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Standard Guide for Installing Bonded Resistance Strain Gages[1]

This standard is issued under the fixed designation E 1237; 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 Department of Defense.

1. Scope

1.1 This document provides guidelines for installing bonded resistance strain gages. It is *not* intended to be used for bulk or diffused semiconductor gages. This document pertains only to adhesively bonded strain gages.

1.2 *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:*

E 251 Test Methods for Performance Characteristics of Metallic Bonded Resistance Strain Gages[2]

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 *Definitions:*

3.1.1 *lead wire*—an electrical conductor used to connect a sensor to its instrumentation.

3.1.2 *resistance strain gage bridge*—a common Wheatsone bridge made up of strain gages used for the measurement of small changes of resistance produced by a strain gage, where the gages may be 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

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *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. (For a complete definition of this term see Test Methods E 251.)

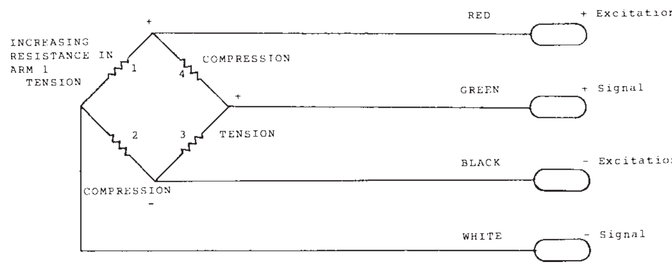

FIG. 1 Designation of Strain Gage Bridge and Color Code of Lead Wires (Full Bridge)

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 detection of surface deformation requires appropriate and consistent surface preparation, mounting procedures, and verification techniques.

5. Gage Selection

5.1 Careful consideration must be given to the intended use when selecting an appropriate 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 tab type and configuration, temperature compensation characteristics, resistance of active elements, gage factor, and options desired.

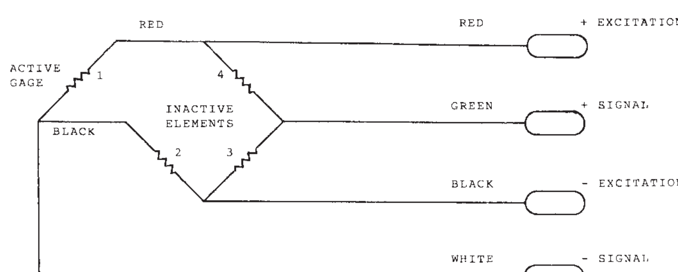

FIG. 2 Designations of Strain Gage Bridge and Color Code of Lead Wires (¼ Bridge)

[1] This guide is under the jurisdiction of ASTM Committee E28 on Mechanical Testing and is the direct responsibility of Subcommittee E28.14 on Strain Gages.

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[2] *Annual Book of ASTM Standards*, Vol 03.01.

[3] Available from American National Standards Institute, 11 W. 42nd St., 13th floor, New York, NY 10036.

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 gage resistance and size of grid.

5.3 To minimize errors due to strain gradients over the gage area, gage size should normally be small with respect to the dimensions of an immediately adjacent geometric irregularity (hole, fillet, etc.). However, the 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 gage should be used unless the strain state is unquestionably uniaxial. A single element 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 gage should be selected to match the thermal coefficient of expansion of the base material, where possible. As a note of caution, for extreme temperature changes, nominal or handbook data on the thermal expansion characteristics of the base material may not be sufficiently accurate, and actual calibration may be required.

5.6 Strain gage manufacturers provide detailed critiques of the various factors which affect gage selection **(1)**.[4]

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

6. Bonding Technique Selection

6.1 Selection of the proper bonding technique and agent is important. Because the bonding agent becomes part of the strain gage system, many of the gage selection factors should be considered in bonding technique or agent selection.

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

6.3 Strain gages from different manufacturers may differ. Generally, each manufacturer will supply instructions and recommendations for bonding. These instructions should be considered when making a selection.

7. Surface Preparation

7.1 The surface must be properly prepared 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 must be compatible with the gage, bonding method, and base material.

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

7.3 Strain gage manufacturers supply surface preparation suggestions and recommendations. This information should be reviewed and considered when preparing base material surfaces for the particular gages selected.

8. Gage Installation—General

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

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

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

8.4 Gage handling and alignment procedures should be rigorously followed. Deviations, if any, should be documented.

9. Gage Installation—Adhesive

9.1 Ensure that the proper adhesive is selected for a given gage type. Follow gage manufacturer's recommendations for selecting an adhesive.

9.2 The environment to which a 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 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, if any, 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 gage. Nonuniform pressure may result in an irregular bond line. Care should be taken to ensure that the gage position does not shift as a result of applying this pressure.

10. Lead Wire Connection

10.1 Care must be exercised in attaching the lead wires. In order to prevent lead wire forces from damaging the strain gage or degrading its performance, the use of gages with integral copper terminals or bonded terminals is recommended. Bondable terminals are recommended where extended use of the test piece is expected. 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. The preferred method includes crimping, soldering, and insulating.

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

10.3 It is important to 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, 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 shall 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 bridge are active, 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 When only one 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 3-wire configuration with 3 lead wires between the gage and bridge.

10.4.5 When two 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 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 are usually the same as those used for most electronic soldering applications, 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. If open faced, protect grid while soldering and cleaning.

11. Verification Checks

11.1 The completed strain gage installation shall be checked prior to use to verify 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 cement has cured, and before the lead wire is soldered. The gage should be examined visually for the following:

11.2.1.1 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 gage periphery.

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

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

11.2.2 Check 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 higher shifts but in no case should they exceed 2 % and then similar installations should exhibit uniformity of the shift to within 0.5 %.

11.2.3 Check resistance between grid of a bonded strain gage and the surface to which the gage is attached. A resistance of at least 1000 MΩ is desirable, and 10 000 MΩ is normal. However, a minimum reading of 20 MΩ is necessary for accurate, stable functioning of the gage.

NOTE 1—When testing for high resistances between the grid/strain element and ground, a conventional low-voltage ohmmeter should be used. High-voltage insulation testers can damage the gage.

11.3 *Checks After Lead Wire Connections*:

11.3.1 After the lead wire has been soldered to the bonded strain gage terminals, and terminals have been properly cleaned, visually examine the connections. They should be:

11.3.1.1 Smooth, no solder spikes,

11.3.1.2 Shiny; frosty appearing surfaces should be resoldered, and

11.3.1.3 Free of discoloration from flux residues.

11.3.2 Verify the electrical continuity by measuring the combined gage and lead wire resistance. This will validate the solder connection, the lead wire, and the splices in the lead wire. If this shows an open circuit or indicates a resistance different from that measured in 12.2.3 plus the resistance of the lead wire, the gage could have been damaged during the lead wire installation, a bad solder joint or a bad splice or both was made. The cause of the observed resistance difference should be determined and corrective action taken.

11.3.3 Quickly check on the gage bond **(5)**.

11.3.3.1 Connect the gage to a static strain indicator, data system, or other readout device.

11.3.3.2 Balance the bridge.

11.3.3.3 Press lightly on the strain gage grid area with the eraser end of a lead pencil.

11.3.3.4 When pressure is applied the strain indicator should show some movement; and, when removed, the indicator should return to zero.

11.3.3.5 If the indicator fails to return to zero or looks unstable, then the gage is probably either poorly bonded (for example air bubbles, delaminations, etc.) or damaged and will have to be replaced.

NOTE 2—This test should not be performed on an open-face gage (exposed grid) without interposing a layer of mylar, TFE fluorocarbon, etc.

12. Protective Coatings

12.1 False or erratic strain indications can result from the effects of moisture, chemical attack, mechanical damage, or other variables. After verification of response, an environmental protection barrier shall be placed over the gage and terminal strips.

12.2 A common cause of failure in strain gage installations is penetration by moisture or other fluids at the lead wire entrance to the coating. To prevent this, protective coatings should encapsulate the lead wires a minimum distance of 1 in. (25 mm) from the installation. Since certain types of lead wire insulation inhibit good coating adhesion, treatment of lead wires with special chemicals that promote good bonding of protective coatings may be required.

12.3 In selecting the protective coating and application methods to be used, consideration should be given to the length of time the gages will be in use, the severity of the environmental conditions, and the degree of accuracy required from the gages.

12.4 Most strain gage manufacturers provide protective coating application information. Final selection should be based on their recommendations.

13. Report

13.1 Any report of the installation practice should includea complete description of the gage(s). The description should include type, lot number, manufacturer, size, method of attachment including adhesive curing schedule, the surface preparation method, and protective coating methods and materials used. Also record the gage resistances measured during the verification tests. In some instances photographs of the installation may be beneficial.

REFERENCES

(**1**) Measurements Group Tech Note TN-505, *Strain Gage Selection—Criteria, Procedures, Recommendations*, Raleigh, NC, 1983.
(**2**) Measurements Group Tech Tip TT-606, *Soldering Techniques for Lead Attachment to Strain Gages with Solder Dots*, Raleigh, NC, 1983.
(**3**) Measurements Group Tech Tip TT-603, *The Proper Use of Bondable Terminals in Strain Gage Applications*, Raleigh, NC, 1983.
(**4**) Measurements Group Tech Tip TT-609, *Strain Gage Soldering Techniques*, Raleigh, NC.
(**5**) C. C. Perry, C. C., Lissner, H. R., *The Strain Gage Primer*, 2nd ed., McGraw-Hill, 1962.