



## Standard Test Methods for Vulcanized Rubber and TPE for Use in Finite Element Analysis Modeling

### 1 Introduction

**Note:** Nothing in this standard supercedes applicable laws and regulations.

**Note:** In the event of conflict between the English and domestic language, the English language shall take precedence.

**1.1 Purpose.** These methods provide a way of obtaining pure strain state physical response for static and short-term relaxation properties at various temperatures. The test data permits a design analyst to characterize “elastic” stress/strain behavior in an elastomer using finite element analysis. It does not, nor is it intended to, replace long term aging tests to characterize performance of elastic material response.

#### 1.2 Applicability.

**1.2.1 Test Method A – Uniaxial Tension.** Uniaxial tension is the measurement of tensile properties from ASTM D3182 sample slabs (Figure 4) of material and includes the preparation of the specimens and the testing of the specimens. Test samples are in the form of ISO 37 S2 micro-dumbbells of uniform cross-sectional area or straight strips with a ratio of 10 units high to 1 unit wide. ASTM D412, type C gauge length is not ten (10) times longer than the width. A Type D specimen has the proper ratio.

**1.2.2 Test Method B – Planar Tension.** Planar tension is the measurement of stress-strain properties from specimens cut from ASTM D3182 slabs of material and includes the preparation and testing of the specimens.

**1.2.3 Test Method C – Equibiaxial Tension.** Equibiaxial tension is the measurement of stress-strain properties from specimens cut from ASTM D3182 slabs of material and includes the preparation and testing of the specimens. Test samples are circular of uniform cross sectional area.

**1.2.4 Test Method D – Volumetric Compression.** Volumetric compression is a measure of the volumetric strain change in response to uniform hydrostatic (equal) pressure.

**1.2.5 Test Protocol.** For analysis, each end use application uses different test combinations of loading within Methods A, B, or C. The step sequence curve loop (SSCL) test is only for applications where repeated loading and unloading occurs, e.g., motor mounts, door seals, body bushings, etc. Data on first time stretch (FTS) and relaxation to equilibrium test (RET) accompanies the SSCL. For all other applications, use the FTS and RET. Volumetric compression applies to designs placed in confined volume (e.g., press-in-place gaskets).

**1.2.6 Thermoplastic Elastomers (TPE).** These test methods also apply to TPEs that meet qualifying requirements in hardness range of 40 to 87 International Rubber Hardness Degree (IRHD) using ASTM D1415 or ISO 48, Method M. See Table 1: Description of All Test Specimens.

**1.2.7 Elastomers Only.** Testing is performed on slabs ranging from 40 IRHD micro-hardness to 90 IRHD micro-hardness. The reading is based on a time delay as required by ASTM D1415 or ISO 48, Method M.

**1.3 Remarks.** A global dedicated lab creates test data to this document. The apparatus, all specimen forms, and procedural requirements to the descriptive level set forth in this document exist only at Axel Products. A single dedicated lab provides the desired level of discipline, consistency, precision, and accuracy for all compound characterization data in the GM material database since 1999.

### GM Confidential

© Copyright 2018 General Motors Company All Rights Reserved

February 2018

Originating Department: North American Engineering Standards

Page 1 of 25



**Documents**  
Document Sharing Hub

## 2 References

**Note:** Only the latest approved standards are applicable unless otherwise specified.

### 2.1 External Standards/Specifications.

|            |            |           |           |
|------------|------------|-----------|-----------|
| ASTM D395  | ASTM D1349 | ASTM E145 | ISO 2393  |
| ASTM D412  | ASTM D1415 | ASTM SI10 | ISO 23529 |
| ASTM D573  | ASTM D3182 | ISO 37    | JIS K6299 |
| ASTM D1329 | ASTM D3767 | ISO 48    |           |

### 2.2 GM Standards/Specifications.

GMW16973

### 2.3 Additional References.

- Axel Products, 2255 South Industrial Hwy., Ann Arbor, Michigan 48104
- Mayhew Tools Catalog

## 3 Resources

### 3.1 Facilities.

**3.1.1 Calibration.** The test facilities and equipment shall be in good working order and shall have a valid calibration label.

**3.1.2 Alternatives.** Alternative test facilities and equipment may also be used. However, all measuring variables as specified in this standard shall be determined correctly with respect to their physical definition.

### 3.2 Equipment.

**3.2.1 Testing Machine.** See ASTM D412 apparatus description. Tests A, B, and C are made on a power-driven machine equipped to produce a uniform rate of grip separation that allows 1% strain per second in the test specimen. The testing machine must have a suitable dynamometer and indicating or recording system for measuring the applied force. The applied force is within  $\pm 1\%$  of readings throughout the entire range of testing (to normalize readings).

**3.2.2 Test Chamber for Elevated and Low Temperatures.** The test chamber must conform to ASTM D412, and ASTM D573 statements. In addition, the following requirements apply.

**3.2.2.1** Air must circulate through the chamber at a velocity of 1 m/s to 2 m/s (3.3 ft/s to 6.6 ft/s) at the location of the grips and specimens maintained within  $\pm 2^\circ\text{C}$  of the specified temperature. Circulation promotes uniformity and minimizes fogging at low temperature. The chamber must maintain isothermal temperatures in the  $-40^\circ\text{C}$  to  $+150^\circ\text{C}$  range. Measurements are made to ASTM E145 requirements.

**3.2.2.2** The chamber internal volume must house the hardware and specimens scheduled for test and permit freedom to mount and remove items in the chamber. Chamber window(s) are needed to accommodate non-contact strain measuring devices (see 3.2.5). The chamber must have access holes for routing thermocouple and other measuring wiring (see 3.2.7).

**3.2.2.3 Cooling.** Chamber and cooling medium (dry air or nitrogen source) must eliminate moisture build-up (snowing) on test specimens and measurement hardware. Fogging of the chamber windows interferes with Light Amplification by Stimulated Emission of Radiation (LASER) detection of the reflective tape strips. A dew point equal or lower than  $-40^\circ\text{C}$  with a slight flow minimizes the fog. An optical device is a suitable alternative for measurements under these conditions.

**3.2.3 Special Specimen Grips.** Type and design varies with material specimen shape and test procedure (see Methods B and C). Grips must apply sufficient pressure to prevent cutting (break) and minimize slip during extension to meet the test procedure requirements. See Note 1.

**Note 1:** Some slip will occur during extension. Too much slip will not produce the step sequence curve loops (see 4.3.9.1 Method A; 4.3.13.12.1 Method B; and 4.3.14.8.1 Method C). Slip (if any) must be uniform across the entire gripped length of the test specimen. Reject test specimens showing localized slip during extension.

**3.2.3.1 Tension Grips.** Uniaxial test. Use standard grips described in and for ASTM D412 measurements.

**3.2.4 Dimensional Measuring Device - Dial Micrometer.** Shall conform to Practice ASTM D3767 (Method A).

## GM Confidential

© Copyright 2018 General Motors Company All Rights Reserved

February 2018

Page 2 of 25



**Documents**

Document Sharing Hub

**3.2.4.1 Dimensional Measuring Device.** Linear calipers with a 150 mm minimum scale length.

**3.2.5 Non-contact Strain Measuring Devices.**

**3.2.5.1 LASER.** Extensometers equipped with laser diodes in continuous wave (cw) mode or helium neon (HeNe) type (mW), emitting a visible wavelength. Use parallel scanning (Class II, IIIa or IIIb) of the test specimen. See 3.2.10.1 Non-contact Strain Measurement – Optical.

**3.2.5.2 Reflective Tape Strips.** Attach the specimen surface in area of intended measurement. LASER or optical device measures movement between strips upon extension.

**3.2.6 Hollow Punch.** 6.3 mm and 75 mm. See Mayhew Tools Catalog. Both sizes are for Method C specimen preparation (Figure 5).

**3.2.6.1 Cutting Die or Hole Punch, 3.17 mm (1/8 in).** See Mayhew Tools Catalog. For Method D specimen preparation.

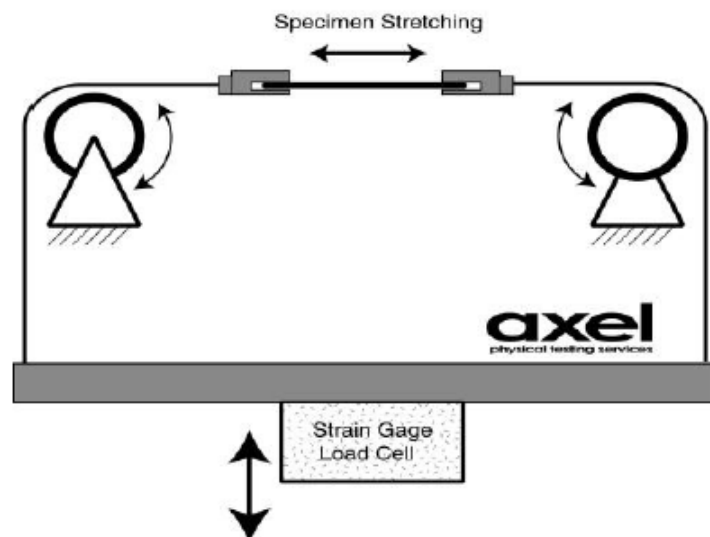
**3.2.7 Thermocouples.** Temperature control devices must be capable of measuring in -40 °C to +150 °C range to  $\pm 2$  °C accuracy. These two devices meet these requirements:

**3.2.7.1 Resistive temperature differential (RTD) sensor.** American National Standards Institute (ANSI) Type E, K, or T thermocouple, solid bare wire diameter (gauge) with wire insulation.

**3.2.7.2 Analog.** Available with test cabinet. Capable of measuring within  $\pm 2$  °C of the specified temperatures.

**3.2.8 Miller-Day Equibiaxial Tension Apparatus.** This apparatus is built from blueprints and parts list by Axel Products, Ann Arbor, Michigan. The fixture (Figure 10) for testing circular sheet specimens consists of a 1008/1010 steel circular base. Attached at equidistant points around the specimen are 16 grips, each attached to its own stainless steel wire or cable (dimensions in millimeters). Each cable is routed radially outward over a pulley and turns 90 degrees down with all attached to a large loading plate. When the plate moves, all of the grips move radially and at equal distance. The force required to move the common loading plate is continually measured by a strain gage load cell (Figure 1). The loading plate movement control and the load cell performance must meet the test machine requirements in 3.2.1.

**Figure 1: Side View of Equibiaxial Tension Apparatus**



**3.2.8.1 Equibiaxial Tension Apparatus Temperature Chamber.** The apparatus (3.2.8) must accommodate an environmental chamber meeting 3.2.2. Note LASER window in top of round metal cover (Figure 2). This unit is built from prints and material list by Axel Products, 2255 South Industrial Hwy., Ann Arbor, Michigan 48104.

**GM Confidential**

© Copyright 2018 General Motors Company All Rights Reserved

February 2018

Page 3 of 25



**Documents**

Document Sharing Hub

Figure 2: Photo of Equibiaxial Temperature Chamber



**3.2.9 Volumetric Compression Fixture.** The fixture for testing button specimens consists of a 1008/1010 steel circular base, plunger diameter 6.350 mm +0.0127 mm/-0.0 mm (0.2500 in +0.0005 in/-0.0000 in) and hole diameter 6.3500 mm +0.000 mm/-0.0127 mm (0.2500 mm +0.0000 mm/-0.0005 in) see Figure 11. The fixture is mounted to a plate and placed between the compression plates on the tester.

**3.2.10 Optional Equipment.** The following alternatives are listed by function, as a replacement for a basic item or a convenience item not included in 5.1.

**3.2.10.1 Non-contact Strain Measurement – Optical.** A suitable alternative to the LASER for low temperature measurement if fogging occurs in the chamber window.

**3.2.10.1.1 Video.** Permits visual recording of strain.

**3.2.10.2 Data Collection.** All have same strain rate (points/second). The strain and load signals together are simultaneously sampled and recorded. Variable data recording rates are possible using MERLIN (Instron) or TESTWORKS (Minnesota Testing Systems) programs.

**3.2.10.3 Mirror.** Size and mounting sufficient to reflect LASER or optical beam across bench marks. Used in angular beam deflection scanning of extended test specimen.

**3.2.10.4 Digital Thermocouple.** Capable of measuring within  $\pm 2$  °C of the specified temperatures.

**3.3 Test Vehicle/Test Piece.** Prepare Method A, B, C, and D test specimens from slabs to ASTM D3182, ISO 2393 or JIS K6299 dimensional requirements, vulcanized for a time and at a temperature specified by the material source. Specimen molding may create anisotropic or a mill/flow direction causing variation in physical property measurement. Report results in the direction indicated by the ASTM or ISO method. If no direction is indicated, test and report in the lowest result direction. Optional ASTM D395 type 2 buttons can be used for Method D test specimens. All specimens from one slab shall have the same test number (Figure 4a).

**3.3.1 ASTM Test Slab Hardness.** Measure compounds using ASTM D1415 or ISO 48, Method B micro-hardness at three locations. Each measurement must be at least 25 mm from the other and at least 12 mm from the edge of the slab. Do not ply slab specimens.

**3.3.2 Specimen Conditioning.** Test specimens shall be pre-conditioned at 20% to 90% relative humidity (RH) and +23 °C for at least 16 h before testing. The minimum time permitted from compound mixing, molding and

**GM Confidential**

© Copyright 2018 General Motors Company All Rights Reserved

February 2018

Page 4 of 25

**AVA Documents**  
Document Sharing Hub

cutting of test specimens is 72 h. A longer time (up to 120 h) may be required to enable the test pieces to attain substantial equilibrium in accordance with ISO 23529.

**3.3.3 Number of Test Specimens.** Run three (3) for each set.

**3.3.4 Minimum Sampling Requirements.** Test specimens used to run Methods A, B and C shall be from the same compound slab. See slab sample specimen layout in Figure 4. Method D test specimens are cut from an ASTM D395 Type 1 button or plied from ASTM D3182, ISO 2393 or JIS K6299 slabs. Use three (3) ASTM D3182 slabs to produce one (1) data set per test. To perform all the methods (A through D) at three temperatures on a single compound requires twelve (12) ASTM slabs, and four (4) temperatures requires 16 slabs. Requests for additional retain slabs are at the discretion of the test lab. See Table 2.

**3.3.4.1** The use of a four-cavity mold, as described in ASTM D3182, ISO 2393 or JIS K6299, and test specimens cut from the same slab reduces test variation from individual sample (single mold) or special specimen shape mold conditions. See Figure 4a and 3.3.

**3.3.5** With the exception of first time stretch (4.3.10), test specimens are not extended to break, but some may break during testing. See 4.3.9.

**3.4 Test Time.** On a single compound analysis for Methods A through D. Multiple submissions do not necessarily double the times. Duplicate instrumentation is the limiting factor.

Calendar time: 21 days

Test time: 110 h  
(approximate)

Coordination time: 10 h

**3.5 Test Required Information.** A standard form (Material Submission for Finite Element Data) is submitted with the slabs and coefficient of linear expansion cubes (GMW16973). Instructions for completing the form are included. All required form fields must be completed before testing can begin. The electronic form is available on the GM Material Database webpage from GM Engine Materials Engineering or the Finite Element Analysis Group. Since form content can change over time, confirm the latest version is used.

**3.5.1 Test Slab Identification.** Use marking practices that are legible and remain so during shipping and storage. The method of marking must not react with the slab material. Each slab shall have the following markings:

- Material type using ISO or ASTM classification codes (ACM, AEM, etc.)
- Lot and batch number.
- Source and compound number.
- Signify L for lab or P for production mixed material.
- Numbered one through four from the first heat (since each mold has four cavities). Additional slabs from another heat are numbered 5 through 8. The process is repeated (9 to 12 or 13 to 16) for the final heat.
- All test specimens from one slab have the same number. See Figure 4a.
- If single cavity molds are used, indicate the heats as individual using the letter "I" after the number on the slab (e.g., 5I).
- Mold flow direction (indicate on slabs with arrow pointing in direction of flow).

**3.5.2 Test Slab Shipping and Handling.** Each slab shall be in an individual bag with an air tight seal strip. Bag the samples within 2 h of the end of the ASTM D3182, ISO 2393, or JIS K6299 conditioning following molding (3.3.2). Paperwork shall accompany all test slabs and is available from the Engine Materials Engineering or Analysis Group personnel at GM Global Propulsion Systems (GPS).

**3.5.3 Retesting.** All test data generated on a specific compound formula will be reported to GM no matter what compound designation code is used to represent that formula. This includes any and all additional testing done for whatever the reason. The report will identify the retested conditions and all results.

**3.6 Personnel/Skills.** Technicians (operators) must be experienced in specimen preparation and equipment operation. It is an acquired skill learned through application. Dedicated personnel are recommended for these procedures.

**GM Confidential**

© Copyright 2018 General Motors Company All Rights Reserved

February 2018

Page 5 of 25

## 4 Procedure

### 4.1 Preparation.

#### 4.1.1 Method A - Uniaxial Test Specimens.

**4.1.1.1 Die.** The shape and dimensions of the die for preparing specimens shall conform to those shown in Figure 4.

**4.1.1.2 Test Specimen Thickness.** Measure cut specimens using a device described in 3.2.4. Record the thickness in millimeters at the ends and middle of the narrow portion (dimension L found in ASTM D412) of the test specimen. Average the results and report one reading on the form.

#### 4.1.2 Method B – Planar Tension Test Specimens.

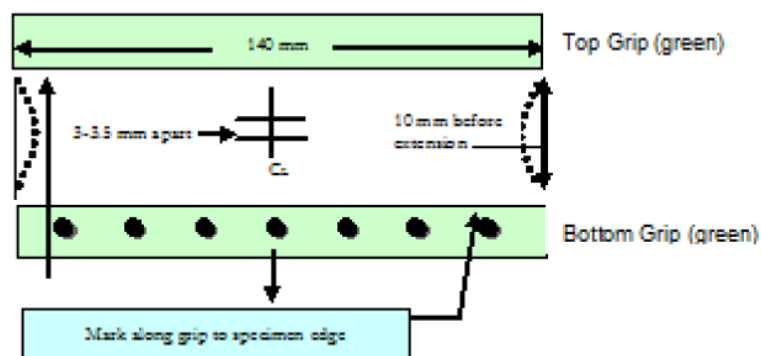
**4.1.2.1 Test Specimen Dimensions.** The shape and dimensions of the straight specimens shall conform to those shown in Figure 3 (see Table 1: Description of All Test Specimens). Specimens shall be cut from ASTM D3182, ISO 2393 or JIS K6299 slabs. See Note 2.

**Note 2:** A scroll-ended specimen is not recommended since its preparation requires a separate mold and conditions that may vary from the standard slab. A properly designed grip is the solution to maintaining parallelism without slip during extension. A reliable grip design was developed by Axel Products for slab specimens. Concerns over grip slip are minimized since planar tension tests are run to 100% or failure without excessive extension.

**4.1.2.2 Test Specimen Thickness.** Measure cut specimens using a device described in 3.2.4. Record the thickness in millimeters at five (5) equidistant points across the width of each specimen (see Figure 3). Average the results and report one reading.

**4.1.2.3 Test Conditions.** Deviations from the requirements of this standard shall have been agreed upon. Such requirements shall be specified on component drawings, test certificates, reports, etc.

Figure 3: Planar Tension Specimen (Method B)



GM Confidential

© Copyright 2018 General Motors Company All Rights Reserved

February 2018

Page 6 of 25



Documents

Document Sharing Hub

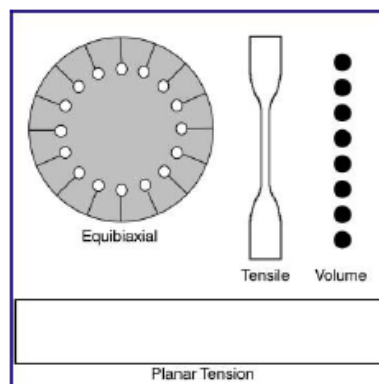
Table 1: Description of All Test Specimens

| Description of All Test Specimens Test Method | Specimen Type/Dimensions (millimeters)                                                                  | Comments                                                                |
|-----------------------------------------------|---------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------|
| 40 to 90 IRHD micro-hardness                  |                                                                                                         | ASTM D1415 or ISO 48                                                    |
| Method A (Uniaxial Tension)                   | Dumbbell/3 wide × 33 long × 1.95 thick<br>optional 1.3 thick in compliance with international standard. | Specimen cut from same slab as B and C (see Figure 2), ASTM D412, Die D |
| Method B (Planar Tension)                     | Molded Form/<br>Straight/140 wide × 25 high × 1.95 thick<br>optional 1.3 thick                          | Specimen cut from same slab as A and C                                  |
| Method C (Equibiaxial Tension)                | Circular/75 OD x hole x 1.95 thick<br>optional 1.3 thick                                                | Specimen cut from same slab as A and B                                  |
| Method D (Volumetric Compression)             | Button or plied/6.3 dia. x 12.7 high                                                                    | Specimen water jet or rotary die cut                                    |

dia. = diameter

OD = outside diameter

Figure 4: Standard Test Specimen Orientation from ASTM D3182 Slab



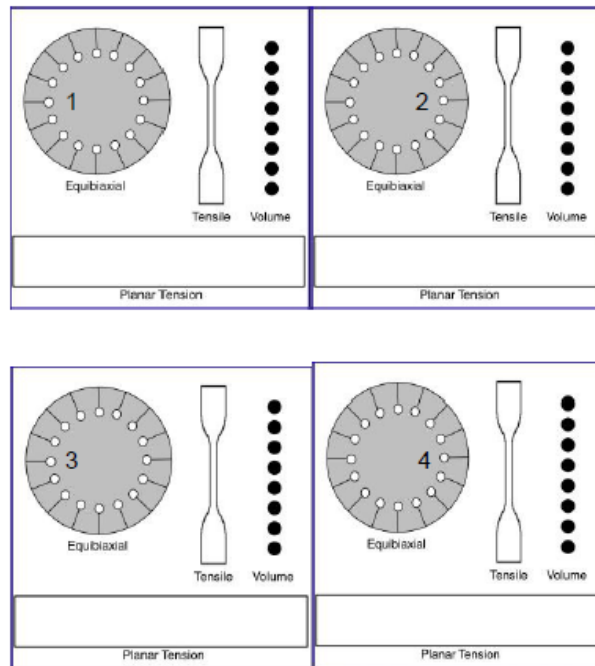
GM Confidential

© Copyright 2018 General Motors Company All Rights Reserved

February 2018

Page 7 of 25

Figure 4a: Numerical Sequence for Four Cavity Mold Specimens

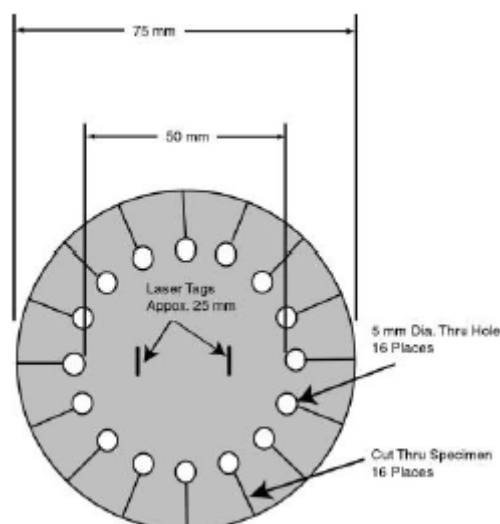


#### 4.1.3 Method C – Equibiaxial Test Specimen.

**4.1.3.1 Specimen.** One from the same ASTM D3182, ISO 2393 or JIS K6299 slab. See Figure 4. The shape and dimensions of the die for preparing circular specimens shall conform to those shown in Figure 5.

**4.1.3.2 Description.** Rotary or die cut a 75 mm diameter circle from an ASTM D3182 slab. Divide the circle into 16 equal sections, drawing lines using a protractor with a silver ink pen. From the center using a compass, (avoid making a hole in the test specimen) mark an inner circle 50 mm in diameter. Measure using calipers. At the outside edge of this circle, punch 3.2 mm holes at each line (see Figure 5) intersecting the circle. From each punched hole, using a straight edge as a guide, cut *through* the rubber along the marked line to the outside. A clear plastic template is recommended for marking and cutting test specimens from slabs.

Figure 5: Miller-Day Equibiaxial Tension Specimen (Method C)



**GM Confidential**

© Copyright 2018 General Motors Company All Rights Reserved