Standard Test Method for Tear Strength of Conventional Vulcanized Rubber and Thermoplastic Elastomers[1]

This standard is issued under the fixed designation D 624; 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.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This test method describes procedures for measuring a property of conventional vulcanized thermoset rubbers and thermoplastic elastomers called tear strength.

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

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 412 Test Methods for Vulcanized Rubber and Thermoplastic Rubbers and Thermoplastic Elastomers—Tension[2]

D 1349 Practice for Rubber—Standard Temperatures for Testing[2]

D 3182 Practice for Rubber—Materials, Equipment, and Procedures for Mixing Standard Compounds and Preparing Standard Vulcanized Sheets[2]

D 3183 Practice for Rubber—Preparation of Pieces for Test Purposes from Products[2]

D 3767 Practice for Rubber—Measurement of Dimensions[2]

D 4483 Practice for Determining Precision for Test Method Standards in the Rubber and Carbon Black Industries[2]

2.2 *ISO Standard:*

ISO/34 Rubber, Vulcanized—Determination of Tear Strength (Trouser, Angle, and Crescent Tear Pieces)[3]

3. Terminology

3.1 *Definitions:*

3.1.1 *thermoplastic elastometer (TPE)*—a diverse family of rubber-like materials that, unlike conventional rubbers, can be processed and recycled like thermoplastic materials.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *complete trace*—the section of the graphical plot of force versus jaw separation distance between the point at which the first peak occurs and the point at which the test is terminated.

3.2.2 *Die A (nicked crescent) tear strength*— the maximum force required to rupture the specified test piece, divided by the thickness of the test piece. The force acts in a direction substantially along the length of the test piece.

3.2.3 *Die B (nicked tab end) tear strength*—the maximum force required to cause a nick or cut in the specified crescent-shaped test piece with tab ends to grow by tearing of the rubber, divided by the thickness of the test piece.

3.2.4 *Die C tear strength*—the maximum force required to cause a rupture by tearing action of the right angle test specimen; the force divided by the thickness of the specimen. The force acts parallel to the tab ends of the specimen or at 45° to the 90° center angle.

3.2.5 *Die T or trouser tear strength*—the mean or median force, calculated in accordance with the Annex (see Annex, Methods A & B) required to propagate a cut or tear in a specified trouser-shaped test specimen, divided by the tear thickness of the test specimen, the grip force acting in a direction parallel to the two legs.

3.2.6 *Discussion*—Other information can be extracted from the tear curve using the methods described in Annex A1.

3.2.7 *median*—if n measured values are arranged in increasing order of magnitude and numbered 1 to n, the median of these n values is the (n + 1)/25th value, if n is odd. If n is even, the median lies between the (n/2)th and (n/2 + 1)th values and is not defined uniquely.

3.2.8 *Discussion*—Unless otherwise specified, it may be taken to be the arithmetic mean of these two measured values.

3.2.9 *peak*—a point at which the slope of a trace changes from positive to negative.

3.2.10 *range*—the difference between the greatest and the smallest observed test values.

3.2.11 *tear strength*—the force per unit thickness to (*1*) initiate a rupture or tear of the material, or (*2*) to propagate a tear in circumstances where continued application of a force on a suitable test specimen results in a quasi-equilibrium tearing action.

3.2.12 *valley*—a point at which the slope of a trace changes

[1] This test method is under the jurisdiction of ASTM Committee D-11 on Rubber and is the direct responsibility of Subcommittee D11.10 on Physical Testing.

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[2] *Annual Book of ASTM Standards*, Vol 09.01.

[3] Available from American National Standards Institute, 11 West 42nd St., 13th Floor, New York, NY 10036.

from negative to positive.

4. Summary of Test Method

4.1 This test method includes test procedures using specimen shapes as follows:

4.2 A razor-nicked crescent specimen (Die A),

4.3 A razor-nicked crescent specimen with tab ends (Die B),

4.4 An unnicked 90° angle specimen (Die C), and

4.5 A specimen described as a trouser tear piece, which is designated as Die T.

4.6 No correlation of results, one specimen versus another, obtained with any of these specimens is implied as an inherent characteristic of this test method.

4.7 Also included in this test method is Appendix X1, which describes a modified trouser tear specimen test designated as a constrained path tear test. Refer to Appendix X1 for more details on this type of tear test which shows substantial promise for measuring a realistic tear strength that has been shown to be correlated with certain rubber product performance.

5. Significance and Use

5.1 Conventional vulcanized rubbers and thermoplastic elastomers often fail in service applications due to the generation and propagation of a special type of rupture called a tear. This test method measures the resistance to tearing action.

5.2 Since tear strength may be affected to a large degree by stress-induced anisotropy (mechanical fibering) of the rubber as well as by stress distribution, strain rate, and size of specimen, the results obtained in a tear strength test can only be regarded as a measure of the strength under the conditions of that particular test and not necessarily as having any direct relation to service value. The significance of tear testing must be determined on an individual application or product performance basis.

5.3 Injection molded thermoplastic elastomers are known to be anisotropic in properties. The tear strength measured in different directions can differ markedly.

6. General Principles

6.1 The test consists of measuring the force required to completely rupture or tear the specified test piece, as a continuation of the cut or nick initially produced in the test piece or, in the case of Die C, completely across the width of the test piece.

6.1.1 The tearing force is applied by means of a tensile testing machine, operated without interruption at a constant rate of cross-head traverse until the test piece is completely torn. For Die A, B, and C samples, the maximum force achieved is used to calculate the tear strength. For Die T, the mean or median force is most commonly used but other ways of interpreting the data are given in Annex A1.

7. Apparatus

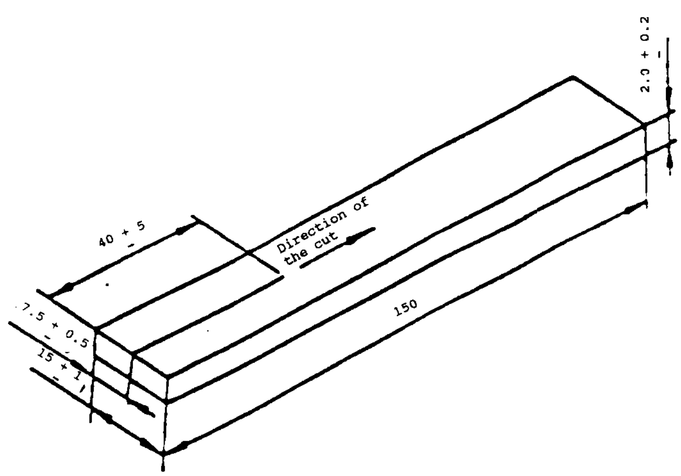
7.1 *Testing Machine*— The testing machine shall, in general, conform to the requirements as specified in Test Methods D 412. It shall be capable of registering the applied forces within 2 % of the total force range or capacity during the test while maintaining the specified constant rate of separation of the jaws of 50 ± 5 mm/min for the trouser test piece Die T and 500± 50 mm/min for Die A, B, or C pieces. A low inertia machine having autographic recording of force is essential when using the trouser test, Die T.

NOTE 1—Inertia (pendulum) type dynamometers are apt to give results that differ one from another because of frictional and inertial effects. A low inertia (electronic or optical transducer) type dynamometer gives results that are free from these effects and is therefore to be preferred.

7.2 The test may be conducted at elevated temperatures using equipment specified in Test Methods D 412.

7.3 *Grips*—The machine shall be provided with a type of grip, for example air-actuated grip, that tightens automatically as the tension increases and exerts a uniform pressure across the widened end of the test piece. Each grip shall incorporate a means for positioning so that the test specimens are inserted symmetrically and in axial alignment with the direction of the pull. The depth of insertion shall be such that the test specimen is adequately gripped, within the parallel portion, when testing Die A, B, or C test pieces. Trouser test pieces shall be inserted in the grip in accordance with Fig. 1.

7.4 *Specimen Cutting Dies*—The specimens for tear resistance tests shall be cut out with one of the steel dies conforming to the dimensions shown in Fig. 2, the cutting edges of which shall be kept sharp and free of all nicks to avoid leaving ragged edges on the specimens. It is important that the



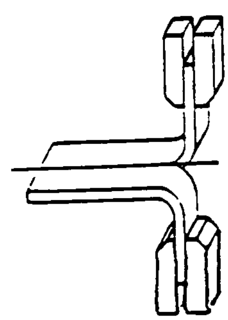
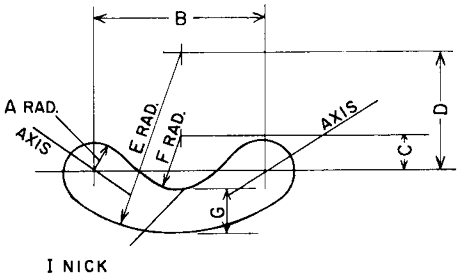


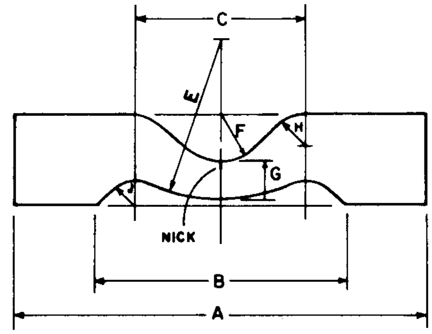
FIG. 1 Trouser Tear Test Specimen



DIE A

Dimension	Millimetres		Inches	
	Value	Tolerance	Value	Tolerance
A	7.6	±0.05	0.3	±0.002
B	42	±0.50	1.65	±0.02
C	8.6	±0.05	0.34	±0.002
D	29	±0.05	1.14	±0.002
E	43.2	±0.05	1.7	±0.002
F	12.7	±0.05	0.5	±0.002
G	10.2	±0.05	0.4	±0.002
Nick[A]	0.50	±0.05	0.02	±0.002

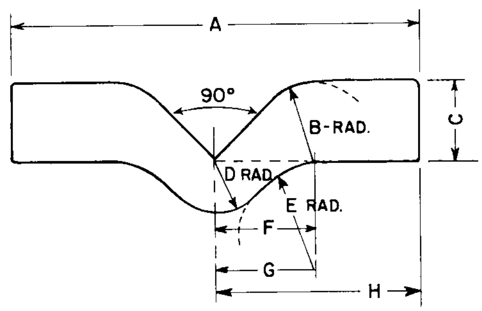
[A] Nick to be cut in specimen with a razor.



Die B (ISO/ 34 Configuration)

Dimension	Millimetres		Inches	
	Value	Tolerance	Value	Tolerance
A	110	±0.50	4.3	±0.02
B	68	±0.50	2.7	±0.02
C	45	±0.05	1.8	±0.002
D	25	±0.05	1	±0.002
E	43	±0.05	1.7	±0.002
F	12.5	±0.05	0.5	±0.002
G	10.2	±0.05	0.4	±0.002
H	9	±0.05	0.375	±0.002
J	7.5	±0.05	0.3	±0.002
Nick[A]	0.5	±0.05	0.02	±0.002

[A] Nick to be cut in specimen with a razor.



DIE C

Dimension	Millimetres		Inches	
	Value	Tolerance	Value	Tolerance
A	102	±0.50	4.0	±0.02
B	19	±0.05	0.75	±0.002
C	19	±0.05	0.75	±0.002
D	12.7	±0.05	0.5	±0.002
E	25	±0.05	1.0	±0.002
F	27	±0.05	1.061	±0.002
G	28	±0.05	1.118	±0.002
H	51	±0.25	2.0	±0.01

FIG. 2 Dies for Tear Test Specimens

apex of the 90° angle due (Die C) be sharpened to provide a sharp corner. Good cutting edges can be obtained by careful honing. Care shall be taken that the cut edges are perpendicular to the other surfaces of the specimen and have a minimum of concavity.

7.5 *Nick Cutter*:

7.5.1 A sharp razor blade or a sharp knife free of ragged edges shall be used for producing a cut or a nick in the Die A and B specimens. The trouser test piece shall be cut to a depth of 40 ± 5 mm in the direction indicated. (See Fig. 1.) It is important that the last 1 mm (approximately) of the cut is made with a razor blade or a sharp knife.

7.5.2 The essentials of a suitable apparatus for introducing the nick required for the nicked angle or crescent test piece are as follows:

7.5.2.1 Means shall be provided for clamping the test specimen firmly, especially in the region where the nick is to be introduced. The cutting tool, consisting of a razor blade or similar blade, shall be clamped in a plane perpendicular to the major axis of the test piece, and positioned so as to introduce the nick in the appropriate place. The blade clamping device shall prevent lateral movement and shall be fitted in guides to enable the blade to be fixed and the test piece arranged to move in an analogous manner. Means shall be provided for fine adjustment of the depth of the nick. The adjustment for the position of the blade holder or the clamped test piece, or both, shall be determined for each blade by cutting one or two preliminary nicks and measuring these with the aid of a microscope. The blade shall be wetted with water or soap solution prior to nicking.

7.5.3 The slit or nick shall be 0.50 ± 0.05 mm (0.020 ± 0.002 in.) in depth.

7.5.4 To check that the depth of the nick is within the specified limits, any suitable means may be used, for example, an optical projection apparatus. A convenient arrangement is a microscope giving at least 10× magnification fitted with travelling stage suitably illuminated. The eyepiece is fitted with a graticule or crosswire by which to record the travel of the stage and test piece through a distance equal to the depth of the nick. The travel of the stage is calibrated with a stage micrometer. Alternatively, a travelling microscopy may be used. The apparatus shall have an accuracy of measurement of 0.025 mm or better.

7.5.5 Die C and Die T test specimens are not nicked.

8. Preparation of Sample

8.1 Except as may be otherwise specified in this test method, the requirements of Practices D 3182 and D 3183 shall be complied with and are made a part of this test method for conventional vulanizer rubber.

8.2 Thermoplastic elastomer test specimens are prepared from injectioned molded plaques prepared in accordance with procedures described in the specification standard for said thermoplastic elastomers.

9. Test Specimens

9.1 The test specimens shall conform in shape according to Die T in Fig. 1 or to Die A, B, or C, as shown in Fig. 2.

NOTE 2—Conventional vulcanized rubber and thermoplastic elastomers often exhibit an anisotropic mechanical strength effect that influences their physical properties. The effect may produce a pronounced difference in physical properties.

9.2 The milling or grain direction of conventional rubber shall be clearly marked on materials to be tested. The usual practice is to test with the grain running the long way of the specimen. Die A, B, and C data so obtained shall be recorded as tear resistance across the grain, and it is assumed that, unless otherwise specified, all Die A, B, and C test specimens are to be prepared in this manner. However, Die T trouser tear samples are also prepared with the mill grain running the long way in the specimen which means the tear is occurring with the grain rather than across it. Where grain effects are significant and are to be evaluated, an additional set of test specimens shall be cut with the grain running across the specimen. Results so obtained shall be recorded as tear strength with the grain for Die A, B, and C and across the grain for Die T trouser tear.

NOTE 3—Die B has been modified slightly from that described in Method D 624 – 54 to conform to that specified in ISO/34. Dies conforming to previous Die B configuration may be used.

9.3 Thermoplastic elastomers shall be tested with the tear direction either parallel or perpendicular to the flow direction of molten material in the injection molded plaque from which the test specimens are die cut.

9.4 The thickness of the specimen shall be measured in three places across the width of the specimen, near its center, with a micrometer conforming to the description as specified in Practice D 3767 and the median measurement used in the calculations. One of the measurements shall be at the apex of the slit or the 90° angle, as applicable. The thickness of the test specimen should not fall outside the limits of 1.3 to 3.2 mm (0.05 to 0.13 in.). It may be necessary to determine the tear strength of finished goods that give specimens outside the above thickness limits. These results may not correlate with results obtained on pieces of standard thickness.

10. Number of Test Specimens

10.1 Three specimens per item shall be tested for tear strength. The value reported shall be the median of those observed. If any individual value deviates more than 20 % from this median, two additional specimens shall be tested, and the median of all five specimens shall be reported.

10.2 Tear testing is inherently a highly variable measurement since it has many characteristics of fatigue testing that is known to give widely dispersed test results, frequently with a non-normal distribution. For referee tear testing, the user of this test method is urged to test at least five specimens.

11. Time Interval Between Vulcanization and Testing

11.1 The minimum time period between vulcanization and testing shall be 16 h.

11.2 The maximum allowable time period between nicking and testing shall be 24 h.

12. Conditioning Period for Test Specimens

12.1 The test pieces of specimens shall be protected from light during the interval between vulcanization and testing.

12.2 The specimens shall be conditioned, after any preparation as necessary, at a standard laboratory temperature (see Practice D 1349) for at least 3 h before they are cut or nicked. The specimens may be nicked, measured and tested immediately but, if not tested immediately, they shall be kept at 23 ± 2°C or 27 ± 2°C, as the case may be, until tested. If the preparation involves buffing, the interval between buffing and testing shall not exceed 72 h. The cut or nick shall be made after any aging treatment has been carried out.

12.3 If the test is to be carried out at a temperature other than a standard laboratory (room) temperature, the test pieces shall be conditioned for a period sufficient to reach temperature equilibrium at the test temperature, immediately prior to testing. This period shall be kept as short as possible in order to avoid aging the rubber.

13. Test Temperature

13.1 Unless otherwise specified, the standard temperature for testing shall be 23 ± 2°C (73.4 ± 3.6°F). If the material is affected by moisture, the relative humidity shall be maintained at 50 ± 5 % and the specimen shall be conditioned for at least 24 h prior to testing. When testing at some other temperature is required, the temperature specified shall be one of those listed in Practice D 1349, and the report shall include a statement of the temperature at which the test was made and the length of time that the specimen was conditioned. Specimens shall be conditioned at least 3 h when the test temperature is 23± 2°C.

14. Test Procedure

14.1 After conditioning as described in Sections 11 and 12, immediately mount the test piece in the testing machine. Apply a steadily increasing traction force at a rate of separation of the grips of 500 ± 50 mm/min for Die A, B and C type specimens and 50 ± 5 mm/min for trouser test pieces until the test piece is completely ruptured. Record the maximum force for Die A, B and C test pieces. When using the trouser test specimen make a strip-chart or autographic recording of the force throughout the tearing process. (See Annex A1).

15. Expression of Results

15.1 The tear strength T_s is given, in kilonewtons per meter of thickness, by the formula:

$$T_s = \frac{F}{d} \tag{1}$$

where:

F = the maximum force, N, in case of Dies A, B and C, and when using Die T, the mean or median (see Annex A1) force obtained from the recorder or autographic trace, N, calculated in accordance with the annex, and

d = the thickness, of the test pieces, mm.

15.2 When anisotropic effects are evaluated, determine the median and the range of the values for each direction. Express the results to the nearest 0.1 kN/m.

15.3 Alternatively the tear strength may be expressed in lbf/in.

NOTE 4—To convert from lbf/inch to kN/m, multiply by 0.175.

16. Report

16.1 Report the following information:

16.1.1 Results calculated in accordance with Section 15, indicating which tear test specimen or die was used and a reference to this standard. In trouser tear strength testing, Method A or B should be specified,

16.1.2 All observed and recorded data on which the calculations are based,

16.1.3 Date of test and date of vulcanization of rubber, if known,

16.1.4 Test temperature,

16.1.5 Type of testing machine used, and

16.1.6 The depth of the nick when using Die A or Die B.

17. Precision and Bias [4]

17.1 This precision and bias section has been prepared in accordance with Practice D 4483. Refer to this practice for terminology and other statistical calculation details.

17.2 A Type 1 (interlaboratory) precision was evaluated in 1981 and another in 1988. Test repeatability and reproducibility are short term; a period of a few days separates replicate test results. A test result is the median value, as specified by this method, obtained on three determination(s) or measurement(s).

17.3 In the 1981 test program, one material (one rubber compound) was tested in four laboratories on two separate days. In the 1983 test program, two materials (rubbers) were tested in five laboratories on two separate days. For both programs tests were conducted for Dies B and C.

17.4 The results of the precision calculations for repeatability and reproducibility are given in Table 1 and Table 2.

17.5 The precision of this test method may be expressed in the format of the following statements which use an appropriate value of *r, R, (r)* or *(R)*, that is, that value to be used in decisions about test results (obtained with the test method). The appropriate value is that value of *r* or *R* associated with a mean level in the precision tables closest to the mean level under consideration at any given time, for any given material in routine testing operations.

17.6 *Repeatability*— The repeatability, *r*, of this test method has been established as the appropriate value tabulated in the precision tables. Two single test results, obtained under normal test procedures, that differ by more than this tabulated *r* (for any given level) must be considered as derived from different or non-identical sample populations.

17.7 *Reproducibility*— The reproducibility, *R*, of this test method has been established as the appropriate value tabulated in the precision tables. Two single test results obtained in two different laboratories, under normal test method procedures, that differ by more than the tabulated *R* (for any given level) must be considered to have come from different or non-identical sample populations.

17.8 Repeatability and reproducibility expressed as a percentage of the mean level, (*r*) and (*R*), have equivalent application statements as above for *r* and *R*. For the (*r*) and (*R*)statements, the difference in the two single test results is expressed as a percentage of the arithmetic mean of the two test results.

17.9 *Bias*—In test method terminology, bias is the difference between an average test value and the reference (or true) test property value. Reference values do not exist for this test method since the value (of the test property) is exclusively defined by the test method. Bias, therefore, cannot be determined.

17.10 For Dies B and C, repeatability, (*r*), is not good (10

TABLE 1 Type 1 Precision for Dies B and C (1981)[A]

Die	Average Value	Within Laboratories			Between Laboratories		
	(kN/m)	S_r	r	(r)	S_R	R	(R)
B	81.6	5.11	14.5	17.7	16.8	47.6	58.3
C	44.5	3.84	10.9	24.4	4.69	13.3	29.8

[A]

S_r = repeatability standard deviation.
r = repeatability = 2.83 × S_r.
(r) = relative repeatability, expressed as a percentage of the average value.
S_R = reproducibility standard deviation.
R = reproducibility = 2.83 × S_R.
(R) = relative reproducibility, expressed as a percentage of the average value.

[4] The full details and test results of the interlaboratory test program used for this precision section are contained in a Research Report RR:D11-1027 obtainable from ASTM headquarters.

TABLE 2 Type 1 Precision for Dies B and C (1983)[A]

Die	Material	Average Value	Within Laboratories			Between Laboratories		
		(kN/m)	S_r	r	(r)	S_R	R	(R)
B	(1) H14327	47.4	2.29	6.47	13.7	14.4	40.7	85.8
B	(2) R19526	85.1	5.50	15.6	18.3	25.0	70.8	83.2
C	(1) H14327	40.0	1.14	3.23	8.1	9.35	26.4	66.1
C	(2) R19526	49.7	2.83	8.02	16.1	8.58	24.3	48.8

[A]

S_r = repeatability standard deviation.
r = repeatability = 2.83 × S_r.
(r) = relative repeatability, expressed as a percentage of the average value.
S_R = reproducibility standard deviation.
R = reproducibility = 2.83 × S_R.
(R) = relative reproducibility, expressed as a percentage of the average value.

to 20 %) range, and reproducibility, (*R*), is poor (60 to 85 %) range.

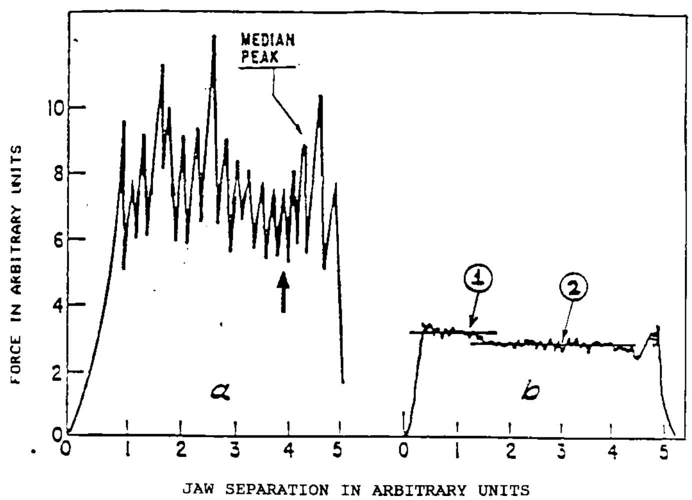
18. Keywords

18.1 tear resistance; tear strength

ANNEX

(Mandatory Information)

A1. TEAR CURVE ANALYSIS



NOTE 1—Curve a—peak or knotty tearCurve b—smooth tear

FIG. A1.1 Smooth Tear and Knotty Tear Curve Types

A1.1 General Discussion

A1.1.1 This annex describes techniques for interpreting tear strength curves created by plotting stress versus grip travel or displacement during testing. The similarities in curve shape for samples cut with Dies A, B, and C allow a simple interpretation while the saw-toothed curve generated during the trouser tear test can be interpreted in several different ways.

A1.2 Curve Shapes

A1.2.1 The simplistic tear curves generated when pulling samples cut from Dies A, B, and C are single-event shapes with one maximum force peak at which catastrophic failure of the specimen occurs.

A1.2.2 There are two primary types of saw-toothed curves which are illustrated in Fig. A1.1. Curve *a* illustrates a characteristic tear commonly called "knotty tear" where the word "knotty" designates a large magnitude transient increase in tearing force followed by a precipitous decrease, and the "increase-decrease" process repeats in cyclic fashion. Each increasing force stage eventually produces a rapid tear or rupture which relieves concentrated stress and increases torn length. Just as the maximum force reached before tearing is a measure of tear strength, the level to which the force decreases before tear ceases also indicates important tear properties of the compound.

A1.2.3 Curve *b* illustrates a typical "smooth tear" curve with minimal tear force amplitudes between the force at which tear initiates and the force at which tear ceases.

A1.3 Method A—Curve Analysis

A1.3.1 *Terms for Curve Analysis*—The terms used for curve analysis are defined in Section 3.

A1.3.2 *Procedure for Die A, B, and C Type Tear Curves*—The recorded plot of stress versus displacement for samples cut with Dies A, B, and C shows a sharply positive slope until catastrophic failure occurs, at which point the trace slope turns sharply negative. This produces a peak or maximum force value from which the tear strength is calculated.

A1.3.3 *Procedure for Die T (Trouser Tear) Type Tear Curves*—The "max-min" stress/displacement curve produced during the Die T trouser tear test can be interpreted in four primary ways to yield different information about the tearing process.

A1.3.3.1 *Peak Only Analysis*:

(1) This method examines only the peak forces generated during the tearing process. The value generated defines the maximum stress concentration that the compound will bear before catastrophic failure occurs.

(2) The sum of the forces (at each peak) can be divided by the number of peaks to define a mean peak value.

(3) In establishing the repetitive pattern of transient tearing that creates the max-min curve, it is not uncommon to have the initial or terminal peaks, or both, be inconsistent in magnitude with those in the center of the curve. Such peaks can be abnormally low or high depending on the physical properties of the compound and how quickly the transient tear pattern is established or ended. Correction is made to eliminate these values in determining the mean by comparing their magnitude to that of the raw mean and discarding all values that deviate from the raw mean by 20 % or more. What results then is a mean of the significant peak data points.

A1.3.3.2 *Valley Only Analysis*:

(1) This method examines only the forces at the valley positions on the saw-toothed curve as a measure of the force to which the stress concentration must be relaxed for tearing to cease.

(2) As in the mean in the peak only procedure, initial and terminal valley force values are compared to the raw mean calculated by summing the force values at each valley and dividing by the number of data points. Initial or terminal values greater than or equal to 20 % of this raw mean are discarded and the mean is recalculated.

A1.3.3.3 *Mean Force Analysis*:

(1) The arithmetic mean of the corrected peak only force value and the corrected valley only force value will yield a mean force value. This should be considered as an average tear force value since it gives equal consideration to peak and valley extremes. Be aware that this value does not indicate the magnitude of the difference between peak and valley forces but only represents the mean force. It is possible for two tear curves to show the same mean force when one has a large magnitude of difference between the peak and valley forces while the other has a small magnitude of difference.

(2) The procedure for Method A analysis, which is the most concise, is to report the mean force value with a plus or minus value determined by averaging the greatest four to six peak force values and the lowest four to six valley force values to define the magnitude of variation there is from the mean.

A1.3.3.4 *Total Work Analysis*—The total work put into the sample to achieve the tear can be obtained by measuring the area under the force-extension curve. This area can be measured electronically by certain equipment with integration capability or it can be measured manually by the use of a planimeter. This parameter will correlate with the mean force since it gives full consideration to both peak and valley extremes although it will not define the magnitude of variation from the mean.

A1.4 Method B—Curve Analysis

A1.4.1 The terms used for Method B are defined in Section 3.

A1.4.2 *Procedure for* a *Type Curves (Knotty Tear):*

A1.4.2.1 Count the number of peaks. Use 3.2.7 as a definition of the median peak force value. To obtain this median value, locate, with a horizontal line, the lowest or No. 1 peak force value. Move upward from this line on the force scale, the required number of peak force values to arrive at the median. Scale from the force axis this value. In Fig. A1.1, the lowest (No. 1) peak is indicated by the boldface arrow. The median peak is indicated as assessed from the lowest No. 1 value.

A1.4.3 *Procedure for* b *Type Curves (Smooth Tear):*

A1.4.3.1 Smooth type tear curves often consist of a series of tear propagation or torn length sequences each at essentially constant tearing force. In Fig. A1.1, Curve *b* shows two such sequences (1) and (2), with (2) approximately twice the length of (1). The tear strength should be calculated on a weighted average force basis.

A1.4.3.2 A general formula for weighted average tear force is:

$$\text{Tear Force (Weighted Average)} = \frac{n_o(TF_1) + N_2(TF_2) + \cdots N_i(TF_i)}{\Sigma(n_i)} \tag{A1.1}$$

where:

n_o = smallest observable segment (chart paper distance) for a constant tear force segment,

N_2 = $\frac{n_2}{n_o}$ = the weighting factor for constant tear force (TF) segment TF_2, with n_2 as the actual segment distance for TF_2, and

$\Sigma(n_i)$ = sum of all n_o values or total torn length or chart paper distance measured in n_o units.

A1.4.3.3 Use this weighted average tear force in Eq 1 (see 15.1).

A1.4.3.4 A median force is specified for Annex A1, curve analysis Method B. The median force (for tear strength calculation) is selected for two reasons: (*1*) it is much easier to obtain than an average, and (*2*) it does not give undue weight to abnormally large or small peak forces.

APPENDIX

(Nonmandatory Information)

X1. DESCRIPTION OF A CONSTRAINED PATH (CP) TEAR TEST SPECIMEN

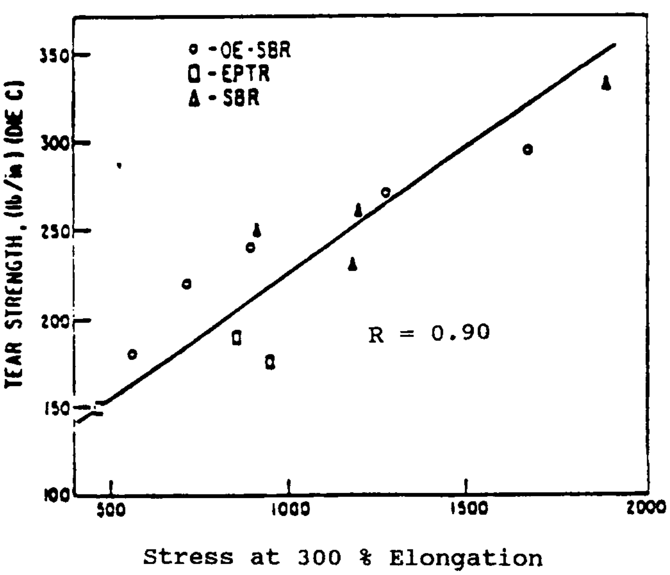
X1.1 Background

X1.1.1 To characterize rubbers adequately, a knowledge of their rupture properties is essential. Tear strength is important in the performance of many rubber products.

X1.1.2 One reason for the lack of discrimination in many current tear tests is a direct influence of compound modulus on measured tear strength. Fig. X1.1 is a plot of D624 Die C tear strength as a function of modulus (300 %) for data taken from the literature. This shows tear strength to be strongly correlated with modulus (correlation coefficient of 0.90). Thus both modulus and tear strength are being measured in unknown proportions. Theoretical calculations, show that the tear rupture force of Die C specimen measurements is approximately equal to the square root of the tangent modulus-tear strength product.

X1.1.3 It should not be inferred that modulus will have no effect on tear strength; however, the influence of modulus should be allowed to operate in the immediate tearing zone and not in regions of the test specimen remote from the locus of tear. In short, a tear test specimen should not be an ill-shaped modulus (tensile) test specimen.

X1.1.4 Rivlin, Thomas, et al. developed tear tests based on theoretical analysis of crack growth behavior. For flat sheet test specimens they defined a tearing energy or strength *T*, that is independent of the geometry of the test specimen provided the stored energy density of the specimen could be measured. Three types of test specimens were used: the strip or tensile specimen, the pure shear specimen and the trousers tear specimen. The relation for the tearing energy with the trouser specimen is:



NOTE 1—Data taken from literature

FIG. X1.1 Plot of ASTM Die C Tear Strength as a Function of Stress at 300 % Elongation

$$T = 2\lambda F/t - wE \quad \text{(X1.1)}$$

where:

T = tear strength in force/unit thickness (per unit length torn),
λ = extension ratio in legs of piece,
F = force applied to ends of test piece,
w = total width of specimen,
t = thickness, and
E = strain energy density in legs of piece.

For certain vulcanizates, if w is chosen large enough, the elongation of the legs is minimal ($\lambda \equiv 1$) and E is essentially zero. Then:

$$T = 2F/t \quad \text{(X1.2)}$$

X1.1.5 Many published reports imply that Eq X1.2 is satisfactory to use for routine tear measurements. However, two serious deficiencies are evident: For many compounds there is appreciable leg extension ($\lambda \neq 1$) even if w is chosen to be quite wide; and secondly knotty tear is frequently encountered and the tear deviates laterally and tears through one leg of the test specimen. Development of Eq X1.1 and Eq X1.2 is based on tear propagation down the central axis of the test piece.

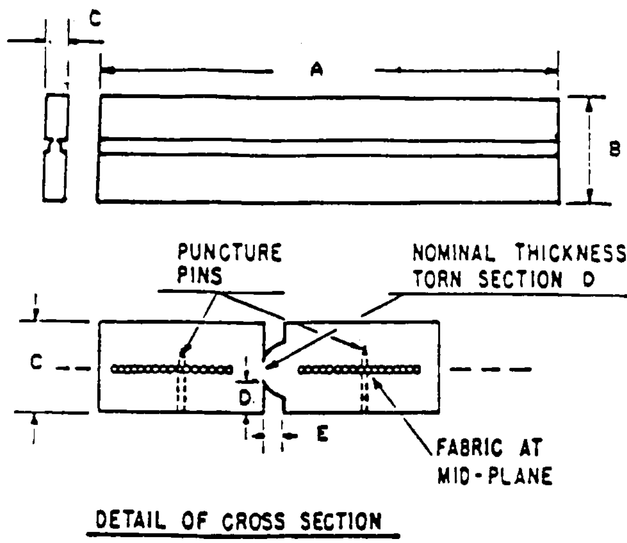
X1.1.6 Leg extension can be allowed for if strain energy density E is known, but a separate stress-strain curve is required. When one leg of the test specimen is torn through, further testing is precluded with that specimen. These deficiencies very often preclude any quick and meaningful routine tear strength measurement with the simple trousers test piece.

X1.1.7 In order to avoid these deficiencies, it is necessary to reinforce the legs to prevent their elongation and to provide a path of least resistance for tear propagation. Fig. X1.2 gives pertinent details and dimensions of a trousers tear specimen designated as a "constrained path" tear test specimen. It consists of a molded piece 125 mm long, 28.5 mm wide, with a nominal thickness of 5 mm. A longitudinal groove with the indicated cross-sectional geometry is molded into the piece. The legs are reinforced with fabric. The fabric is placed at the mid-plane of the piece to avoid an appreciable bending moment and to facilitate its reinforcing action during actual tear testing. The bottom of the mold contains two puncture pins; these puncture and hold the fabric as the mold is closed and prevent a lateral fabric shift.

X1.2 Test Procedure

X1.2.1 A 60-mm cut is made down the groove with a razor blade. This produces two legs, each of which is inserted into the jaws of a tensile testing machine. The final length of the specimen is torn at a selected testing speed and temperature.

X1.2.2 The thickness of the torn rubber is measured inone of two ways: (*1*) the average total thickness of the test piece along the groove is measured and from this is subtracted 3.60 mm, the combined height of the insert sections that form the



A	=	125 mm
B	=	28.5 mm
C	=	5.33 mm
D	=	1.77 mm
E	=	0.75 mm

FIG. X1.2 Schematic Diagram of "Constrained Path" Tear Test Specimen

groove; or (*2*) the torn surface is examined with a small binocular magnifier with a graduated reticle and the thickness measured. The latter method is more accurate but they agree to within about 5 %. For routine work the first method has been found to be satisfactory.

X1.3 Constrained Path Tear Curves

X1.3.1 Two types of tear curves are obtained for various vulcanizates (see Fig. A1.1). For Curve (*b*), smooth tear, tearing load fluctuates only slightly and rate of tear propagation is essentially continuous and roughly equal to one-half that of jaw separation. Curve (*a*) is typical of knotty tear, consisting of a series of peak loads, each corresponding to a catastrophic tear. This behavior is the result of a strengthening structure or strain energy dissipation process in the immediate tearing zone. The mechanism consists of a build-up of strain (stress) in the tearing zone with a concurrent strengthening structure formation. This retards onset of rupture. As strain (stress) continues to increase, tear strength is exceeded at some point and a catastrophic rupture occurs. Rate of tear propagation after this rupture is quite rapid and the tear continues to advance until the high strain (stress) gradient is removed; the rate then drops to zero. The jaws continue to separate, however, and the process repeats several times during a test.

X1.4 Correlation of Constrained Path Tear Versus Off Road Tire Performance

X1.4.1 Fig. X1.3 illustrates the degree of correlation between CP tear strength at 100°C and the cutting-chipping rating of a series of compounds in an off-road tire performance test.

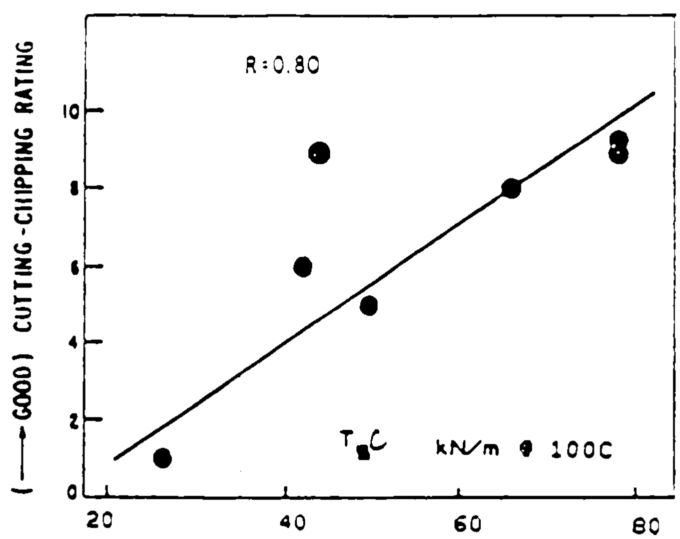


FIG. X1.3 Tear Strength (CP-Specimen) Tc versus Cutting-Chipping Performance