This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.

Designation: D395 – 16$^{\varepsilon 1}$

Standard Test Methods for Rubber Property—Compression Set[1]

This standard is issued under the fixed designation D395; 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 U.S. Department of Defense.

ε[1] NOTE—Editorially corrected 1.1 in March 2017.

1. Scope

1.1 These test methods cover the testing of rubber intended for use in applications in which the rubber will be subjected to compressive stresses in air or liquid media. They are applicable particularly to the rubber used in machinery mountings, vibration dampers, and seals. Three test methods are covered as follows:

Test Method	Section
A—Compression Set Under Constant Force in Air	8 – 11
B—Compression Set Under Constant Deflection in Air	12 – 15
C—Compression Set Under Constant Deflection in Air Considering Material Hardness	16 – 21

1.2 The choice of test method is optional, but consideration should be given to the nature of the service for which correlation of test results may be sought. Unless otherwise stated in a detailed specification, Test Method B shall be used.

1.3 Test Method B is not suitable for vulcanizates harder than 90 IRHD.

1.4 The values stated in SI units are to be regarded as the standard.

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

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D1349 Practice for Rubber—Standard Conditions for Testing

D3182 Practice for Rubber—Materials, Equipment, and Procedures for Mixing Standard Compounds and Preparing Standard Vulcanized Sheets

D3183 Practice for Rubber—Preparation of Pieces for Test Purposes from Products

D3767 Practice for Rubber—Measurement of Dimensions

D4483 Practice for Evaluating Precision for Test Method Standards in the Rubber and Carbon Black Manufacturing Industries

E145 Specification for Gravity-Convection and Forced-Ventilation Ovens

3. Summary of Test Methods

3.1 A test specimen is compressed to either a deflection or by a specified force and maintained under this condition for a specified time and at a specified temperature.

3.2 The residual deformation of a test specimen is measured 30 min after removal from a suitable compression device in which the specimen had been subjected for a definite time to compressive deformation under specified conditions.

3.3 After the measurement of the residual deformation, the compression set, as specified in the appropriate test method, is calculated according to Eq 1 and Eq 2.

4. Significance and Use

4.1 Compression set tests are intended to measure the ability of rubber compounds to retain elastic properties after prolonged action of compressive stresses. The actual stressing service may involve the maintenance of a definite deflection, the constant application of a known force, or the rapidly repeated deformation and recovery resulting from intermittent compressive forces. Though the latter dynamic stressing, like the others, produces compression set, its effects as a whole are simulated more closely by compression flexing or hysteresis tests. Therefore, compression set tests are considered to be mainly applicable to service conditions involving static stresses. Tests are frequently conducted at elevated temperatures.

[1] These test methods are under the jurisdiction of ASTM Committee D11 on Rubber and Rubber-like Materials and are the direct responsibility of Subcommittee D11.10 on Physical Testing.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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5. Test Specimens

5.1 Specimens from each sample may be tested in duplicate (Option 1) or triplicate (Option 2). The compression set of the sample in Option 1 shall be the average of the two specimens expressed as a percentage. The compression set of the sample in Option 2 shall be the median (middle most value) of the three specimens expressed as a percentage.

5.2 The standard test specimen shall be a cylindrical disk cut from a laboratory prepared slab.

5.2.1 The dimensions of the standard specimens shall be:

Type	1[A]	2[B]
Thickness, mm (in.)	12.5 ± 0.5 (0.49 ± 0.02)	6.0 ± 0.2 (0.24 ± 0.01)
Diameter, mm (in.)	29.0 ± 0.5 (1.14 ± 0.02)	13.0 ± 0.2 (0.51 ± 0.01)

[A] Type 1 specimen is used in Test Methods A, B, and C.
[B] Type 2 specimen is used in Test Method B and C.

5.2.2 When cutting the standard specimen, the circular die having the required inside dimensions specified in 5.2.1 shall be rotated in a drill press or similar device and lubricated by means of a soap solution. A minimum distance of 13 mm (0.51 in.) shall be maintained between the cutting edge of the die and the edge of the slab. The cutting pressure shall be as light as possible to minimize cupping of the cut edges. The dies shall be maintained carefully so that the cutting edges are sharp and free of nicks.

5.3 An optional method of preparing the standard specimen may be the direct molding of a circular disk having the dimensions required for the test method used and specified in 5.2.1.

NOTE 1—It should be recognized that an equal time and temperature, if used for both the slab and molded specimen, will not produce an equivalent state of cure in the two types of specimen. A higher degree of cure will be obtained in the molded specimen. Adjustments, preferably in the time of cure, must be taken into consideration if comparisons between the specimens prepared by different methods are to be considered valid.

NOTE 2—It is suggested, for the purpose of uniformity and closer tolerances in the molded specimen, that the dimensions of the mold be specified and shrinkage compensated for therein. A two-plate mold with a cavity 13.0 ± 0.1 mm (0.510 ± 0.004 in.) in thickness and 29.20 ± 0.05 mm (1.148 ± 0.002 in.) in diameter, with overflow grooves, will provide Type 1 specimens for Test Method A and Test Method B. A similar mold but having a cavity of 6.3 ± 0.3 mm (0.25 ± 0.012 in.) in thickness and 13.3 ± 0.1 mm (0.52 ± 0.004 in.) in diameter will provide Type 2 specimens for Test Method B.

5.4 When the standard test specimen is to be replaced by a specimen taken from a vulcanized rubber part of greater thickness than the one indicated in 5.2.1, the sample thickness shall be reduced first by cutting transversely with a sharp knife and then followed by buffing to the required thickness in accordance with Practice D3183.

5.5 An alternative method of preparing specimens is by plying up cylindrical disks cut from a standard sheet prepared in accordance with Practice D3182 using the specimen sizes specified in 5.2.1 and cutting as described in 5.2.2, or where a drill press is not available cutting the specimens with a single stroke from a cutting die.

5.5.1 The disks shall be plied, without cementing, to the thickness required. Such plies shall be smooth, flat, of uniform thickness, and shall not exceed seven in number for Type 1 specimens and four in number for Type 2 specimens.

5.5.2 Care shall be taken during handling and placing of the plied test specimen in the test fixture by keeping the circular faces parallel and at right angles to the axis of the cylinder.

5.5.3 The results obtained on plied specimens may be different from those obtained using solid specimens and the results may be variable, particularly if air is trapped between disks.

5.5.4 The results obtained on the specimens prepared by one of the methods may be compared only to those prepared by the same method.

5.6 For routine or product specification testing, it is sometimes more convenient to prepare specimens of a different size or shape, or both. When such specimens are used, the results should be compared only with those obtained from specimens of similar size and shape and not with those obtained with standard specimen. For such cases, the product specification should define the specimen as to the size and shape. If suitable specimens cannot be prepared from the product, the test method and allowable limits must be agreed upon between the producer and the purchaser.

6. Conditioning

6.1 Store all vulcanized test specimens or product samples to be tested at least 24 h but not more than 60 days. When the date of vulcanization is not known, make tests within 60 days after delivery by the producer of the article represented by the specimen.

6.2 Allow buffed specimens to rest at least 30 min before specimens are cut for testing.

6.3 Condition all specimens before testing for a minimum of 3 h at 23 ± 2°C (73.4 ± 3.6°F). Specimens whose compression set properties are affected by atmospheric moisture shall be conditioned for a minimum of 24 h in an atmosphere controlled to a relative humidity of 50 ± 10 %RH (40 to 60 %RH).

7. Precision and Bias[3]

7.1 These precision statements have been prepared in accordance with Practice D4483. Please refer to Practice D4483 for terminology and other testing and statistical concepts.

7.2 Prepared test specimens of two rubbers for Test Methods A and B were supplied to five laboratories. These were tested in duplicate each day on two separate testing days. A test result, therefore, is the average of two test specimens, for both Test Methods A and B.

7.3 One laboratory did not run the Test Method A testing; therefore, the precision for Test Method A is derived from four laboratories.

7.4 The Type 1 precision results are given in Table 1 and Table 2.

[3] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D11-1038.

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TABLE 1 Type 1 Precision Results, % Compression Set—Test Method A

Material	Mean Level	Within Laboratory[A]			Between Laboratory[A]		
		S_r	r	(r)	S_R	R	(R)
1	1.73 (%)	0.050	0.142	8.2	0.190	0.54	31.1
2	26.1	0.898	2.54	9.7	2.37	6.71	25.7

[A] S_r = within laboratory standard deviation.
r = repeatability (in measurement units).
(r) = repeatability (in percent).
S_R = between laboratory standard deviation.
R = reproducibility (in measurement units).
(R) = reproducibility (in percent).

TABLE 2 Type 1 Precision Results, % Compression Set—Test Method B

Material	Mean Level	Within Laboratory[A]			Between Laboratory[A]		
		S_r	r	(r)	S_R	R	(R)
1	13.7 (%)	0.591	1.67	12.2	1.54	4.36	31.8
2	52.8	0.567	1.60	3.0	5.92	16.8	31.7

[A] S_r = within laboratory standard deviation.
r = repeatability (in measurement units).
(r) = repeatability (in percent).
S_R = between laboratory standard deviation.
R = reproducibility (in measurement units).
(R) = reproducibility (in percent).

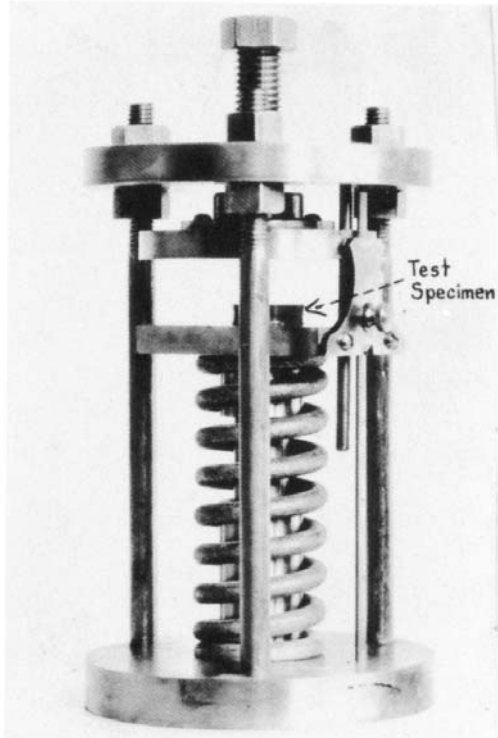

FIG. 1 Device for Compression Set Test, Using Calibrated Spring Loading, Test Method A

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

TEST METHOD A—COMPRESSION SET UNDER CONSTANT FORCE IN AIR

8. Apparatus

8.1 *Micrometer*—A micrometer, analog or digital, for measuring specimen thickness, in accordance with Practice D3767, Method A1.

8.2 *Compression Device,* consisting of a force application spring and two parallel compression plates assembled by means of a frame or threaded bolt in such a manner that the device shall be portable and self-contained after the force has been applied and that the parallelism of the plates shall be maintained. The force may be applied in accordance with either 8.2.1 or 8.2.2.

8.2.1 *Calibrated Spring Force Application*—The required force shall be applied by a screw mechanism for compressing a calibrated spring the proper amount. The spring shall be of properly heat-treated spring steel with ends ground and perpendicular to the longitudinal axis of the spring. A suitable compression device is shown in Fig. 1. The spring shall conform to the following requirements:

8.2.1.1 The spring shall be calibrated at room temperature 23 ± 5°C (73.4 ± 9°F) by applying successive increments of force not exceeding 250 N (50 lbf) and measuring the corresponding deflection to the nearest 0.2 mm (0.01 in.). The curve obtained by plotting the forces against the corresponding deflections shall have a slope of 70 ± 3.5 kN/m (400 ± 20 lbf/in.) at 1.8 kN (400 lbf). The slope is obtained by dividing the two forces above and below 1.8 kN by the difference between the corresponding deflections.

8.2.1.2 The original dimensions of the spring shall not change due to fatigue by more than 0.3 mm (0.01 in.) after it has been mounted in the compression device, compressed under a force of 1.8 kN (400 lbf), and heated in the oven for one week at 70 ± 2°C (158 ± 3.6°F). In ordinary use, a weekly check of the dimensions shall show no greater change than this over a period of 1 year.

8.2.1.3 The minimum force required to close the spring (solid) shall be 2.4 kN (530 lbf).

8.2.2 *External Force Application*—The required force shall be applied to the compression plates and spring by external means after the test specimen is mounted in the apparatus. Either a calibrated compression machine or known masses may be used for force application. Provision shall be made by the use of bolts and nuts or other devices to prevent the specimen and spring from losing their initial deflections when the external force is removed. The spring shall have essentially the same characteristics as described in 8.2.1, but calibration is not required. A suitable compression device is shown in Fig. 2.

8.3 *Plates*—The plates between which the test specimen is compressed shall be made of steel of sufficient thickness to withstand the compressive stresses without bending.

8.3.1 The surfaces against which the specimen is held shall have an industrial chrome (hard chrome) plated finish and shall be cleaned thoroughly and wiped dry before each test.

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