<– 3.0	−3.0	−2.5	−2.0	−1.5	−1.0	−0.5	0.0	0.5	1.0	1.5	2.0	2.5	3.0	>3.0
15 Histogram:	NNNN	NNNN	NNNN	NNNN	NNNN	NNNN	NNNN	NNNN	NNNN	NNNN	NNNN	NNNN	NNNN	NNNN	NNNN

16	Flare: 'AA'		Straightness: 'AA'					
30	Low load elongation:	NN	NN.NN	NN.NN	NN.NN	NN.NN	NN.NN	'A'
31	Elasticity:	NN	NN.N	NN.N	NN	NN	NN.NN	'A'
32	Spare	N	N	N	N	N	N	—
33	Spare	N	N	N	N	N	N	—
34	Spare	N	N	N	N	N	N	—

Symbol Dictionary:
A – alphanumeric character
N — numeric character
YYMMDD — international date format

[A] All test methods and reporting units must be in accordance with purchaser specification.