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.

Designation: E1237 – 20

Standard Guide for Installing Bonded Resistance Strain Gages[1]

This standard is issued under the fixed designation E1237; 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 This guide provides guidelines for installing bonded resistance strain gages. It is *not* intended to be used for bulk or diffused semiconductor gages. This guide pertains only to adhesively bonded strain gages.

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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.4 *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.*

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2. Referenced Documents

2.1 *ASTM Standards:*[2]

E6 Terminology Relating to Methods of Mechanical Testing

E251 Test Methods for Performance Characteristics of Metallic Bonded Resistance Strain Gages

2.2 *Other Standards:*

ANSI/SEM 1-1984; Standard for Portable Strain-Indicating Instruments—Designation of Strain Gage Bridge and Color Code of Terminal Connections; August 16, 1984.[3]

3. Terminology

3.1 The terms accuracy, gage factor, lot, and type are used as defined in Terminology E6. In addition, the following terms common to strain gages from Terminology E6 are defined.

3.2 *Definitions:* Definitions of terms common to mechanical testing:

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

3.3 *Definitions of Terms Specific to This Standard:*

3.3.1 *bonded resistance strain gage*—a resistive element with a carrier that is attached by bonding to the base material so that the resistance of the element will vary as the surface of the base material to which it is attached is deformed.

3.3.1.1 *Discussion*—For a complete explanation of this term see Test Methods E251.

3.3.2 *resistance strain gage bridge*—a common Wheatstone bridge made up of strain gages used for the measurement of small changes of resistance produced by a strain gage, where the strain gages are wired in the following configuration (see also Fig. 1 and Fig. 2):

Arm 1 between + excitation and – signal
Arm 2 between – excitation and – signal
Arm 3 between + signal and – excitation
Arm 4 between + signal and + excitation

3.3.2.1 *Discussion*—In this standard, the term "strain gage bridge" is equivalent to resistance strain gage bridge.

3.3.3 *strain gage, n*—The term "strain gage" is equivalent to the longer, but more accurate, "bonded resistance strain gage."

4. Significance and Use

4.1 Methods and procedures used in installing bonded resistance strain gages can have significant effects upon the performance of those sensors. Optimum and reproducible

[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] 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] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

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

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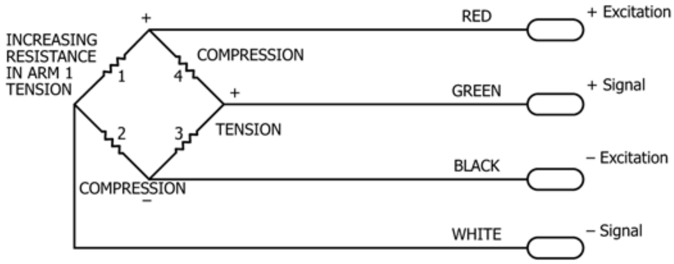

FIG. 1 Designation of Resistance Strain Gage Bridge and Color Code of Lead Wires (Full Bridge)

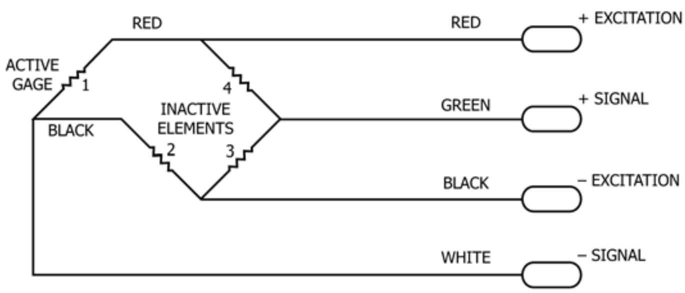

FIG. 2 Designations of Resistance Strain Gage Bridge and Color Code of Lead Wires (Quarter Bridge)

detection of surface deformation requires appropriate and consistent strain gage and bonding technique selection, surface preparation, procedures for gage installation and adhesive use, lead wire connection, validation of operation, and protective coating application.

5. Strain gage Selection

5.1 Carefully consider the intended use when selecting an appropriate strain gage. Installation and operating characteristics of a gage are affected by many factors such as resistive element alloy, carrier material, gage length, gage and resistive element pattern, solder terminal type and configuration, temperature compensation characteristics, resistance of active elements, gage factor, and options desired.

NOTE 1—Strain gage manufacturers provide detailed critiques of the various factors that affect strain gage selection (**1**)[4]

5.2 Factors that should also be considered include type of test or application, operating temperature range, environmental conditions, accuracy requirements, stability, maximum elongation, test conditions (static or dynamic) and duration, and simplicity and ease of installation. Dissipation of self-generated heat to the carrier should be considered in selecting strain gage resistance and size of grid.

5.3 To minimize errors due to strain gradients over the strain gage area, strain gage size should normally be small with respect to the dimensions of an immediately adjacent geometric irregularity (hole, fillet, etc.). However, the strain gage size should generally be large relative to the underlying material structure (grain size, fabric-reinforced composite weave pattern, etc.).

5.4 A two- or three-element rosette strain gage should be used unless the strain state is unquestionably uniaxial. A single-element strain gage may be selected to measure the strain due to a uniaxial strain state if the principal directions are known.

5.5 Temperature compensation of the strain gage should be selected to match the thermal coefficient of expansion of the base material, where possible.

NOTE 2—For extreme temperature changes, the accuracy of nominal or handbook data on the thermal expansion characteristics of the base material can be insufficient, and actual calibration can improve the accuracy.

5.6 For nonroutine applications, the advice of experienced users and of strain gage manufacturers should be sought. Specific validation tests may be required to ensure accurate results.

6. Bonding Technique Selection

6.1 Select the proper bonding technique and adhesive. Because the adhesive becomes part of the strain gage system, many of the strain gage selection factors should be considered in bonding technique or adhesive selection.

6.2 Additional selection factors include compatibility of the bonding materials used in the selected strain gage construction with the material under test, environmental conditions, and available installation time.

6.3 Strain gage manufacturers' bonding instructions should be considered when making a selection.

NOTE 3—Strain gages from different manufacturers can differ. Generally, each manufacturer will supply instructions and recommendations for bonding.

7. Surface Preparation

7.1 Properly prepare the surface to ensure good bonding. Surface preparation includes solvent degreasing, cleaning, mechanical preparation, and chemical preparation. The surface should be smooth, but not highly polished. Preparation of this surface shall be compatible with the strain gage, bonding method, and base material.

NOTE 4—Erroneous strain gage readings can be caused by poor bonding of strain gages, which could be due to unremoved coatings such as paint, scale, rust, and oils. Poor bonding can also result from applying strain gages to improperly prepared surfaces, such as mirror smooth finishes or surfaces containing deep pits and gouges.

7.2 Strain gage manufacturers' surface preparation suggestions and recommendations should be reviewed and considered when preparing base material surfaces for the particular strain gages selected.

8. Strain Gage Installation—General

8.1 Perform all work with clean hands and tools. All materials needed should be assembled and readily available at the strain gage installation location.

8.2 The specific surface preparation procedures should be in accordance with the instructions supplied for the adhesive selected. Adhesive handling and safety precautions should be reviewed and carefully followed.

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

8.3 The detailed strain gage installation procedures available from the strain gage manufacturer for the particular strain gage/bonding technique system selected should be carefully reviewed and rigorously followed. Deviations from these procedures should be documented and validated to ensure that the installation will yield suitably accurate results.

8.4 Strain gage handling and alignment procedures should be rigorously followed. Deviations, should be documented.

9. Strain Gage Installation—Adhesive

9.1 Select the proper adhesive for a given strain gage type. Follow strain gage manufacturer's recommendations for selecting an adhesive.

9.2 The environment to which a strain gage is to be subjected and test duration should be considered when selecting an adhesive.

9.3 Ensure that the adhesive to be used is not out-of-date with regard to storage and shelf-life requirements.

9.4 Ensure that test material temperature range and strain gage/bonding system temperature range are compatible.

9.5 Temperatures and times should be monitored to ensure that the adhesive temperature and pot life requirements, if applicable, are not exceeded.

9.6 Adhesive curing methods and schedules should be rigorously followed. Deviations should be documented.

9.7 If curing with pressure is required, take special care to make sure the pressure is proper and is distributed uniformly over the entire strain gage.

NOTE 5—Nonuniform pressure can cause an irregular bond line.

9.7.1 Care should be taken to ensure that the strain gage position does not shift as a result of applying this pressure.

10. Lead Wire Connection

10.1 Exercise care in attaching the lead wires. In order to prevent lead wire forces from damaging the strain gage or degrading its performance, strain gages with integral copper terminals or bonded terminals should be used. Bondable terminals should be used where extended use of the test piece is expected.

NOTE 6—References (2), (3), and (4) provide supplemental information on these subjects.

10.2 Wire splices should be avoided, but if a splice is required, ensure a good electrical and mechanical connection. Wire splices should be crimped, soldered, and insulated.

10.3 Select the proper wire type, size, and length to maintain strain gage stability, sensitivity, and integrity. Moisture can cause signal instability and drift, hence the lead wire insulation integrity should be checked before installation.

10.4 The lead wires shall be identifiable by color or other identifying mark. Unless specified otherwise, strain gages shall be wired into a strain gage bridge configuration that conforms to the *ANSI/SEM 1-1984.*

10.4.1 The following sign conventions should be used: tension, elongation, increased pressure, or other generally accepted positive quantities should produce positive output signals.

10.4.2 The color code for strain gage bridge wiring and connections shall be as follows:

Red	+ excitation
Green	+ signal
Black	– excitation
White	– signal

10.4.3 If all elements of the strain gage bridge are active, the strain gage bridge elements shall be arranged so that functions producing positive output will cause increasing resistance in arm 1, or 3, or both, and decreasing resistance in arm 2, or 4, or both, of the bridge.

10.4.4 If only one strain gage bridge element is active (quarter bridge), arm 1 shall be used. (Arms 2, 3, and 4 shall be used as inactive elements.)

10.4.4.1 For quarter-bridge applications, the installation should usually consist of the three-wire configuration with three lead wires between the strain gage and strain gage bridge.

10.4.5 If two strain gage bridge elements are active and of opposite polarity (half bridge), arms 1 and 2 shall be used. (Arms 3 and 4 shall be used as inactive elements.) When two strain gage bridge elements are active and of the same polarity, arms 1 and 3 shall be used. (Arms 2 and 4 shall be used as inactive elements.)

10.4.6 Soldering techniques similar to those used for most electronic soldering applications should be used, although some strain gage installations require more sophisticated techniques. Noncorrosive fluxes and minimum heats shall be employed.

10.4.7 Residual flux shall be removed with a suitable brush or cotton swab and cleaning solvent. Protect open-faced grids while soldering and cleaning.

11. Validation Checks

11.1 The completed strain gage installation shall be checked prior to use to validate its integrity and ability to provide reliable and repeatable data.

11.2 *Initial Checks After Installation:*

11.2.1 Visually check the bonded strain gage after installation, after the adhesive has cured, and before the lead wire is soldered. The strain gage should be examined visually for the following:

11.2.1.1 The strain gage is accurately located and oriented with respect to pre-marked reference lines.

11.2.1.2 A small amount of excess adhesive is visible completely around the strain gage periphery.

11.2.1.3 There is complete adhesion at the strain gage edges and corners. The strain gage should appear to be flat on the surface.

11.2.1.4 There is no evidence of air bubbles or mottled strain gage appearance.

11.2.2 Check the strain gage resistance. Shifts greater than 0.5 % are indicative of damage due to improper handling or clamping when using adhesives with room temperature cure. Installations using elevated temperature cure may exhibit

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