



## Standard Test Methods for Rubber Deterioration—Dynamic Fatigue<sup>1</sup>

This standard is issued under the fixed designation D 430; 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 ( $\epsilon$ ) 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 These test methods cover testing procedures that estimate the ability of soft rubber compounds to resist dynamic fatigue. No exact correlation between these test results and service is given or implied. This is due to the varied nature of service conditions. These test procedures do yield data that can be used for the comparative evaluation of rubber compounds or composite rubber-fabric materials for their ability to resist dynamic fatigue.

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<sup>2</sup>
- D 1349 Practice for Rubber—Standard Temperatures for Testing<sup>2</sup>
- D 1682 Test Methods for Breaking Load and Elongation of Textile Fabrics<sup>3</sup>
- D 3183 Practice for Rubber—Preparation of Pieces for Test Purposes from Products<sup>2</sup>

### 3. Summary of Test Methods

3.1 Three test methods are covered, using the following different types of apparatus:

- 3.1.1 *Method A*—Scott Flexing Machine.
- 3.1.2 *Method B*—De Mattia Flexing Machine.
- 3.1.3 *Method C*—E. I. du Pont de Nemours and Co. Flexing Machine.
- 3.1.4 The Scott flexing machine is used principally for tests

<sup>1</sup> These test methods are under the jurisdiction of ASTM Committee D11 on Rubber and are the direct responsibility of Subcommittee D11.15 on Degradation Tests.

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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 09.01.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 07.01.

of Type I, the De Mattia flexing machine for tests of Type II, while the du Pont apparatus is adapted to tests of either Type I or II.

### 4. Significance and Use

4.1 Tests for dynamic fatigue are designed to simulate the continually repeated distortions received in service by many rubber articles, such as tires, belts, footwear, and various molded goods. These distortions may be produced by extension, compressive, and bending forces or combinations of them. The effect of the distortions is to weaken the rubber until surface cracking or actual rupture occurs. In the case of combinations of rubber with other flexible material such as fabric, the effect may be evidenced by separation at the interface between the materials, caused either by breaking of the rubber or failure of the adhesion or both.

4.2 These tests are, therefore, of the following two types:

4.2.1 *Type I*—Tests designed to produce separation of rubber-fabric combinations such as are used in belts and tires, involving controlled bending of the specimens.

4.2.2 *Type II*—Tests designed to produce cracking on the surface of rubber by either repeated bending or extension as occurs in service with parts such as tire treads and sidewalls, rubber soles, and shoe uppers, diaphragms, hose covers, etc.

### 5. Application

5.1 In case of conflict between the provisions of these methods and those of detailed specifications or methods of test for a particular material, the latter shall take precedence.

### 6. Preparation of Specimen

6.1 Except as may be otherwise specified in these test methods, the requirements of Practice D 3183 shall be complied with and are made a part of these methods.

### 7. Temperature of Test

7.1 The standard temperature for testing shall be  $23 \pm 2^\circ\text{C}$  ( $73.4 \pm 3.6^\circ\text{F}$ ). Specimens shall be conditioned for at least 12 h. Controlled temperatures outside the standard range are acceptable and often desirable. Special note of such temperatures shall appear in the report.

NOTE 1—The standard test temperature herein specified is the same as that prescribed for the Standard Laboratory Atmosphere in Practice D 1349. Any changes or revisions hereafter in Practice D 1349 relating to

the standard test temperature shall be considered effective at once for this procedure.

## METHOD A: SCOTT FLEXING MACHINE<sup>4</sup>

### 8. Type of Strain

8.1 The Scott flexing machine test method is used to test for ply separation in test specimens prepared from belts, tires, or other articles composed of plies of fabric bonded together by rubber compounds.

### 9. Test Specimens from Belts

9.1 The specimens shall be 209.5 mm (8.25 in.) in length by  $25 \pm 2$  mm ( $1 \pm 0.08$  in.) in width. The actual thickness shall be measured and recorded. Test specimens selected from samples of belts shall be cut lengthwise of the belt and their locations recorded. The seam area of a folded belt shall not be included in any of the test specimens and the folded edge shall be removed before cutting the specimens. The specimens shall consist of four plies for routine tests, any excess plies being removed by stripping carefully so as not to weaken the remaining bonds.

### 10. Test Specimens from Tires

10.1 If suitable test specimens cannot be cut from tires it is necessary to prepare special flexing pad samples as described in 10.1.1-10.1.3 from the cord fabric and rubber compounds that are to be tested:

10.1.1 *Building Unvulcanized Flexing Pad Specimen*—Solution-coated, frictioned, or bare cord fabric shall be calendered with the rubber compound to a total thickness of 1.25 mm (0.050 in.). Six plies of this material shall be assembled using a hand roller so that the plies run in alternate directions. The first, third, and fifth plies shall have the cords lengthwise and the second, fourth, and sixth plies crosswise of the pad. Care shall be taken that the same calendered side of each piece is facing up and that each alternate ply crosses at right angles. The pad, which shall have a thickness of 7.6 mm (0.300 in.), shall be cut by means of a template and knife to dimensions of 125 by 202 mm (4.94 by 7.94 in.). The long edge of the template shall be held parallel with the lengthwise cords in the pad.

10.1.2 *Vulcanization of Flexing Pad Specimens*—The flexing pad specimen shall be vulcanized in a steel mold having a cavity measuring 125 by 203 by 8.25 mm (5 by 8 by 0.325 in.). Uniform compression shall be applied over the entire top surface of the pad. This compression, together with slight stretching produced by the unvulcanized pad being cut slightly smaller than the cavity, ensures straight cords in the cured pad. In order to obtain the compression it is necessary to make up the difference between the pad thickness and the mold depth by means of filler layers of holland cloth or aluminum foil which

are placed on top of the pad. These filler layers shall be added until the total thickness of the assembly, measured by means of a dial micrometer gage using a little pressure with the fingers on both sides of the gage foot, is 7.75 mm (0.305 in.). A sheet of rubber compound containing curing ingredients and measuring 0.5 by 152 by 228 mm (6 by 9 by 0.02 in.) shall be placed on top of the flexing pad and filler layers over the cavity of the mold before the mold cover is placed in position. The total thickness of the material in the mold is then 8.25 mm (0.325 in.) and expansion will produce the correct pressure to make a compact, undistorted pad. The purpose of the top rubber layer is to fill the overflow space and seal the mold. In placing the flexing pad in the mold, care shall be taken to keep uppermost that side of the pad having the cords running crosswise. Vulcanization shall be carried out by heating the mold under pressure at a known temperature for the required time in a rubber vulcanizing press. After curing, the filler layers shall be removed and the pad allowed to cool and rest at a room temperature between 21 and 32°C (70 and 90°F) for not less than 36 h before being tested. Pads made in this manner shall be 203 mm (8 in.) in length by 127 mm (8 in.) in width and shall have a thickness of 7.0 to 7.1 mm (0.275 to 0.280 in.). Any pads having wrinkled cords shall not be tested.

10.1.3 *Cutting Tire Test Specimens*—Four strips each 203 mm (8 in.) in length by 25 mm (1 in.) in width shall be cut from the tire flexing pad. On the first cut, a strip 0.250 to 12.5 mm (0.50 in.) in width from the edge along the long side of the pad shall be removed and discarded. Care shall be taken to cut the strips straight, with smooth edges and as closely to the exact width as possible. If reasonable care has been taken in preparing the pads and in cutting the specimens, there should not be more than five or six cut longitudinal threads showing on the two edges of a six-ply specimen. An excessive number of such cut threads indicates that many of the threads of alternate plies are not parallel.

### 11. Number of Test Specimens

11.1 At least five specimens from each belt sample or four specimens from each tire pad shall be tested and the results averaged. The precision of the final value may be increased by testing a greater number of specimens.

### 12. Scott Flexing Machine

12.1 The essential features of the apparatus, illustrated in Fig. 1, are as follows: The flexing machine has five hubs and is capable of testing five specimens at one time. Each hub rotates on a double row, radial type, ball bearing of the grease-sealed type with double shields. The test specimens shall be bent around the hubs having an arc of contact of about 165°, and the ends shall be gripped by clamps that are oscillated up and down by rocker arms driven through a chain of gears by a 190 W (0.25 hp) 1750 r/min motor. The action on the specimen is a flexing back and forth over the hub while pulled taut by the loading lever and weight. The specimen has a travel in one direction of 66.5 mm (2.62 in.) and a full-cycle travel of 132.0 mm (5.2 in.). The speed of operation is approximately 2.7 Hz (160 cpm) the exact number of cycles in each test being recorded on a counter affixed to each rocker arm. The entire machine is approximately 1.27 m (50 in.) in height and

<sup>4</sup> Method A was originated by General Laboratories, U.S. Rubber Co. For further information concerning this test see Gibbons, W. A., "Flexing Test for Tire Carcass Stocks," *Industrial and Engineering Chemistry*, Analytical Edition, Vol 2, No. 1, Jan. 15, 1930, p. 99; also Sturtevant, W. L., "Rubber Power Transmission Belting, Part III—Flexing Machine and Dynamometers for Testing Belting Quality," *India Rubber World*, Vol 83, No. 3, 1930, p. 67.



FIG. 1 Scott Flexing Machine with Five Hubs

occupies a floor space of about 0.66 by 0.97 m (26 by 38 in.).

### 13. Hub Size and Flexing Load

13.1 Specimens of belts shall be tested using hubs 31.7 mm (1.250 in.) in diameter with a 445 N (100-lbf) flexing load. Specimens of tire cord shall be tested using hubs 14.3 mm (0.563 in.) in diameter with a 445 N (100-lbf) flexing load.

### 14. Procedure for Belt Specimens

14.1 Bend the belt test specimens around the hubs with the pulley side of the belt against the metal and the ends clamped in the grips. Carefully apply the flexing load without shock, set the counter at zero, and start the machine. Allow it to run until some fine particles dislodged by friction may be seen on the white plate beneath the hub, which indicates that separation of the plies has started. Frequent inspection of the specimens undergoing test is imperative if reliable results are to be expected. When the first indication of ply separation appears, note the counter reading; thereafter watch the specimen more closely and increase the frequency of the inspection to ensure proper determination of the end point. When there is a clear separation across the width of the specimen it shall be considered to have failed. Record the minimum counter reading for this failure as the end point. Also note the location of the separation. When a test is started, continue to completion without interruption. Do not stop the machine and allow it to remain inactive for any length of time and then start it again. However, for examining the specimen, each hub may be released momentarily from its weight by means of the foot lever provided. Only experienced operators should make this determination.

### 15. Procedure for Tire Specimens

15.1 Mount the tire test specimens with the lengthwise outer ply cords against the hub of the machine and test in a manner

similar to the procedure for belts (Section 13). In the case of tire specimens, after the specimen has been run about 10 min, brush a thick coat of molten carnauba wax on the outer side of the specimen at the flexing region. As soon as separation begins, the temperature of this section increases very rapidly and the wax melts. The melting of the wax starts with a small area and gradually spreads as separation increases. This serves as a warning that complete separation will occur shortly thereafter. The interval between the melting of the wax (the time at which separation actually starts) and complete separation across the specimen may not always be the same.

NOTE 2—A specimen with a short flexing life will show complete separation soon after the wax melts, whereas a sample with a greater flexing life might require a time interval two or three times as long. However, with specimens having similar flexing life, the time interval between the melting of the wax and complete separation is fairly constant.

### 16. Calculation

16.1 Calculate the result of the test of any sample as the average of the number of flexing cycles required to produce complete separation of each test specimen as determined from the counter readings.

### METHOD B: DE MATTIA FLEXING MACHINE<sup>5</sup>

### 17. Type of Strain

17.1 The De Mattia flexing machine test method may be used to test rubber specimens for resistance to cracking produced either by extension or bending, depending on the relative adjustment of the stationary and movable grips, and the distance of travel of the latter. The choice of type of strain is optional (Note 3) but notation shall be made of the type actually used, giving full details of the relative positions of the grips and of the travel.

NOTE 3—In choosing the type of strain, it should be remembered that the phenomenon of cracking starts on the surface of the rubber and rapidly progresses inward as new surface is exposed. Since rubber is practically noncompressible but highly extensible, the rupture of the surface fibers in both types of strain must come from disturbances due to elongation. The magnitude of the extension, however, may differ and the internal distribution of force in the specimens is not the same in the two cases. The choice, therefore, will depend considerably on the purpose of the test and the kind of service for which correlation of the test results may be sought.

### 18. Test Specimens for Extension Fatigue Cracking

18.1 When the extension type of strain is used the standard test specimen shall be the dumbbell-shape tension specimen shown in Fig. 1 (Die C) of Test Methods D 412. The actual thickness shall be measured and recorded, and results shall be compared only when obtained using specimens of substantially the same thickness. The specimens shall be prepared in the same manner as for tension tests, and special care shall be taken to avoid any surface imperfections which might start the cracking. All specimens with irregularities on any surface shall be discarded. On specimens cut from molded sheets, highly

<sup>5</sup> See Cooper, L. V., "Laboratory Evaluation of Flex-Cracking Resistance," *Industrial and Engineering Chemistry*, Analytical Edition, Vol 2, No. 1, Oct. 15, 1930, p. 391.

polished surfaces are very desirable. When buffing is necessary, as with samples cut from finished products, great care shall be exercised that the buffing is alike on all specimens that are to be compared. Test specimens shall be conditioned at least 12 h at the test temperature.

## 19. Test Specimens for Bend Flexing

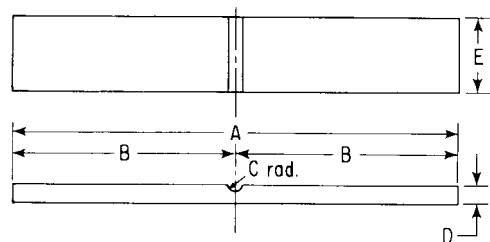
19.1 When the strain type is bending, special molded specimens of the shape shown in Fig. 2 shall be used. The specimens shall be prepared in molds with highly polished surfaces and shall be free from surface irregularities which might start the cracking prematurely. The thickness of the specimen shall be measured close to the groove. Test results shall be compared only between test specimens that have thicknesses of  $6.4 \pm 0.1$  mm ( $0.250 \pm 0.005$  in.) because the results of the test are dependent upon the thickness of the test specimen. The test specimen must be conditioned at least 12 h at the test temperature.

## 20. Number of Test Specimens

20.1 At least three specimens from each sample shall be tested and the results averaged. It is desirable, when possible, to test simultaneously with each set of specimens a set of control specimens of which the resistance to flex cracking is known.

## 21. De Mattia Flexing Machine

21.1 The essential features of the apparatus, one design of which is shown in Fig. 3, are as follows: The machine has an adjustable stationary head or member provided with suitable grips for holding one end of each of the test specimens in a fixed position and a similar reciprocating member for holding the other end of the specimens. The reciprocating member is so mounted that its motion is straight in the direction of and in the same plane as the center line between the grips. The travel of the moving members shall be adjustable and shall be obtained by means of a connecting rod and eccentric having a minimum length ratio of 10 to 1. The eccentric shall be driven by a motor operating at constant speed under load and giving 5 Hz ( $300 \pm 10$  flexing cpm). Provision shall be made for a maximum travel of the moving grips of 100 mm (4 in.). The capacity of the machine shall be such that tests at the same time may be made on at least six and preferably twelve specimens. The grips shall hold the specimens firmly throughout the test and those on the reciprocating member may clamp each specimen individually to facilitate proper adjustment of the specimens.



	A	B	C	D	E
mm	150	75	$2.39 \pm 0.03$	$6.35 \pm 0.13$	25
(in.)	(6)	(3)	$(0.094 \pm 0.001)$	$(0.250 \pm 0.005)$	(1)

FIG. 2 De Mattia Bend Flexing Specimen with Circular Groove

## 22. Clamping Specimens in Machine

22.1 One end of the specimen shall be clamped in the stationary grip and the other in the movable grip, care being taken to see that the long axis of the specimen is parallel to the direction of motion. The constricted section or the circular groove of the clamped specimens shall be located symmetrically midway between the clamps. The specimens for extension fatigue cracking shall be gripped only on the enlarged ends. The specimens may be mounted on the machine most conveniently by holding them properly spaced in parallel positions in a special rack. The distance between the outer edges of the side bars of the rack shall be equal to the space between the jaws of the testing machine when positioned for holding the specimens without tension. The specimens can be mounted on the testing machine by bringing the jaws into contact with the mounting rack and tightening the clamps on the projecting ends of the specimens. In the case of specimens for bend flexing, the free length of the specimens between the clamps shall be  $76.2 + 0.3$  or  $- 0.0$  mm ( $2.99 + 0.01$  or  $- 0.00$  in.). The circular groove must be so restrained that it will become the outer surface when the specimens are bent.

## 23. Adjustment of Machine

23.1 *Extension Fatigue Cracking*—For these tests, the positions of the stationary and movable grips relative to each other and the length of the eccentric arm and connecting rod shall be adjusted by trial so that the movable grip will approach the stationary grip 13 mm (0.5 in.) closer than necessary to relieve the elongation stress in the specimen and so that the grips will separate a maximum distance sufficient to elongate the portion of the specimen between the gage marks a predetermined and recorded amount. The elongation of the specimens between the gage marks shall not exceed one fourth of the ultimate breaking elongation. For highly extensible rubbers a maximum elongation of 125 % is suitable.

23.2 *Bend Flexing*—For bend flexing tests the positions of the stationary and movable grips relative to each other and the length of the eccentric arm and connecting rod shall be adjusted so that during each stroke of the machine the grips approach each other to a distance of  $19.0 \pm 0.1$  mm ( $0.750 \pm 0.005$  in.) and separate to a distance of  $75.9 + 0.3$  or  $- 0.00$  mm ( $2.99 + 0.01$  or  $- 0.000$  in.).

## 24. Procedure

24.1 After adjustment of the apparatus and specimens is completed, start the machine and record the time. Continue the test until, by frequent inspection, the appearance of the first minute sign of cracking is detected. At this point, again record the time. The first cracking may be evidenced as either very fine hairline cracks or as slight pinholes. After this time, observe the specimens very closely until the test is discontinued, and record the final time when the cracks have developed sufficiently to permit grading the degree of the cracking in all specimens as described in Section 25. It is not desirable to run the specimens until actual complete rupture occurs when this can be avoided. When testing specimens of which the dynamic fatigue properties are approximately known, run the test for a known predetermined number of cycles and then make the grading comparison.

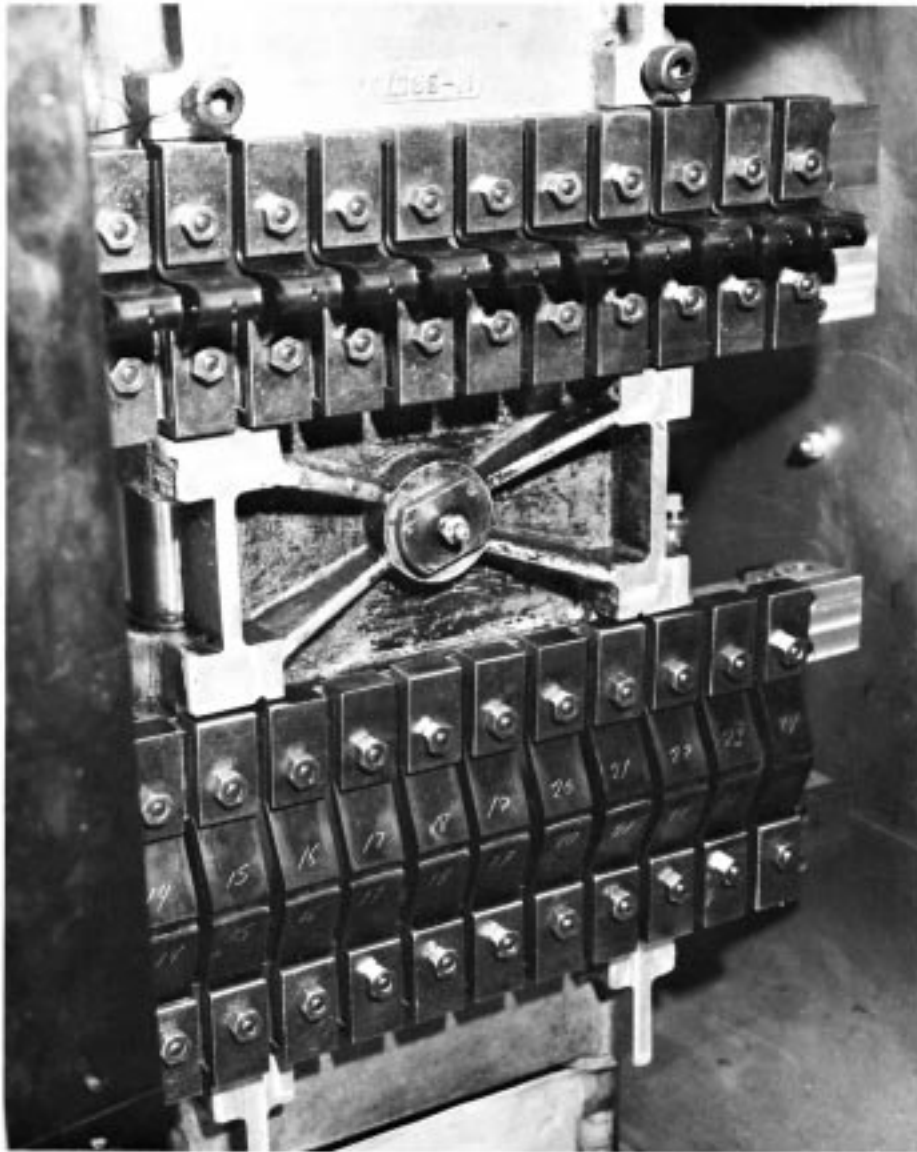


FIG. 3 De Mattia Tester with Time-Switch for Starting or Stopping, Arranged with Specimens for Flex-Cracking Test

## 25. Interpretation of Results

25.1 After the conclusion of the test, remove the specimens from the machine and evaluate them in sequence relative to the seriousness of the cracking by comparison with a standard scale of cracked specimens of the same type. Compare by judging visually the length, depth, and number of cracks. The standard comparison scale shall consist of eleven specimens equally graded and numbered from No. 0, showing no cracking, to No. 10, which is completely cracked through. A guide for evaluating the specimens is given in Table 1. For improved precision make observations with a ruler in 0.5-mm (0.020-in.) increments, using a low-powered magnifying glass. Record the final result for a given sample as the average of the numbers so obtained from all of the specimens. Calculate the number of cycles required for the first sign of cracking and for the final result by multiplying the observed time expressed in minutes by the rate of 5 Hz (300 cpm) and record. Compare the test results only between specimens of similar sizes and shapes,

tested in the same manner under identical conditions. The test results may be expressed as: (1) a severity comparison of the various samples at a definite number of flexing cycles, (2) the number of flexing cycles required to attain a definite severity rating, or (3) a comparison of the number of cycles required to attain progressive degrees of severity ratings. In the latter case where several degrees of severity ratings are observed, the data may be compared numerically or graphically as desired, expressing the number of flexing cycles either in kilocycles or logarithms of kilocycles.

## 26. Precision and Bias

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

26.2 The precision results in this precision and bias section give an estimate of the precision of this test method with the materials (rubbers, etc.) used in the particular interlaboratory

**TABLE 1 Evaluation of De Mattia Bend Flexing Specimens**

NOTE 1— No distinction is made between cracks that grow in isolation and those that have grown by coalescence.

Grade 0	No cracking has occurred.
Grade 1	Cracks at this stage appear as pin pricks to the naked eye. Grade as 1 if the pin pricks are less than 10 in number and less than 0.5 mm in length.
Grade 2	Assess as Grade 2 if either of the following applies: (1) The pin pricks are in excess of 10 in number, or (2) The number of cracks is less than 10 but one or more cracks have developed beyond the pin prick stage, that is, they have perceptible length without much depth, but their length is still less than 0.5 mm.
Grade 3	Assess as Grade 3 if one or more of the pin pricks have become obvious cracks with a length greater than 0.5 mm but not greater than 1.0 mm.
Grade 4	The length of the largest crack is greater than 1.0 mm but not greater than 1.5 mm (0.06 in.).
Grade 5	The length of the largest crack is greater than 1.5 mm but not greater than 3.0 mm (0.12 in.).
Grade 6	The length of the largest crack is greater than 3.0 mm but not greater than 5.0 mm (0.20 in.).
Grade 7	The length of the largest crack is greater than 5.0 mm but not greater than 8.0 mm (0.31 in.).
Grade 8	The length of the largest crack is greater than 8.0 mm but not greater than 12.0 mm (0.47 in.).
Grade 9	The length of the largest crack is greater than 12.0 mm but not greater than 15.0 mm (0.60 in.).
Grade 10	The length of the largest crack is greater than 15.00 mm. This indicates complete failure of the specimen.

program as described in 26.3. The precision parameters should not be used for acceptance or rejection testing of any group of materials without documentation that the parameters are applicable to the particular group of materials and the specific testing protocols of the test method.

26.3 A Type 1 interlaboratory test program was evaluated in 1993 with three compounds (materials) tested in five laboratories on two separate test days one week apart. Both repeatability and reproducibility are therefore short-term; a period of a few days separates replicate test results. A test result is the mean (average) value of three determinations (or test specimens) of the flex life in kilocycles to first cracking.

26.4 The results of the precision evaluation are given in Table 2.

26.5 The precision of the test method may be expressed in the format of the following statements that use an appropriate value of  $r$ ,  $R$ ,  $(r)$ , and  $(R)$  to be used in the decisions about the test results. The appropriate value is that value of  $r$  or  $R$ , associated with a mean level in Table 2, closest to the mean level under consideration at any given time for any test result for a material in routine testing operations.

26.5.1 *Repeatability*— The repeatability,  $r$ , of this test method has been established as the appropriate value tabulated in Table 2. Two single test results, obtained under normal test

**TABLE 2 Type 1—Precision Results: Method B**

$S_r$  = repeatability standard deviation, in measurement units,  
 $r$  = repeatability =  $2.83 \times$  repeatability standard deviation,  
 $(r)$  = repeatability, as percentage of material mean (average) value,  
 $SR$  = reproducibility standard deviation, in measurement units,  
 $R$  = reproducibility =  $2.83 \times$  reproducibility standard deviation, and  
 $(R)$  = reproducibility, as percentage of material mean (average) value.

Material	Mean <sup>A</sup>	Within Laboratories			Between Laboratories		
		$S_r$	$r$	$(r)$	$SR$	$R$	$(R)$
CPD A	11.3	2.90	8.11	71.8	3.66	10.2	90.3
CPD C	20.0	3.71	10.40	52.0	8.40	23.5	118.0
CPD B	21.0	5.91	16.50	78.6	8.51	23.8	113.0

<sup>A</sup>Units = Kilocycles to first cracking.

$p = 5$ ,  $q = 3$ , and  $n = 2$ .

Laboratory 5, Material B values replaced.

method procedures, that differ by more than this tabulated  $r$  (for any given level) must be considered as derived from different or nonidentical sample populations.

26.5.2 *Reproducibility*— The reproducibility,  $R$ , of this test method has been established as the appropriate value tabulated in Table 2. 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.

26.5.3 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 (in absolute units).

26.6 This precision evaluation program had an inadequate number of laboratories for a satisfactory evaluation of the testing precision.

26.7 *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.

## METHOD C: E. I. DU PONT DE NEMOURS AND CO. FLEXING MACHINE<sup>6</sup>

### 27. Test Specimens for Flex Cracking

27.1 Specimens shall be specially prepared from the unvulcanized rubber compounds to be tested. They shall have a fabric base to prevent stretching during test and shall be strips 25 mm (1 in.) in width by 100 mm (4 in.) in length cut at right angles to the grooves from vulcanized test slabs prepared as described in 27.1.1 and 27.1.2.

<sup>6</sup>Method C was originated by Fisk Rubber Co. Laboratories. For further information respecting this test see Neal, A. M., and Northam, A. J., "Some Factors Affecting the Resistance to Flexing," *Industrial and Engineering Chemistry*, Vol 23, No. 12, Dec., 1931, p. 1449.

27.1.1 The unvulcanized stock shall be prepared in sheets having a thickness of 4.3 to 4.5 mm (0.170 to 0.175 in.). A slab 75 by 190 mm (3 by 7.5 in.) shall be cut so that the grain of the stock runs parallel to the 75 mm (3 in.) side. The slab shall then be backed with a layer of frictioned belt fabric. Cut the fabric 146 by 190 mm (5.75 by 7.5 in.) so that the warp is parallel to the 146-mm (5.75-in.) side and prepare as follows: The upper surface of this fabric shall be covered with a 5.1- mm (0.020-in.) layer of tie gum (rubber tread stock). After the tie gum has been put on the frictioned fabric, two 3-mm (0.125-in.) diameter steel rods 190 mm (7.375 in.) long covered with a paper soda straw shall be placed on the tie gum side of the fabric so that the center of the rod is approximately 24 mm (0.938 in.) from each side of the 190-mm (7.5-in.) edges. The 24-mm (0.938-in.) projecting fabric shall be folded over and rolled down so that the finished fabric will have a dimension of approximately 100 mm (4 in.) in width by 190 mm (7.5 in.) in length. The surface of the slab of 75 by 190 mm (3 by 7.5 in.) and also the tie gum shall be freshened with hexane and permitted to dry before assembly to ensure good adhesion. Semi-cured white letters may be placed along the side of the slab for the identification of the test specimens, which shall be subsequently cut out and assembled for flexing. Before vulcanizing, the stock shall be allowed to rest 16 h after mixing. The fabric shall conform to the following requirements:

27.1.2 The fabric shall be frictioned on both sides with a conventional gum-friction compound. The slab shall be placed in the mold shown in Fig. 4 with the rubber side of the slab next to the mold corrugations and vulcanized as required for the particular compound. After the vulcanized slab has been allowed to cool in air, the two steel rods shall be removed. This produces a cured slab with a fabric backing 7.5 in. in length by 4 in. in width and 4.8 mm (0.188 in.) in thickness at the smooth portion and 5.9 mm (0.233 in.) in thickness at the corrugated portion. There are seven transverse V-shaped grooves 4 mm (0.156 in.) in width and 1.1 mm (0.045 in.) in depth. The angle of the "V" is 120°. Notation shall be made of the time and temperature of vulcanization.

## 28. Number of Test Specimens

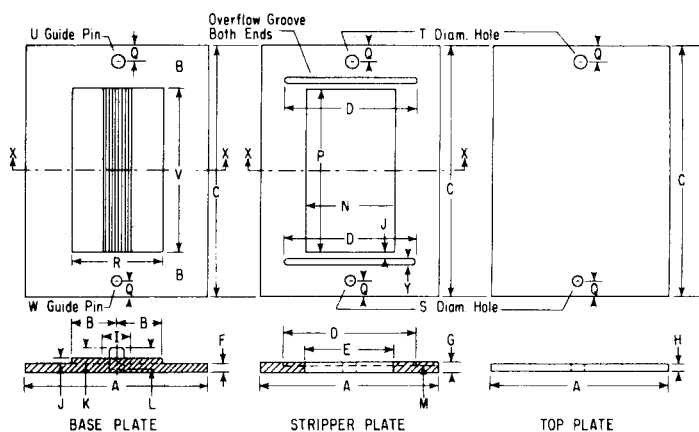
28.1 At least three specimens from each test slab shall be tested and the results averaged. The accuracy of the final value may be increased by testing a greater number of specimens. Since the test is primarily comparative, a set of control specimens from samples of which the qualities are known should be tested simultaneously whenever possible. Flex cracking results shall be compared only between specimens having thicknesses agreeing within  $\pm 0.04$  mm ( $\pm 0.0015$  in.).

## 29. du Pont Flexing Machine

29.1 The du Pont flexing machine, shown in Fig. 5, consists essentially of four pulleys around which a test belt is run. The belt shall be composed of 21 test pieces acting as links held together with chain master links. The machine may be arranged as shown so that three separate belts may be run at the same time. Facing the front of the machine, the upper left-hand pulley is driven by a 373-W (0.5-hp) motor. This driving pulley shall have a speed of 860 r/min. The upper right-hand pulley is mounted in an angular balance arm which supports a 6.8-kg (15-lb) weight. The weight is 11 in. and the pulley 123 mm (4.85 in.) from the supporting pin, producing a belt tension of approximately 76 N (17 lbf). The angle between the two

Raw Fabric, Silver Hard Duck:		Warp Filler
Threads per cm (in.)		11 by 7.4 (27½ by 18½)
Ply		7 by 4
Crimp, %		25 by 4
Breaking Resistance (ASTM Grab Method), <sup>A</sup>		2700 by 1300 (600 by 290)
12-h exposure in an atmosphere having a relative humidity of 65 % at 21°C, N (lbf)		
Thickness, mm (in.)		1.45 (0.057)
Mass in g/m <sup>2</sup> (oz/yd <sup>2</sup> )		950 (28)
Frictioned Fabric (frictioned both sides):		
Mass in g/m <sup>2</sup> (oz/yd <sup>2</sup> )		1220 (36)
Thickness, mm (in.)		1.2 ± 0.1 (0.049 + 0.003)

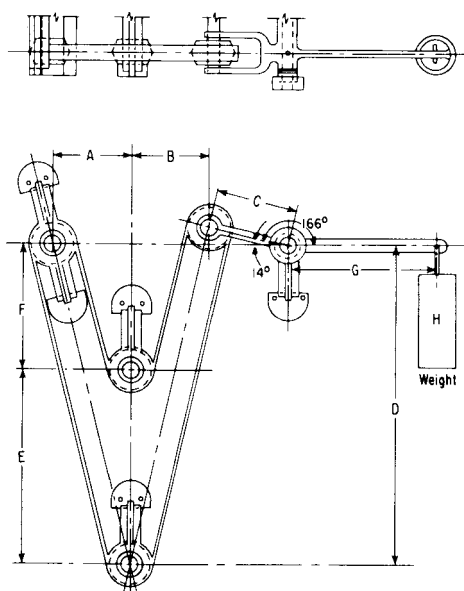
<sup>A</sup> The grab test method is described in Test Methods D 1682.



	A	B	C	D	E	F	G	H	I	J	K	L
mm	203	51	290	150	102	10	11	8	32	6.4	17.5	24
(in.)	(8½)	(2)	(11½)	(6)	(4¼)	(¾)	(7/16)	(5/16)	(1¼)	(¼)	(11/16)	(15/16)
	M	N	P	O	R	S	T	U	V	W	Y	
mm	14	102	190.6	19	102	13	16.3	16	190	12.7	7.2	
(in.)	(9/16)	(4¼)	(7¾)	(¾)	(4)	(33/64)	(41/64)	(5/8)	(7½)	(½)	(9/32)	

FIG. 4 Mold for Preparing Test Specimens for du Pont Flexing Test

 D 430



	A	B	C	D	E	F	G	H
mm	160	155	123	600	365	245	280	6.8 (kg)
(in.)	(6.25)	(6.05)	(4.85)	(24)	(14.375)	(9.625)	(11)	(15 (lb))

FIG. 5 du Pont Flexing Machine

sections of the balance arm is  $166^\circ$ ,<sup>7</sup> as shown in Fig. 5. This angle results in less change in tension on the belt as the belt increases in length. The center and lower pulleys are idlers. All pulleys are 75 mm (3 in.) in diameter without flanges and have faces 45 mm (1.75 in.) in width with 0.8-mm (0.031-in.) crowns and are mounted on sealed ball bearings. The bottom and center pulleys are on the same vertical line and their centers shall be 365 mm (14.375 in.) apart. The driving pulley shall be located 160 mm (6.25 in.) to the left of the center pulley and 245 mm (9.625 in.) above it. The balance pulley shall be located 154 mm (6.05 in.) to the right of the center pulley when the weight arm (280-mm (11-in.) section) is horizontal. The specimen belt runs over the driving pulley, under the center pulley, over the right-hand or balance pulley, and under the bottom pulley back to the driving pulley. In order to record when a belt breaks, the lever arm contacts a switch which stops an electric clock or running time meter.

### 30. Procedure

30.1 Assemble 21 test specimens into a test belt by means of master chain links.<sup>8</sup> If the number of specimens to be tested is insufficient, dummy specimens of the same construction as the test specimens may be used. Place the belts on the machine with the fabric face next to the drive pulley. Flex each specimen three times with the face under tension and once under compression with each revolution. The direction of

rotation of the belt shall be clockwise when standing in front (Section 29) of the machine. Note the time of starting the machine. Continue flexing and inspect the specimens visually at periodic intervals until all specimens show some sign of failure. At this point discontinue the test and record the time. Failure is indicated by the appearance in the corrugations of small nicks or pinholes which soon increase in size until they become deep cracks, which may extend all the way across the specimen. The frequency of inspection of the specimens shall be sufficient to give a reliable measure of the failure of the specimens. If a specimen breaks prematurely, replace it with a dummy specimen and continue the test.

### 31. Evaluation of Results

31.1 Evaluate the results of the test as given in Section 25, except record the number of flexures in terms of total belt revolutions at the end of the test calculated by multiplying the observed flexing time expressed in minutes by the assumed belt speed of 1.6 Hz (95 r/min). Make a detailed permanent record of the cracking in each specimen by indicating on a suitable form the location, number, and intensity of the nicks and cracks. Dots may be used for nicks and straight lines for cracks. Very light marks may be used for first indications with heavier marks to indicate increased depth and width of failure.

### 32. Report

32.1 For each of the three alternative test methods, the report shall include the following:

32.1.1 The results of the test expressed in accordance with Section 16, 25, or 31.

32.1.2 Statement of the purpose of the test and the method used, including a description of the specimen,

32.1.3 All observed and recorded data,

32.1.4 Description of the sample,

<sup>7</sup> Buist, J. M., *Fundamentals of Rubber Technology*, Imperial Chemical Industries, Ltd., 1947, p. 162.

<sup>8</sup> These links, known as No. 35 single link assemblies having 9.5-mm (3/8-in.) pitch with 32-mm (1 1/4-in.) rivets supplied by the Boston Gear Works, Inc., 14 Hayward St., North Quincy, MA 00171, have been found satisfactory. The end plates of these links shall be sufficiently filed or cut down to prevent them from contacting the surface of the pulleys of the flexer when belt is under test.



- 32.1.5 Date of manufacture or vulcanization, if known,
- 32.1.6 Date of test, and
- 32.1.7 Temperature of the test room.

### **33. Keywords**

33.1 crack growth; De Mattia flexing machine; du Pont flexing machine; flex fatigue; flexing; flexing fatigue; ply separation; rubber products; Scott flexing machine

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