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Standard Guide for High-Temperature Static Strain Measurement[1]

This standard is issued under the fixed designation E1319; 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 guide covers the selection and application of strain gages for the measurement of static strain up to and including the temperature range from 425 °C to 650 °C (800 °F to 1200 °F). This guide reflects some state-of-the-art techniques in high-temperature strain measurement.

1.2 This guide assumes that the user is familiar with the use of bonded strain gages and associated signal conditioning circuits and instrumentation as discussed in (1) and (2).[2] The strain gage systems described are those that have proven effective in the temperature range of interest and were available at the time of issue of this guide. It is not the intent of this guide to limit the user to one of the strain gage types described nor is it the intent to specify the type of strain gage system to be used for a specific application. However, in using any strain gage system including those described, the proposer shall be able to demonstrate the capability of the proposed strain gage system to meet the selection criteria provided in Section 5 and the needs of the specific application.

1.3 The devices and techniques described in this guide can sometimes be applicable at temperatures above and below the range noted, and for making dynamic strain measurements at high temperatures with proper precautions. The strain gage manufacturer should be consulted for recommendations and details of such applications.

1.4 The references are a part of this guide to the extent specified in the text.

1.5 The values stated in metric (SI) units are to be regarded as the standard. The values given in parentheses are for informational purposes only.

1.6 *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.*

1.7 *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:*[3]

E6 Terminology Relating to Methods of Mechanical Testing

3. Terminology

3.1 *Definitions of Terms Common to Mechanical Testing:*

3.1.1 The terms calibration, elastic limit, error, gage factor, lead wire, modulus of elasticity, Poisson's ratio, and Young's modulus are used as defined in Terminology E6. Some important terms from E6 are reprinted here.

3.1.2 *gage factor—for strain gages*, the ratio between the unit change of strain gage resistance due to strain and the causing strain.

3.1.2.1 *Discussion*—The gage factor is dimensionless and is expressed as follows:

$$K = \frac{\frac{R - R_0}{R_0}}{\frac{L - L_0}{L_0}} = \frac{1}{\varepsilon}\frac{\Delta R}{R_0} \quad (1)$$

where:

K = gage factor,
R = strain gage resistance at test strain,
R_0 = strain gage resistance at zero or reference strain,
L = test structure length under the strain gage at test strain,
L_0 = test structure length under the strain gage at zero or reference strain,
ΔR = change in strain gage resistance when strain is changed from zero (or reference strain) to test strain, and
ε = the mechanical strain $\frac{L-L_0}{L_0}$

[1] This guide is under the jurisdiction of ASTM Committee E28 on Mechanical Testing and is the direct responsibility of Subcommittee E28.01 on Calibration of Mechanical Testing Machines and Apparatus.

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[2] The boldface numbers in parentheses refer to the list of references at the end of this guide.

[3] 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.

***A Summary of Changes section appears at the end of this standard**

3.1.3 *lead wire—for strain gages*, an electrical conductor used to connect a strain gage to its instrumentation.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *capacitive strain gage*—a strain gage whose response to strain is a change in electrical capacitance which is predictably related to that strain.

3.2.1.1 *Discussion*—Capacitive strain gages are also commonly referred to as capacitance strain gages.

3.2.2 *compensating strain gage*—a strain gage element that is subject to the same environment as the active strain gage element, and that is placed in the adjacent leg of a Wheatstone bridge to provide thermal, pressure, or other compensation in the strain gage system.

3.2.3 *electrical simulation*—a method of calibration whereby a known voltage is generated at the input of an amplifier, equivalent to the voltage produced by a specific amount of strain.

3.2.4 *free-filament strain gage*—a resistance strain gage made from a continuous wire or foil filament that is fixed to the test article along the entire length of the strain gage, and that is supplied without a permanent matrix.

3.2.4.1 *Discussion*—The matrix is an electrically nonconductive layer of material used to support a strain gage grid.

3.2.5 *integral lead wire*—a lead wire or portion of a lead wire that is furnished by a strain gage manufacturer as part of the strain gage assembly.

3.2.6 *resistance strain gage*—a strain gage whose response to strain is a change in electrical resistance that is predictably related to that strain.

3.2.7 *shunt calibration*—a method of calibration whereby a resistor or capacitor of known value is placed electrically in parallel with another resistor or capacitor in a circuit, causing a calculable change in the total resistance or capacitance that is predictably related to a specific amount of strain.

3.2.8 *signal conditioning circuit*—a circuit or instrument subsystem that applies excitation to a strain gage, detects an electrical change in the strain gage, and converts this change to an output that is related to strain in the test article.

3.2.8.1 *Discussion*—The signal conditioning circuit may include one or more of the following: bridge completion circuit, signal amplification, zero adjustment, excitation adjustment, calibration, and gain (span) adjustment.

3.2.9 *strain gage system*—the sum total of all components used to obtain a strain measurement.

3.2.9.1 *Discussion*—The strain gage system may include a strain gage; a means of attaching the strain gage to the test articles; lead wires; splices; lead-wire attachments; signal conditioning circuit and read-out instrumentation; data-logging system; calibration and control system; environmental protection; or any combination of these and other elements required for the tests.

3.2.10 *static strain*—a strain that is measured relative to a constant reference value, as opposed to dynamic strain, which is the peak-to-peak value of a cyclic phenomenon, without reference to a constant zero or reference value (Fig. 1).

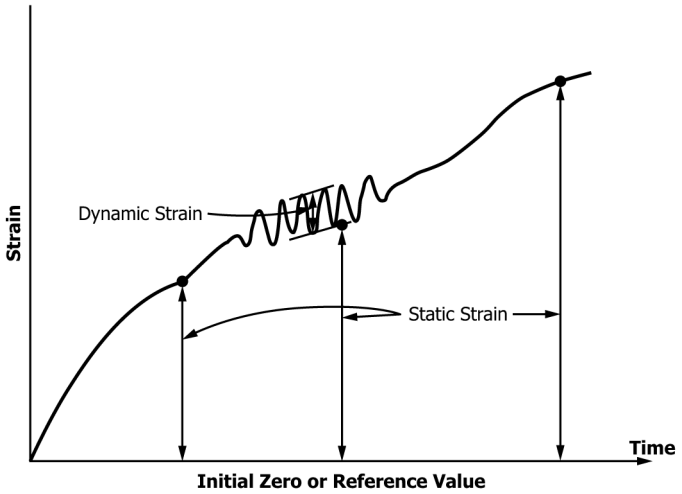

FIG. 1 Relationship Between Static and Dynamic Strain

3.2.11 *test article*—an item to which a strain gage system is installed for the purpose of measuring strain in that item.

3.2.12 *thermal compensation*—the process by which the thermal output of a strain gage system is counteracted through the use of one or more supplementary devices, such as a thermocouple or compensating strain gage.

3.2.12.1 *Discussion*—The counteraction may be integral to the strain gage system or may be accomplished by data processing methods, or both.

3.2.13 *thermal output*—the reversible part of the temperature-induced indicated strain of a strain gage installed on an unrestrained test article when exposed to a change in temperature.

4. Significance and Use

4.1 The use of this guide is voluntary and is intended for use as a procedures guide for selection and application of specific types of strain gages for high-temperature installations. No attempt is made to restrict the type of strain gage types or concepts to be chosen by the user. The provisions of this guide may be invoked in specifications and procedures by specifying those that shall be considered mandatory for the purpose of the specific application. When so invoked, the user shall include in the work statement a notation that provisions of this guide shown as recommendation shall be considered mandatory for the purposes of the specification or procedure concerned, and shall include a statement of any exceptions to or modifications of the affected provisions of this guide.

5. Strain Gage Selection Criteria

5.1 The factors listed in this section shall be considered when selecting a strain gage system for use in the temperature range specified in 1.1. The risk of compromising certain test objectives shall be evaluated.

NOTE 1—It is possible that no strain gage has all of the desired capabilities to meet all requirements of a particular test. Some test objectives will have to be modified to match the capabilities of the available strain gage selected. Guidelines for this evaluation are provided in Section 9.