Designation: C 769 – 98 (Reapproved 2005)

An American National Standard

# Standard Test Method for Sonic Velocity in Manufactured Carbon and Graphite Materials for Use in Obtaining an Approximate Young's Modulus[1]

This standard is issued under the fixed designation C 769; 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.

## 1. Scope

1.1 This test method covers a procedure for measuring the sonic velocity in manufactured carbon and graphite materials having a grain size less than 0.80 mm (1⁄32 in.). The sonic velocity can be used to obtain an approximate value for Young's modulus.

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

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:* [2]

C 559 Test Method for Bulk Density by Physical Measurement of Manufactured Carbon and Graphite Articles

C 747 Test Method for Moduli of Elasticity and Fundamental Frequencies of Carbon and Graphite Materials by Sonic Resonance

IEEE/ASTM SI 10 Standard for Use of the International System of Units (SI) (the Modern Metric System)

## 3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *longitudinal sonic pulse*—a sonic pulse in which the displacements are in the direction of propagation of the pulse.

3.1.2 *pulse travel time,* ($T_t$)—the total time, measured in seconds, required for the sonic pulse to traverse the specimen being tested, and for the associated electronic signals to traverse the circuits of the pulse-propagation circuitry.

3.1.3 *zero time,* ($T_o$)—the travel time (correction factor), measured in seconds, associated with the electronic circuits in the pulse-propagation system.

## 4. Summary of Test Method

4.1 The velocity of sound waves passing through the test specimen is determined by measuring the distance through the specimen and dividing by the time lapse, between the transmitted pulse and the received pulse.[3,4] An approximate value for Young's modulus can then be obtained as follows:

$$E = \rho v^2 \quad (1)$$

where:

$E$ = Young's modulus of elasticity, Pa,
$\rho$ = density, kg/m$^3$, and
$v$ = signal velocity, m/s.

Strictly speaking, the elastic constant given by this measurement is not $E$ but $C_{33}$, provided the sonic pulse is longitudinal and the direction of propagation is along the axis of symmetry.[3,4]

## 5. Significance and Use

5.1 Sonic velocity measurements are useful for comparing materials.

5.2 A value for Young's modulus can be obtained for many applications, which will generally be within 10 % of the value obtained by other methods, such as in Test Method C 747.

## 6. Apparatus

6.1 *Driving Circuit*, which consists of an ultrasonic pulse generator capable of producing pulses in a frequency range from 0. 5 to 2.6 MHz.

6.2 *Transducer*, input.

6.3 *Transducer*, output.

6.4 *Oscilloscope, dual trace* with a preamplifier and time-delay circuitry.

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[1] This test method is under the jurisdiction of ASTM Committee D02 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.F0 on Manufactured Carbon and Graphite Products.

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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.

[3] Schreiber, Anderson, and Soga, *Elastic Constants and Their Measurement,* McGraw-Hill Book Co., 1221 Avenue of the Americas, New York, NY 10020, 1973.

[4] *American Institute of Physics Handbook*, 3rd ed., McGraw-Hill Book Co., 1221 Avenue of the Americas, New York 10020, 1972, pp. 3–98ff.

6.5 See Fig. 1 for a typical setup.

## 7. Test Specimen

7.1 *Selection and Preparation of Specimens*—Take special care to assure obtaining representative specimens that are straight, uniform in cross section, and free of extraneous liquids. The specimen end faces shall be perpendicular to the specimen cylindrical surface to within 0.125 mm (0.005 in.) total indicator reading.

7.2 *Measurement of Weight and Dimensions*—Determine the weight and the average specimen dimensions to within ±0.5 %.

7.3 *Limitations on Dimensions*—The specimen shall have a diameter and length that is large compared to the wavelength of sound in the material under test.

## 8. Procedure

8.1 Connect the apparatus as shown in Fig. 1, and refer to equipment manufacturers instructions for hookup precautions. Allow adequate time for equipment warm-up and stabilization.

8.2 Provide a suitable coupling medium on transducer faces.

NOTE 1—Hydroxyethyl cellulose may be used. Petroleum jelly couples work well but may be difficult to remove for subsequent tests on the same specimen.

8.3 Bring transducer faces into intimate contact but do not exceed manufacturer's recommended contact pressures.

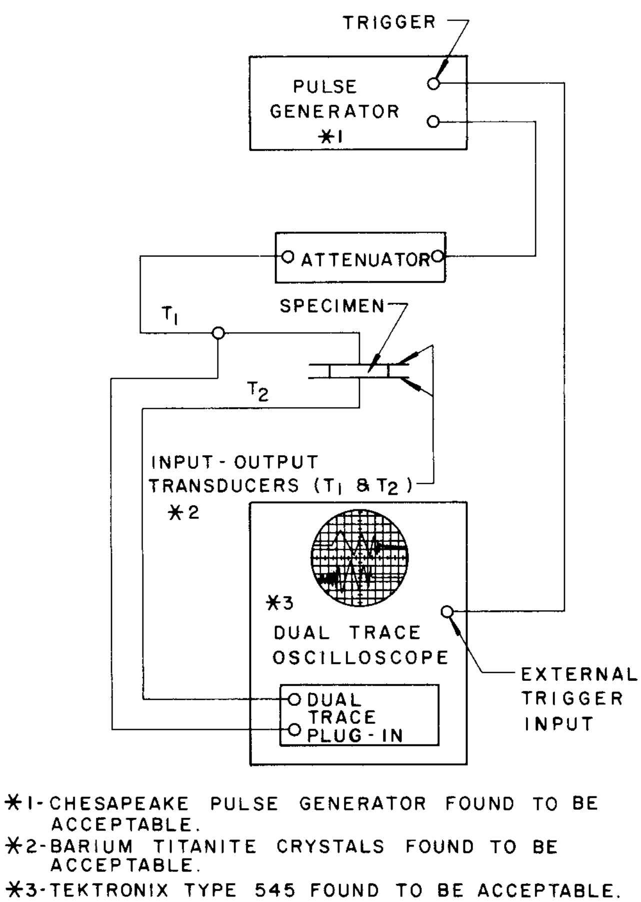


FIG. 1 Equipment Setup

8.4 Determine $T_o$, the travel time (zero correction) measured in seconds, associated with the electronic circuits in the pulse-propagation instrument and coupling.

8.5 Measure and weigh the test specimen as in 7.2.

8.6 Calculate the density of the test specimen in accordance with Test Method C 559.

8.7 Lightly grease the faces of the test specimens that will contact the transducers or provide another suitable medium for this purpose. Place the transducers against the test specimen end faces.

8.8 Tune the signal generator to transducer frequency, and adjust the electronic components to give good visual amplitude resolution on the oscilloscope.

8.9 Determine $T_t$, the total traverse time from the oscilloscope traces, as illustrated in Fig. 2, preferably by using time-delay circuitry.

## 9. Calculation

9.1 *Velocity of Signal*:

$$v = \frac{L}{T_t - T_o} \quad (2)$$

where:

$v$ = velocity of signal, m/s,
$L$ = specimen length, m,
$T_t$ = traverse time, s, and
$T_o$ = travel time, s.

9.2 Since graphites are not isotropic, the value of Young's modulus cannot be determined by a velocity measurement in only one direction. However, an approximation to Young's modulus is obtained as follows:

$$E = \rho v^2 \quad (3)$$

$E$ = Young's modulus, Pa (approximate),
$\rho$ = density, kg/m$^3$, and
$v$ = velocity of sound, m/s.

9.3 *Conversion Factors*—See IEEE/ASTM SI 10.

## 10. Report

10.1 The report shall include the following:

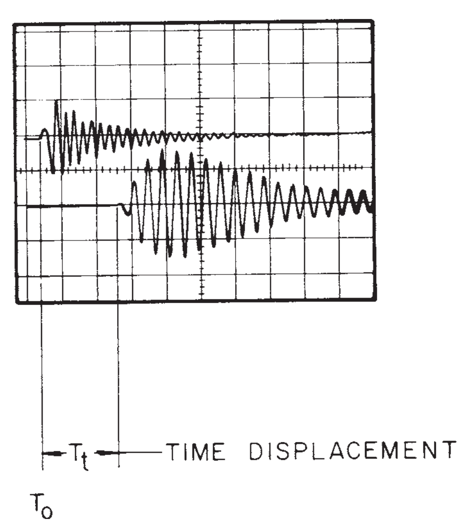


FIG. 2 Typical Oscilloscope Display

10.1.1 Specimen dimensions, weight, and test specimen orientation with respect to forming direction;

10.1.2 Sonic velocity for each specimen;

10.1.3 Density of each specimen, if calculated;

10.1.4 Young's modulus of each specimen, if calculated;

10.1.5 It is recommended that average and standard deviation values be included for each group of specimens;

10.1.6 Environmental conditions of test, including temperature, humidity, and special atmosphere (if used);

10.1.7 Frequency of transducers used and sonic velocity equipment identification;

10.1.8 Method of coupling the transducers to the specimen; and

10.1.9 As available, complete identification of the material being tested including manufacturer, grade identification, lot number and grain orientation, original billet size, and specimen sampling plan.

## 11. Precision and Bias [5]

11.1 A round-robin series of sonic velocity measurements as performed on four different materials by two laboratories. Twelve samples of each material were measured. In all, four sets of measurements were made on each group of twelve samples for a total of sixteen sets of data. The average coefficient of variance for the sixteen sets was 3.8 %, which is indicative of the sample-to-sample and measurement-to-measurement variation in each set of twelve.

11.2 There was a difference between the moduli measured on a given material by the two laboratories ranging from 0 to 14 %, which suggests that the methods used are material dependent.

11.3 Also included in the round-robin were resonant-bar-modulus (see Test Method C 747) and stress-strain modulus measurements. Differences between the resonant-bar modulus and the sonic velocity modulus were also significant, being as high as 10 %. Although most of the resonant-bar moduli are lower than the sonic velocity moduli, in one material, the reverse was true. Thus a simple correction factor cannot be applied.

11.4 The systematic differences between laboratories and materials and methods can occur for several reasons:

11.4.1 Frequency of the wave used.

11.4.2 Sample size-to-wavelength ratio.

11.4.3 Interpretation of the breakaway point on the received signal.

11.4.4 Coupling factors, such as transducer pressure.

11.4.5 Different modes of propagation for the different sample configuration used in the tests.

11.5 The value of Young's modulus obtained by this method must not be construed as accurate or absolute to better than about 10 % as evidenced by the interlaboratory differences. However, in a given laboratory setup, a relatively high degree of precision is obtainable and might be construed as an accurate value. For comparative purposes in a given material, the method is adequate, but from one material to another, the modulus comparison must be considered approximate.

## 12. Keywords

12.1 carbon; graphite; sonic; velocity; Young's Modulus

[5] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR: C05-1001.