



Designation: D945 – 22

Standard Test Methods for Rubber Properties in Compression or Shear (Mechanical Oscillograph)¹

This standard is issued under the fixed designation D945; 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.

1. Scope

1.1 These test methods cover the use of the Yertzley mechanical oscillograph for measuring mechanical properties of rubber vulcanizates in the generally small range of deformation that characterizes many technical applications. These properties include resilience, dynamic modulus, static modulus, kinetic energy, creep, and set under a given force. Measurements in compression and shear are described.^{2,3}

1.2 The test is applicable primarily, but not exclusively, to materials having static moduli at the test temperature such that forces below 2 MPa (280 psi) in compression or 1 MPa (140 psi) in shear will produce 20 % deformation, and having resilience such that at least three complete cycles are produced when obtaining the damped oscillatory curve. The range may be extended, however, by use of supplementary masses and refined methods of analysis. Materials may be compared either under comparable mean stress or mean strain conditions.

1.3 Computerized data acquisition systems and data evaluation methods for Yertzley Mechanical Oscillograph are included. The mechanical portion of the oscillograph remains the same. In the computerized type (digital data acquisition and recording), the mechanical recording mechanism has been replaced with a displacement transducer and digital data acquisition system, by which the required calculations are such that the results are available immediately and recorded in real time.

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

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 A survey of some aspects of hysteresis and modulus in dynamic performance of polymers is available in a paper by Payne, A. R., “The Role of Hysteresis in Polymers,” *Rubber Journal*, January 1964, p. 36.

³ One method of correlating fundamental data from the Yertzley oscillograph with dynamic tests at constant amplitude is described by Baldwin, F. P., in his paper, “Determination of the Dynamic Properties of Rubberlike Materials by Means of a Modified Yertzley Oscillograph,” *The Rubber Age*, April 1950.

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, health, and environmental practices and determine the applicability of regulatory limitations prior to use. For a specific warning see 12.14.

1.6 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.

2. Referenced Documents

2.1 ASTM Standards:⁴

D832 Practice for Rubber Conditioning For Low Temperature Testing

D1207 Recommended Practice for Classifying Elastomeric Compounds for Resilient Automotive Mountings (Withdrawn 1971)⁵

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

D5992 Guide for Dynamic Testing of Vulcanized Rubber and Rubber-Like Materials Using Vibratory Methods

2.2 SAE Standard:

SAE J16 Classification of Elastomer Compounds for Automotive Resilient Mountings^{6,7}

3. Terminology

3.1 Definitions of Terms Specific to This Standard:

⁴ 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.

⁵ The last approved version of this historical standard is referenced on www.astm.org.

⁶ Available from Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, PA 15096.

⁷ The Yertzley oscillograph was originally described in detail in the paper by Yertzley, F. L., “A Mechanical Oscillograph for Routine Tests of Rubber and Rubber-Like Materials,” *Proceedings, ASTM*, Vol 39, 1939, p. 1180; also *Rubber Chemistry and Technology*, Vol XIII, No. 1, January 1940, p. 149.

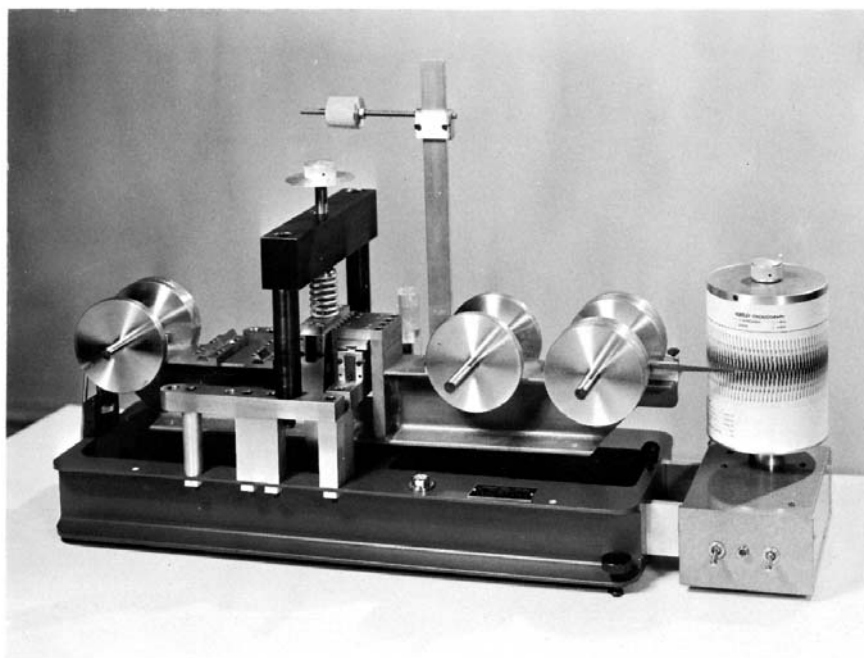


FIG. 1 Advanced Yerzley Oscillograph

3.1.1 *effective dynamic modulus, n* —a modulus calculated from the formula for simple harmonic motion in a damped free oscillation. It is a composite index which includes the effect of such diverse factors as nonlinearity of stress-strain, changing molecular energies, and heat losses.

3.1.2 *point modulus, n* —the ratio of total stress (force/area) to total strain (change in dimension/unstressed dimension) at one point of the stress-strain curve. Sometimes called the “secant modulus,” it is equal to the slope of a line from the origin to the chosen point.

3.1.3 *static modulus, n* —a property synonymous with “tangent modulus” and is the slope of the tangent to the stress-strain curve at a chosen point. It can provide a reference for comparison with the effective dynamic modulus at that point.

3.2 Acronyms:

3.2.1 *AYO-IV*—Advanced Yerzley Oscillograph IV.

3.2.2 *DMYO-V*—Dynamic Mechanical Yerzley Oscillograph V.

4. Summary of Test Methods

4.1 Specimens are loaded by an unbalanced lever and the resultant deflections are recorded on a chronograph. This permits calculations to be made of static modulus at any stage of a stepwise loading or unloading schedule. Creep and recovery rates, including set under prescribed conditions, can be obtained. Since the lever is supported on a knife edge, the system can be impact-loaded to produce a damped free oscillation trace. This trace yields a dynamic modulus, a resilience index, an oscillation frequency, and a measurement of stored energy.

4.2 Three test methods are described:

4.2.1 Method A employs the the original Yerzley oscillograph with the mechanical data recording equipment consisting of a chronograph and a pen attached to the end of the beam.

4.2.2 Method B introduces the displacement transducer and a data acquisition system, replacing the pen and chronograph.

4.2.3 Method C introduces a new test machine configuration derived from the Yerzley Oscillograph, DMYO-V. This new machine incorporates a load cell as well as a displacement transducer. This configuration enables the measurement of viscoelastic properties such as the actual phase angle between load and displacement at natural frequency.

5. Significance and Use

5.1 The rubber properties that are measurable by these test methods are important for the isolation and absorption of shock and vibration. These properties may be used for quality control, development and research.

5.2 Measurements in compression are influenced by specimen shape. This shape factor may be described as the ratio of the loaded surface area to the unloaded surface area. In applying data from a compression specimen, shape factor must be incorporated into the mathematical transferal to the application.

6. Apparatus

6.1 The essential features of the apparatus^{7,8} (Method A illustrated in Fig. 1 and Fig. 2; Method B

⁸ The sole source of supply of the Yerzley oscillograph known to the committee at this time is Tavdi Co., Inc., P.O. Box 298, Barrington, RI 02806, www.tavdico.com. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee.

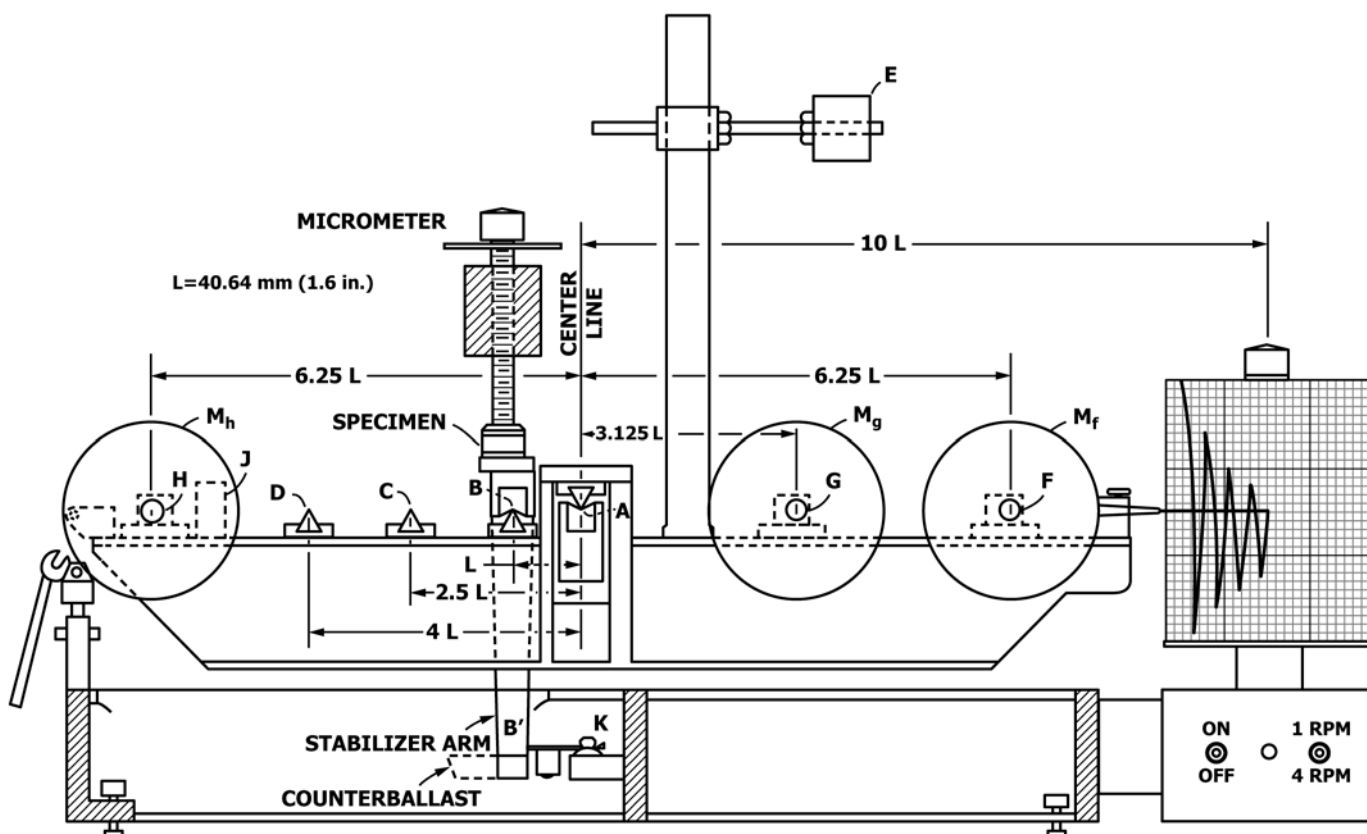


FIG. 2 Diagrammatic Sketch of Advanced Yerzley Oscillograph

illustrated in Fig. 3) are as follows:

6.1.1 The beam shall be supported at its center by a knife-edge, A, and shall be so designed that a test specimen placed beneath the micrometer can be loaded by placing standard masses alternatively on front and back portions of the cross-rod, F, at the pen end of the beam. A second knife-edge, B, and a stabilizing arm, B', (as shown in Fig. 2), shall be used to apply load to the test specimen and to maintain parallelism of the loading platens. Optional knife-edges, C and D, may be used to extend the range of the oscillograph.

6.1.2 *Method A*—A pen shall extend lengthwise from the beam to record deflections on the oscillogram automatically. From Fig. 2, it is apparent that the deflection of the specimen under test will be magnified by the travel of the pen in proportion to the lever ratio which will be 10:1 when the sample is on the inner test position, B. Therefore, a deformation of 2.5 mm, for example, will be registered on the oscillogram as a vertical displacement of 25 mm.

6.1.3 *Method B*—The pen and chronograph have been replaced with a displacement transducer and a data acquisition subsystem.

6.1.4 The masses, M_F , M_G , and M_H , derive from the mass of accurately machined disks, 99.06 mm in diameter with a central hole 12.7 mm in diameter. Standard masses shall be an integral or fractional multiple either of 641.252 g (1.41372 lb) for convenience of testing in inch-pound units or of 489.464 g for greater convenience of testing in SI units. The lever ratio for the masses is 6.25:1 for the outer mass position in reference to the inner specimen position. Using the 6.25:1 ratio, each

unbalanced mass on the pen end of the beam therefore will produce the following forces on the specimen on the inner position at W_{S_r} :

	Mass Value	Force Resulting From 6.25:1 Ratio
SI units	489.46 g	30.000 N
Inch-pound units	1.4137 lb	8.8357 lbf

6.1.5 It follows that positioning the masses on the inner mass position, M_G , will reduce the load values to half of the foregoing values.

6.2 *Method C*—DMYO-V is illustrated in Fig. 4. The test machine has been redesigned without compromising concepts fundamental to the Yerzley Oscillograph. Just like its predecessor, all fulcrums are on the same plane, minimizing cosine error. There are four weights at 2.27 kg (5 lb) each, which are installed on a motor driven weight table. This configuration results in a moment arm that can vary between 10 cm (4 in.) and 28 cm (11 in.). Besides a displacement sensor, a load cell is also integrated into the machine. The data acquisition electronics allow sampling of both sensors at up to 500 times a second. The “hook” of AYO-IV has been replaced with an electromagnetic trigger on DMYO-V, all test procedures are automated improving repeatability.

MEASUREMENTS IN COMPRESSION – METHODS A, B, AND C

7. Test Specimens for Methods A, B, & C

7.1 Solid Rubber Specimens:

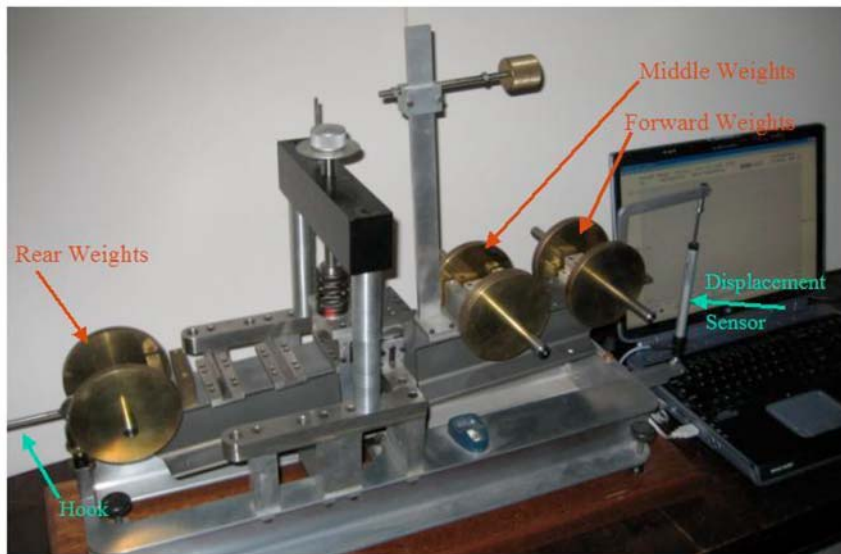


FIG. 3 Method B Yerzley Oscillograph AYO-IV With Displacement Sensor and Computer System

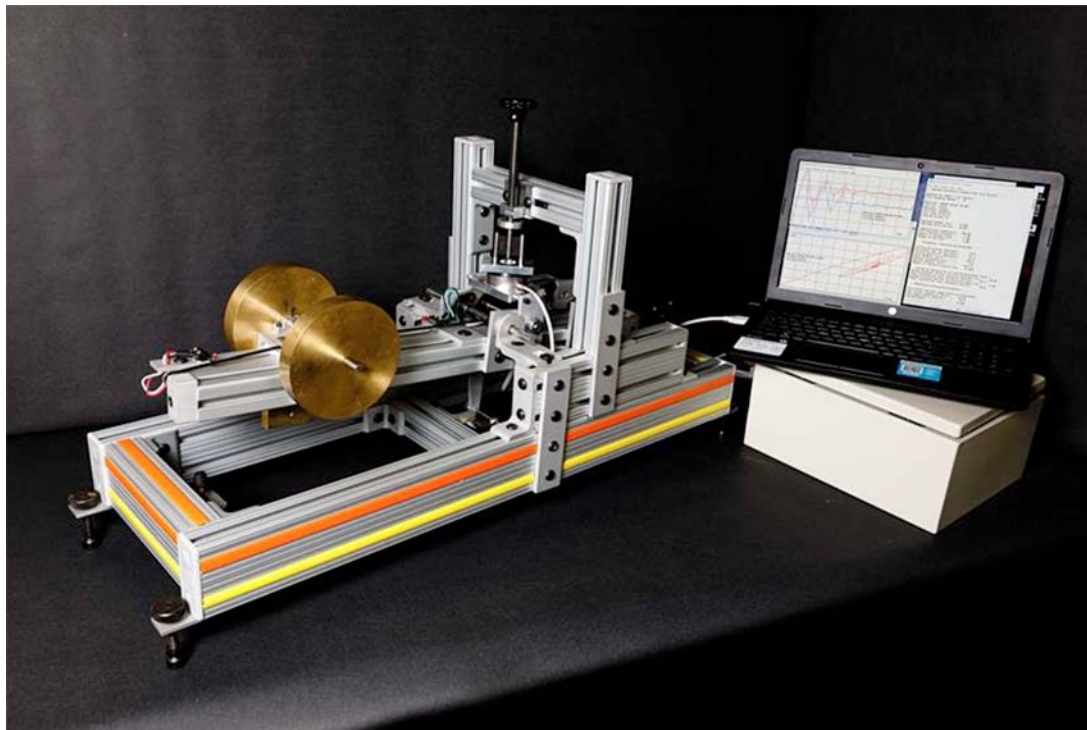


FIG. 4 Method C: The testing machine and its control box along with the laptop computer for test sequencing and data evaluation

7.1.1 Test specimens for all methods are identical. Methods B and C can also handle non-circular cross sections provided the “shape factors” are consistent with the standard specimen. At least two specimens shall be tested, except that at least three shall be required if measurement of creep is to be included. The test specimens for measurements in compression shall be right circular cylinders chosen from the following alternatives:

Shape Factor	Primary Practice	Diameter
0.390	SI units	19.5 ± 0.13 mm
0.375	Inch-pound units	0.75 ± 0.005 in.

Shape Factor	Height	Reference Area of Nominal Circle
0.390	12.5 ± 0.25 mm	300 mm^2
0.375	0.5 ± 0.010 in.	0.442 in.^2

7.1.2 The specimens may be molded, or cut from finished products and buffed to the specified dimensions. Test specimens shall be free from porosity, nicks, and cuts. (Molded specimens are preferred for dimensional accuracy and consistency.)

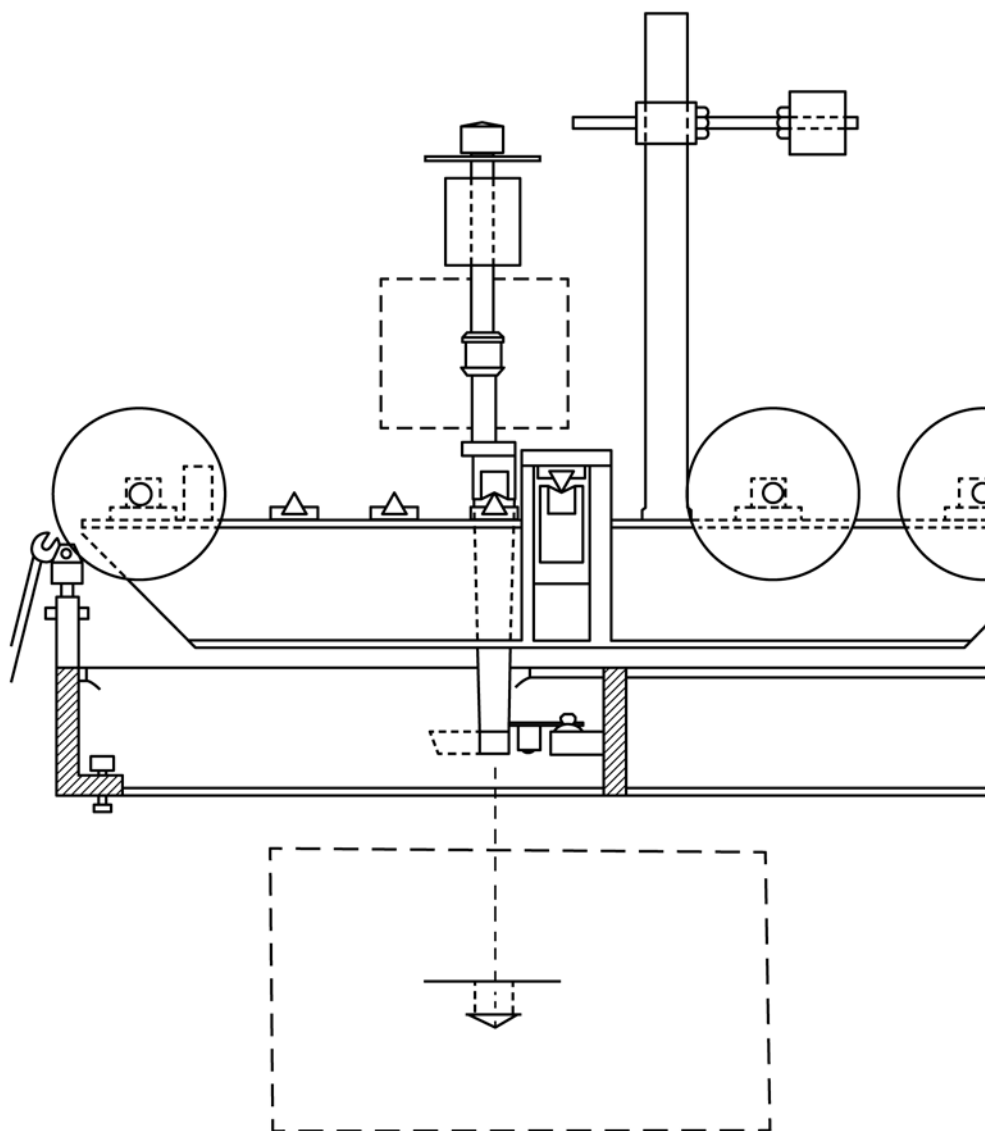


FIG. 5 Section of Oscillograph to be Enclosed for Tests at Other than Room Temperature

7.2 Cellular Test Specimens:

7.2.1 Specimens of cellular rubber shall be prepared as follows: The specimen shall be a circular cylinder cut with a circular metal die 43.70 ± 0.01 mm (1.720 ± 0.001 in.) in inside diameter for cutting the specimen in a drill press or similar device for rotating the die. The pressure applied to the die shall be sufficiently small to keep “cupping” of the cut surfaces to a minimum. In some cases, it may be necessary to freeze the cellular rubber before cutting the specimen in order to obtain parallel cut surfaces. To facilitate cutting of the specimen with smooth-cut surfaces and square edges, the die may be lubricated with water containing a wetting agent and a corrosion inhibitor such as 0.5 % sodium chromate or with silicone mold release emulsion before each specimen is cut. If a lubricant is used, the specimen shall be permitted to dry before testing. The circular bases of the specimens shall be parallel to each other and at right angles to the axis of the cylinder. The area of the circular bases is 15.00 cm^2 (2.323 in.^2).

7.2.2 The specimen shall be not less than 6.4 mm (0.25 in.) and not more than 29 mm (1.125 in.) in thickness. If the material is too thick, it shall be sliced to the required thickness.

7.2.3 Unless otherwise specified in the detail specification, materials thinner than 6.4 mm (0.25 in.) shall be plied up to obtain the required thickness, in which case the report is to include the number of plies.

8. Conditioning for Methods A, B, & C

8.1 Conditioning procedures for all methods are identical. Expose the test specimens and the apparatus to the temperature of the test for sufficient time to ensure temperature equilibrium. For testing at low temperatures (below room temperature), the section of the oscillograph to be enclosed shall be one of those shown by broken lines in Fig. 5. The enclosure shall be equipped with a shelf for storing test specimens and supplied with a circulating atmosphere at the temperature of test. Unless otherwise specified, the cold chamber and testing conditions shall conform to the conditions specified in 10.8.2.

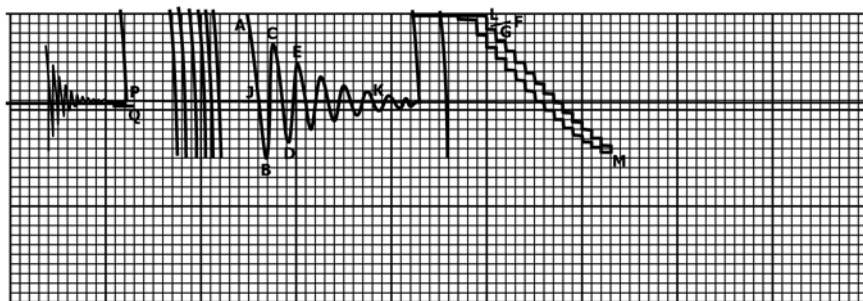


FIG. 6 Typical Compression Oscillogram

After the test specimens have been conditioned at the test temperature, proceed in accordance with Section 9. Similar conditioning requirements apply also to tests at elevated temperatures.

9. Procedure

9.1 *Procedure for Solid Rubber Specimens*—Three categories of test operation are described separately under subsequent section headings to provide data for purposes as follows:

9.1.1 In 9.4 – 9.6 for initial creep and set under a given load.

9.1.2 In 9.10 – 9.12 for Yertzley resilience and hysteresis, point modulus, frequency in hertz, effective dynamic modulus, and maximum impact energy absorbed at a given test load value.

9.1.3 In 9.13 – 9.17 for stepwise loading and unloading and hysteresis loop, and stresses in pascals or in pounds-force per square inch at any deformation.

9.1.4 Depending on the purpose of any test program, primary reliance may be placed on any one of the foregoing categories, on a combination of two categories, or upon all three. It is important, however, to record adequately all data required to identify the test conditions fully.

9.2 Lock the beam of the oscillograph in position by means of the release hook at the left end of the machine and remove all masses. Place the test specimen centrally on the lower platen between the grit sides of two pieces of 400 grit A sandpaper (Note 1). Adjust the micrometer until the upper platen rests snugly against the sandpaper without deforming the test specimens; then lock the micrometer by means of the set screw or lock nut. This setting can be verified as follows:

NOTE 1—Silicon carbide particles have an average size of $22 \pm 2 \mu\text{m}$.

9.2.1 Upon disengaging the release hook the recording device (pen or transducer) end should retain its position. If the recording device (pen or transducer) drops noticeably, a change of 0.02 mm (0.001 in.) may be visibly observed, the micrometer must be readjusted downward.

9.2.2 When this adjustment is completed and verified, reengage the hook. Now apply a small downward force by hand on the recording device (pen or transducer) end of the beam. If the added force depresses the beam, the micrometer platen is too low. Readjust the micrometer until the micrometer

setting is correct. Opening and closing the release hook should then have no effect on the position of the recording device (pen or transducer).

9.3 *Method A*—Place the graph paper on the chronograph drum and adjust its position so that the zero position of the pen point is on one of the horizontal lines of the paper. An engineering grade of graph paper ruled in 1 in. squares and subdivided into ten equal squares per inch shall be used for measurements in inch-pound units. A quality grade of graph paper ruled in 1 cm squares subdivided in millimeter squares is preferable for measurements in SI units, although it should be noted that for 4 rpm and 1 rpm speeds of the chronograph 25.4 mm on the horizontal scale equals 1 and 4 s, respectively.

9.4 *Measurement of Initial Creep and Set*—With the beam elevated and with the hook engaged prepare to add masses to the recording device end of the beam prior to recording both the initial impact on the sample and the subsequent creep. Normally the test will be directed toward a final total deformation of 20 % plus the value of the creep. If creep of 2 % should develop, the total deformation thus would be 20 + 2 %, or 22 %. A tolerance of ± 2 % has been found convenient. Trial and error with one sample may be used to establish the necessary number of masses. When the load value is established, proceed.

9.5 With the hook engaged, a fresh test specimen, sandpaper in position, the correct micrometer setting, and the established number of masses installed, switch on the power to the drum, to rotate at 4 rpm in order to draw the horizontal reference line at the top of the chart. This will also take up slack in the gear train driving the drum. As the drum approaches the beginning of the second revolution, change the drum speed to 1 rpm. About three small squares into the second revolution release the hook, allowing the beam to fall in an impact on the specimen, as indicated in Fig. 6. Allow the drum to rotate one or more complete revolutions beyond the end of any oscillations. Stop the motor. The creep of the sample after the end of the oscillations will be recorded on the chart for 1 min or more. If desired, the creep for a longer time may be recorded by timing a longer period and observing the further slow downward motion of the pen as a vertical downward trace. The amount of further drift after the longer time interval can be