Designation: C769 – 09

An American National Standard

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

This standard is issued under the fixed designation C769; 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 which can be used to obtain Young's modulus.

1.2 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this 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]

C559 Test Method for Bulk Density by Physical Measurements of Manufactured Carbon and Graphite Articles
C747 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 *end correction time* (T_e)—the non-zero time of flight (correction factor), measured in seconds, that may arise by extrapolation of the pulse travel time, corrected for zero time, back to zero sample length.

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

3.1.3 *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 transducer coupling medium and electronic circuits of the pulse-propagation system.

3.1.4 *zero time,* (T_0)—the travel time (correction factor), measured in seconds, associated with the transducer coupling medium and electronic circuits in the pulse-propagation system.

4. Summary of Test Method

4.1 The velocity of longitudinal 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] Provided the wavelength of the transmitted pulse is a sufficiently small fraction of the sample later dimensions, a value of Young's modulus for isotropic graphite can then be obtained using Eq 1 and Eq 2:

$$E = C_v \rho V^2 \tag{1}$$

where:

E = Young's modulus of elasticity, Pa,
ρ = density, kg/m^3,
V = longitudinal signal velocity, m/s, and
C_v = Poisson's factor.

The Poisson's factor, C_v, is related to Poisson's ratio, ν, by the equation:

$$C_\nu = \frac{(1+\nu)(1-2\nu)}{1-\nu} \tag{2}$$

If Poisson's ratio is unknown, it can be assumed as an approximation in the method. For nuclear graphites, a typical Poisson's ratio of 0.2 corresponds to a Poisson's factor of 0.9.

If the wavelength is not a small fraction of the sample lateral dimensions, and instead is much larger than the specimen lateral dimensions, then the Young's modulus, E is given by Eq 1 with C_v set to one rather than being determined by Eq 2.

---

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

Current edition approved June 1, 2009. Published July 2009. Originally approved in 1980. Last previous edition approved in 2005 as C769–98(2005). DOI: 10.1520/C0769-09.

[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, NY 10020, 1972, pp. 3–98ff.

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 be in good agreement with the value obtained by other methods, such as in Test Method C747. The accuracy of the Young's modulus calculated from Eq 1 will depend upon the uncertainty in Poisson's ratio and its impact on the evaluation of the Poisson's factor in Eq 2.

5.3 If the grain size of the carbon or graphite is greater than or about equal to the wavelength of the sonic pulse, the method may not be providing a value of Young's modulus representative of the bulk material. Therefore, it would be desirable to test a lower frequency (longer wavelength) to demonstrate that velocity is independent of frequency. Significant signal attenuation should be expected when the grain size of the material is greater than or about equal to the wavelength of the transmitted sonic pulse.

5.4 If the sample is only a few grains thick, the acceptability of the method's application should be demonstrated by initially performing measurements on a series of tests covering a range of sample lengths between the proposed test length and a test length incorporating sufficient grains to adequately represent the bulk material.

6. Apparatus

6.1 *Driving Circuit,* consisting of an ultrasonic pulse generator.

6.1.1 The user should select a pulse frequency to suit the material being tested. High frequencies are attenuated by carbon and graphite materials and, while typical practicable frequencies lie in the range 0.5 to 2.6 MHz, the user may show that frequencies outside this range are acceptable.

6.2 *Transducer,* input, with suitable coupling medium (see 8.5).

6.3 *Transducer,* output, with suitable coupling medium (see 8.5).

6.3.1 The signal output will depend upon the characteristics of the chosen transducers and the test material. It is recommended that the user analyses the input and output frequency spectra to determine optimum conditions. Band pass filters and narrow band transducers may be used to simplify the signal output which could improve the measurement of the time of flight.

6.4 *Computer,* with analogue to digital converter, or oscilloscope, and external trigger from driving circuit.

6.5 See Fig. 1 for a typical schematic setup.

NOTE 1—Some manufacturers combine items 6.1 and 6.4 into a single package with direct time readout. Such apparatus can operate satisfactorily, provided the frequency of the propagated pulse is already known, in order to check that wavelength requirements for the method are satisfied.

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 total indicator reading.

7.2 *Measurement of Weight and Dimensions*—Determine the weight and the average specimen dimensions to within ±0.2 %.

7.3 *Limitations on Dimensions*—These cannot be precisely specified as they will depend upon the properties of the material being tested. In order to satisfy the theory that supports Eq 1, as a guide, the specimen should have a diameter that is at least a factor two, and ideally a factor five, greater than the wavelength of sound in the material under test. In practice, the length of the specimen will be determined taking account of the comments in 5.3 and 5.4.

7.4 *Limitations on Ultrasonic Pulse Frequency*—Generally speaking, a better accuracy of time of flight will be obtained at higher frequencies. However, attenuation increases at higher frequencies leading to weak and distorted signals.

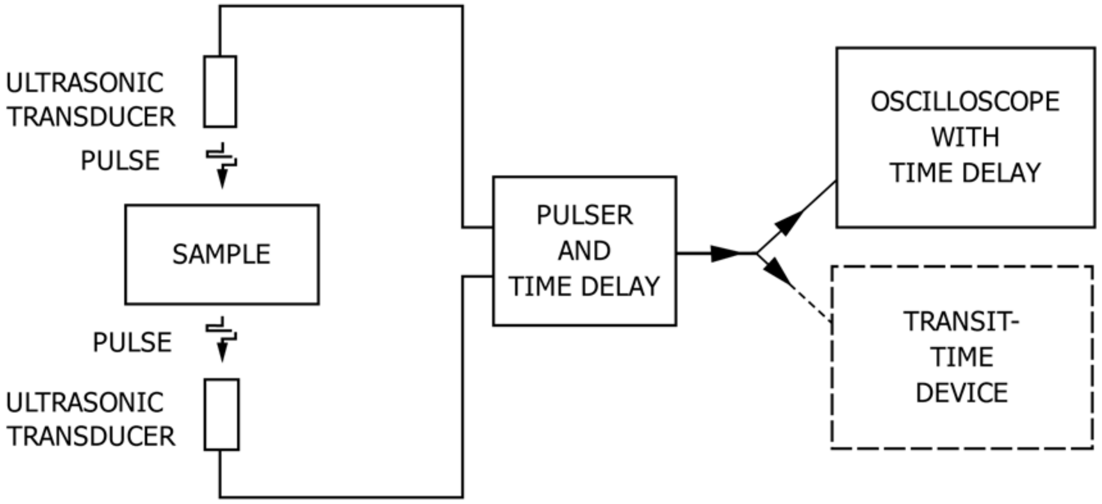

FIG. 1 Basic Experimental Arrangement for the Ultrasonic Pulsed-Wave Transit Time Technique