



Designation: **E1319–98 (Reapproved 2014) E1319 – 21**

Standard Guide for High-Temperature Static Strain Measurement¹

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~~ 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~~425 °C to ~~650~~650 °C (~~800~~800 °F to ~~1200~~1200 °F). This guide reflects some ~~current~~ state-of-the-art techniques in ~~high-temperature strain measurement~~, and will be expanded and updated as new technology ~~develops~~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 measuring 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 measuring gage~~ system including those described, the proposer ~~must~~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 ~~may~~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~~ safety, health, and health 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.*

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.

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

2. Referenced Documents

2.1 ASTM Standards:³

E6 Terminology Relating to Methods of Mechanical Testing

3. Terminology

3.1 *Definitions: Definitions of Terms Common to Mechanical Testing:*

3.1.1 ~~Refer to~~ 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** for definitions of terms relating. Some important terms from **E6** to stress and strain 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:

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

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 $\frac{L - L_0}{L_0}$

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 Terms pertinent to this guide are described as follows:

3.2.1 capacitive strain gage—a strain gage whose response to strain is a change in electrical capacitance which is 1s predictably related to that strain.

3.2.1.1 Discussion—

Capacitive strain gages are also commonly referred to as capacitance strain gages.

3.2.3 conditioning circuit—a circuit or instrument subsystem that applies excitation to a strain gage, detects an electrical change in the strain gage, and provides a means for converting this change to an output that is related to strain in the test article.

3.2.3.1 Discussion—

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

3.2.2 compensating strain gage—a strain gage element that is subject to the same environment as the active strain gage element, and ~~which~~ 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 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.

3.2.4 *free filament*~~free-filament strain gage~~—a resistive~~resistance~~ strain gage made from a continuous wire or foil filament which~~that~~ is fixed to the test article along the entire length of the strain gage, and which~~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.

3.2.7 *gage factor*—the ratio between the unit change of strain gage resistance due to strain and the measurement.

3.2.7.1 *Discussion*—

The gage factor is dimensionless and is expressed as follows:

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

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 = mechanical strain $\frac{L - L_0}{L_0}$

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.

3.2.9 *linearity*—the value measured as the maximum deviation between an actual instrument reading and the reading predicted by a straight line drawn between upper and lower calibration points, usually expressed as a percent of the full scale of the sensor range.

3.2.10 *lead wire*—a conductor used to connect a sensor to its instrumentation.

3.2.11 *matrix*—an electrically nonconductive layer of material used to support a strain gage grid.

3.2.11.1 *Discussion*—

The two main functions of a matrix are to act as an aid for bonding the strain gage to a structure and as an electrically insulating layer in cases where the structure is electrically conductive.

3.2.6 *resistive*~~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 *strain, linear*—*signal conditioning circuit*—the unit elongation induced in a specimen either by a stress field (mechanical strain) or by a temperature change (thermal expansion); 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*—

May 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~~ 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).

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 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 specimen when exposed to a change in temperature.

3.2.20 *thermal output-unmounted*—the reversible part of the temperature-induced indicated strain of an unmounted strain gage 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 which 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 must shall be considered when selecting a strain gage system for use in the temperature range specified in 1.1. It is recognized that no gage may have all of the desired capabilities to meet all requirements of a particular test. The risk of compromising certain test objectives must be evaluated, and some test objectives may have to be modified to match the capabilities of the available gage selected. Guidelines for this evaluation are provided in Section 9.

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.

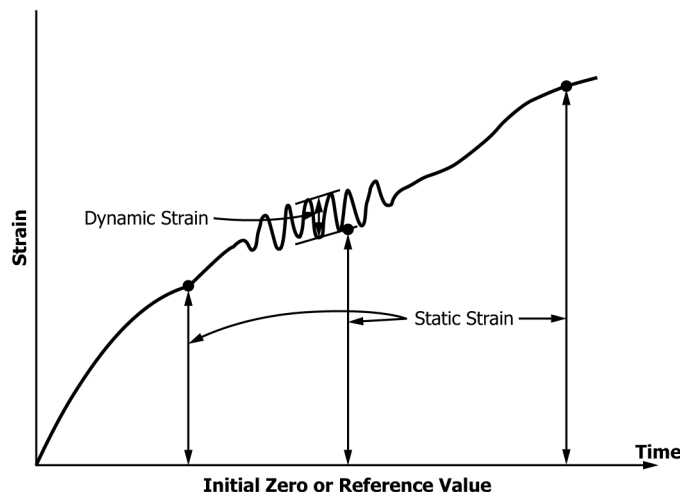


FIG. 1 Relationship Between Static and Dynamic Strain

5.2 Operating Temperature:

5.2.1 *Isothermal Tests*—Stability of the reference value with respect to time is essential when tests are to be made at constant temperature. The stability of the candidate strain gage system at the specified temperature mustshall be such that any shift that occurs in the reference value is tolerable for the duration of the test.

5.2.2 *Thermal Compensation and Transients*—The adequacy of the thermal compensation mustshall be considered when the measurement of strain during a thermal transient is required. ~~Thermal output is a function of temperature, thus its value at a temperature depends not only on temperature, but on the temperature history followed in reaching that temperature. If significant hysteresis in the thermal response is present, large errors or uncertainties can result. This is especially true when the calibration procedure used to characterize the thermal output does not accurately reflect the temperature sequence to which the gages will be exposed during testing. If the response time of the compensation is exceeded, the resulting uncertainty must be considered. The ability of the gage system to withstand the transient without a detrimental shift of the reference value must be verified. This is true whether or not strain is measured during the transient. Any gage factor change as a function of temperature change must also be considered.~~

NOTE 2—Thermal output is a function of temperature, thus its value at a temperature depends not only on temperature, but on the temperature history followed in reaching that temperature. If significant hysteresis in the thermal response is present, large errors or uncertainties can result. This is especially true when the calibration procedure used to characterize the thermal output does not accurately reflect the temperature sequence to which the strain gages will be exposed during testing.

5.2.2.1 If the response time of the thermal compensation is exceeded, the resulting uncertainty shall be considered.

5.2.2.2 The ability of the strain gage system to withstand the transient without a detrimental shift of the reference value shall be verified. This is true whether or not strain is measured during the transient.

5.2.2.3 Any gage factor change as a function of temperature change shall also be considered.

5.2.3 *Pre-calibration: Pre-test Calibration:*

5.2.3.1 ~~Thermal~~ If thermal output calibration on the structure test article is usually not possible and precalibration of gages not possible, strain gages shall be precalibrated on a similar material is necessary. However, variations of up to 0.5 ppm/°F are possible within a material. Often, rolling direction will influence thermal expansion coefficient.

NOTE 3—Variations of up to $0.3 \times 10^{-6}/^{\circ}\text{C}$ are possible within a material. Often, rolling direction will influence thermal expansion coefficient.

5.2.3.2 ~~Precalibration of resistive~~ Precalibrate resistance or capacitive strain gages is performed using a calibration fixture made from material similar to the test article. The calibration fixture mustshall be made to precisely fit the strain gage, especially if curvature is involved. Experience has shown mating parts must Mating parts shall be lapped together to provide uniform clamping pressure around the periphery of the strain gage weld area.

5.2.3.3 The calibration test should be repeated to ensure precise duplication of the calibration. Zero return should also repeat exactly. If calibration data does not repeat, either the calibration setup or the gages are faulty.

NOTE 4—If calibration data does not repeat, either the calibration setup or the strain gages are faulty.

5.2.4 *Post-Test Calibration: Post-Test Calibration*—If a more precise thermal output calibration is needed, a post-test calibration should be conducted.

5.2.4.1 ~~A more precise thermal output calibration can be achieved after the test by removing the test~~ Remove the test strain gage (cut it out of the structure) test article) and running a precision test on the test strain gage still attached to the test article material. The test coupon is relieved of all induced stresses (thermal, mechanical, residual) and is free to expand freely with temperature. The integral gage lead wire should be exposed to thermal gradients similar to those that occurred during the test program.

NOTE 5—The test article is relieved of all induced stresses (thermal, mechanical, residual) and is free to expand freely with temperature.

5.2.4.2 The strain gage integral lead wire should be exposed to thermal gradients similar to those that occurred during the test program.

5.3 *Duration of Test*—The ability of all parts of the strain gage system to function for the specified duration of test should be demonstrated; if multiple tests are required on the same test article, the capability and effect of strain gage replacement mustshall also be established.

5.4 *Strain Rate*—The time response of the candidate strain gage system mustshall be adequate to meet test requirements if rapid changes of load are anticipated. ~~It may be necessary to design the loading rate of the test to accommodate limitations of the strain measurement system selected.~~

NOTE 6—Limiting the loading rate of the test is one solution to accommodate limitations of the selected strain gage system.

5.5 *Environment*—Some strain gages are limited to specific operating environments and therefore, the strain gage system selected mustshall be capable of withstanding the environment in which it will operate. Such limitations mustshall be carefully considered when selecting the strain gage system to be used. ~~Factors such as pressure, vibration, radiation, magnetic fields, humidity, etc., must be considered. The ambient and test environments of the elements of the strain gage system must be considered in the selection of lead wires, connectors, instrumentation, and seals (when required).~~

5.5.1 Factors such as pressure, vibration, radiation, magnetic fields, and humidity shall be considered.

5.5.2 The ambient and test environments of the elements of the strain gage system shall be considered in the selection of lead wires, connectors, instrumentation, and seals (when required).

5.6 *Strain Range:*

5.6.1 *Total Strain Range*—The maximum strain ranges of the candidate strain gage types mustshall be defined and mustshall be adequate for the test. Mechanical strain attenuators, when permissible, may be added to extend the strain range of a given strain gage system, subject to the limitation of **5.6.2**.

5.6.2 *Resolution*—The ability of the candidate strain gage system to measure small increments of strain within the total strain range should be compared with the incremental strain measurement requirements of the test. When mechanical strain attenuators are used, the resulting loss of resolution mustshall be considered.

5.7 *Strain Gradient*—The gage-length of the candidate strain gage establishes the length over which the unit strain is averaged. This factor mustshall be considered.

5.8 *Uncertainty Factor*—Uncertainty information that is available from the manufacturer mustshall be considered, in conjunction with conditions ~~which~~that are unique to the test, in order to estimate the total uncertainty.

~~5.9 *Space Requirements*—If space on or adjacent to the test article is limited, the space requirements for the complete strain gage system may be a critical consideration in determining the suitability of a particular gage system. Working space for installation of the system may also be limited and must also be strain gage system shall be considered. Space adjacent to the installed strain gage should be provided for installation of room-temperature strain gages required for making in-place calibrations.~~

NOTE 7—If space on or adjacent to the test article is limited, the space requirements for the complete strain gage system can be a critical consideration in determining the suitability of a particular strain gage system.

~~5.10 *Effects of the Strain Gage on the Test Article*—In most cases the reinforcing effect of the strain gage on the test article is negligible, particularly in the case of capacitance gages where the spring rate is extremely low. If a weldable strain gage is to be used on thin sections, an evaluation of the reinforcing effect should be made. Technical data concerning this effect can be obtained from a strain gage manufacturer.~~

NOTE 8—In most cases the reinforcing effect of the strain gage on the test article is negligible, particularly in the case of capacitive strain gages where the spring rate is extremely low. Technical data concerning this effect can be obtained from a strain gage manufacturer.

6. Characteristics of Available Strain Gages

6.1 The two basic types of strain gages used for high temperature static strain measurements are ~~resistive~~resistance strain gages and capacitive strain gages.

6.1.1 ~~Resistive~~ Resistance strain gages are usually small, ~~low-profile~~ low-profile units superbly suited for dynamic strain measurements and relatively short-term static measurements. Because high temperatures cause metallurgical instability, oxidation, relaxation, and phase change of the strain sensing materials, all of which affect resistance change, ~~resistive~~resistance gages are generally not used for long-term measurements.

6.1.2 Capacitive strain gages are devices that measure changes in geometry and are unaffected by temperature or temperature changes, oxidation, relaxation, creep, grain growth, or phase change. They are best suited for measuring creep strains, or for very long-term tests on applications where a relatively large strain gage can be used, and when the strain gage will not be subjected to high vibration, gravity, or acceleration forces, shock loading, or an electrically conductive atmosphere.

6.1.3 When selecting a specific strain gage for a given application, the strain gage system ~~must~~shall be qualified for the specific conditions under which it will be required to operate and for the characteristics it ~~must~~shall exhibit under service conditions. This section describes some of the capability of currently available strain gages, suitable for use in the specified temperature range, to meet the selection criteria of ~~Section~~ Section 5.

6.1.4 ~~Wire and foil free-filament strain gages may be usable to approximately 400°C (750°F) under static conditions, and to approximately 1250°C (2280°F) for certain dynamic applications. However, the bonding methods used (ceramic cement, flame spray) are cumbersome and difficult to employ on large structures, particularly under field conditions. Ceramic cements require heat-curing and are generally unsuitable for large structures such as nuclear or fossil-fuel power-generating equipment. Flame spray is also difficult to use in the field. Free-filament gages, although useful for strain measurement on small items under laboratory conditions, are, therefore, not included in this guide. This does not preclude the use of these strain gages for specific tests based on the selection criteria of Section 5.~~

NOTE 9—Wire and foil free-filament strain gages are usable to approximately 400 °C (750 °F) under static conditions, and to approximately 1250 °C (2280 °F) for certain dynamic applications. However, the bonding methods used (ceramic cement, flame spray) are cumbersome and difficult to employ on large structures, particularly under field conditions. Ceramic cements require heat-curing and are generally unsuitable for large structures such as nuclear or fossil-fuel power-generating equipment. Flame spray is also difficult to use in the field. Free-filament strain gages, although useful for strain measurement on small articles under laboratory conditions, are, therefore, not included in this guide. This does not preclude the use of these strain gages for specific tests based on the selection criteria of Section 5.

6.1.4 The strain gages described in this section have been used at high temperature for sufficient time and with sufficient success to warrant consideration in this guide. Each type has unique features, advantages, and limitations ~~which must~~that shall be carefully evaluated relative to the selection factors of ~~Section~~ Section 5.

6.2 Bonded Weldable Resistance Strain Gage:

6.2.1 This strain gage, shown in Fig. 2, consists of a ~~free-filament~~ free-filament strain gage ceramic bonded to a shim. While it is not usually sealed or intended for underwater use, some hermetically sealed strain gages are bonded to the shim with ceramic cements or flame sprayed ceramics. The following alloys are available: (1) self temperature compensated nickel chrome alloy sensors usable to ~~340°C~~ 340 °C in quarter bridge (single element) configuration, (2) platinum tungsten and palladium chrome alloy sensors (dual element) compensated with platinum elements in ~~half-bridge~~ half-bridge configuration, and (3) iron chrome aluminum alloys having low temperature coefficient are available in ~~half-~~ or full-bridge configuration for applications where ~~active-dummy~~ active-dummy combinations (slow temperature changes) are usable.

6.2.2 Except for long-term stability, the bonded strain gage has excellent performance with minimal hysteresis, small zero shift,

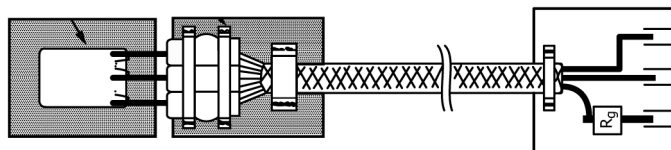


FIG. 2 Bonded Weldable Resistance Strain Gage

long fatigue life, and accurate gage factor among its salient features. An integral weldable terminal and integral high temperature cable are usually supplied with these units, especially when the strain gages are supplied precalibrated for apparent strain.

6.2.3 The thermal output of the dual element gages can be adjusted to produce a zero output at any two selected temperatures. The thermal output of the platinum tungsten gage is usually well within $\pm 200 \mu\text{m/m}$ between 20 and 500°C. The shape of the thermal output curve is influenced by the thermal expansion characteristics of the test material. Fig. 3 shows the completion circuit for the dual element half bridge gage. There are two methods of compensation, (1) NASA method (3) and (2) the wire method (4).

6.2.3 With the NASA method, the gage is manufactured to fit a specific type of material with the platinum thermometer element resistance value selected to provide an almost perfectly balanced bridge. This permits a three wire cable to be used without sacrificing inherent lead wire compensation. The five wire system employs a thermometer element sufficiently high in resistance to compensate on virtually any material. This makes for universal compensation on any material. The drawback of this universal system is that five wires are required. A shunt resistor R_g placed across the thermometer element only shunts the output of the compensator. If the shunt resistor were placed across the thermometer-platinum tungsten strain gage is usually well within $\pm 200 \mu\text{m/m}$ between 20 °C and 500 °C. The shape of the thermal output curve is influenced by the thermal expansion characteristics of the test material. Fig. 3 shows the bridge completion circuit for the dual element half-bridge strain gage. There are two methods of thermal compensation: (1) NASA method (3) and (2) wire, inherent lead compensation the wire method would (4be), sacrificed.

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6.2.4 The user may precalibrate the strain gage and cable system and determine the bridge completion resistor values using a set of equations provided with the strain gage, or the strain gage may be precalibrated at the factory (5) and supplied precalibrated with the bridge completion resistors included in a network circuit attached to the cool end of the cable. The user needs only to hook up connect the strain gage as a full bridge transducer and insert the calibration curve into his the data acquisition system.

6.3 *Hermetic Weldable Resistance Strain Gage*—This strain gage, which is shown several times the actual size in Fig. 4, is hermetically sealed and furnished with integral lead wires, and may be used in a variety of severe environments at high temperature. The strain tube is welded to a thin mounting flange, which is welded to the surface of the test article, thus providing transfer of strain from the test article to the strain gage. Although Fig. 4 shows stainless steel strain tube, mounting flange, and cladding of the integral lead wire, other materials are available to meet the requirements of specific applications; consult the manufacturer for available materials. Within limits, the thermal output of the strain gage due to temperature can be adjusted to produce a zero output at any two selected temperatures by inserting a temperature thermal compensation resistor, R_{tc} in Fig. 5 in series with either the active or compensating strain gage element; the proper resistor is furnished by the manufacturer. Because of the added resistance in series with one of the strain gage elements, the bridge-completion resistors must shall also be adjusted for balance by adding a balancing resistor (R_{bal} in Fig. 5) in the opposite half of the bridge. This resistor is also furnished by the strain gage manufacturer. The value of R_{bal} is based on the use of 120 Ω bridge-completion resistors to produce a balanced bridge when the strain gage is connected.

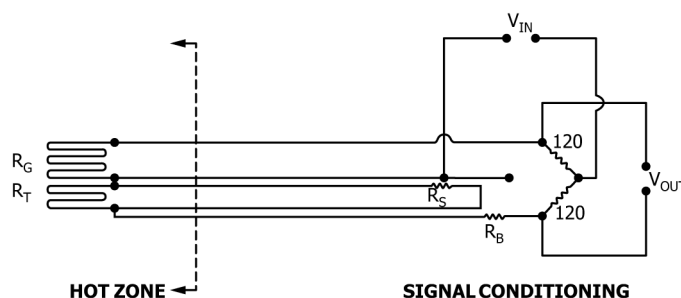


FIG. 3 Five-Wire Five-Wire Circuit

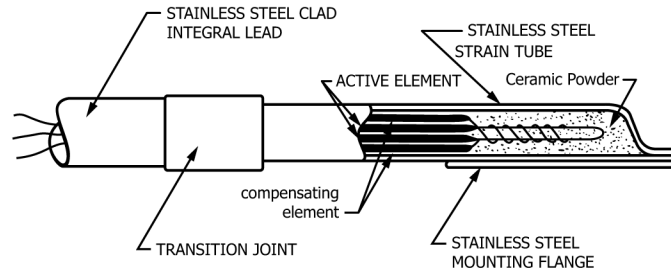


FIG. 4 Hermetic Weldable Resistance Strain Gage

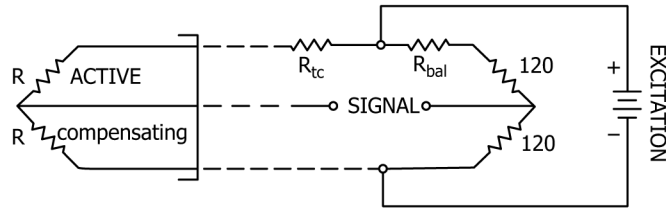


FIG. 5 Bridge Completion Network Circuit and Power Supply

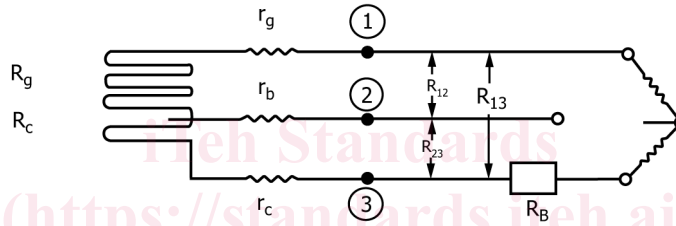
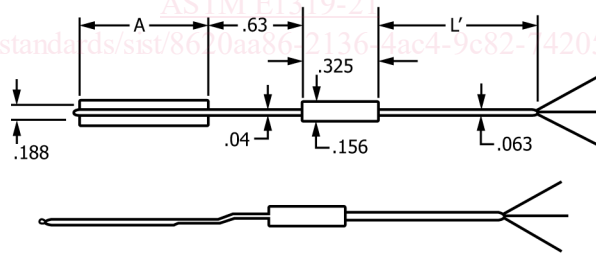


FIG. 6 Three-Wire Three-Wire Circuit

TYPE	SG 425	MG 425
DIM. A	1.09	.62



NOTE 1—All dimensions are in inches.

FIG. 7 Dimensions of Hermetic Weldable Resistance Strain Gage

6.3.1 Operating Temperature and Thermal Stability:

6.3.1.1 The platinum tungsten element is essentially stable for short-term testing to 500°C (days) with shorter excursions up to 580°C (hours) without damage to the strain gage. Longer tests (weeks) can be run to up to 425°C . Beyond these limits is the domain of the a capacitive strain gage.

6.3.2 Thermal Compensation and Transients—Thermal output characteristics must shall be considered for operation at varying temperatures. This information is furnished by the manufacturer for use of the gage on the material specified by the user. For precise evaluation, a calibration is necessary, with thermal output determined at the temperatures of interest. Temperatures should be measured by a thermocouple(s) mounted immediately adjacent to the gage. Thermal output and hysteresis of a test are usually repeatable under identical test conditions; however, even the slightest change in test conditions may result in a change of thermal

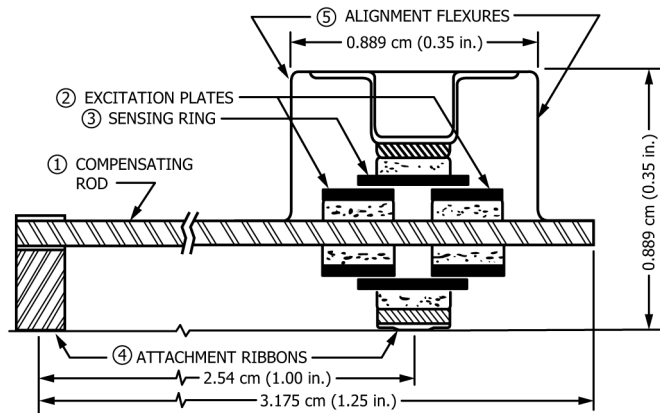
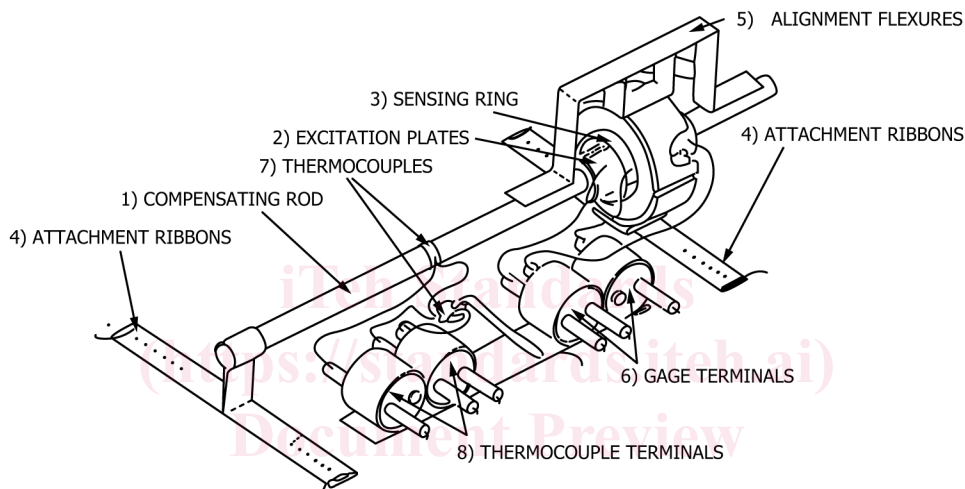


FIG. 8 Differential Capacitance Strain Gage



NOTE 1—Overall strain gage dimensions are 3.175 cm (1.25 in.) by 1.524 cm (0.60 in.)

FIG. 9 Isometric View, Differential Capacitance Strain Gage

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output, hysteresis, or both. To qualify the gage for thermal shock, laboratory tests should be made to determine the stability characteristics and the limits of thermal compensation.

NOTE 10—Information about the thermal output characteristics is furnished by the manufacturer for use of the strain gage on the material specified by the user.

6.3.2.1 For precise evaluation, the strain gage system shall be calibrated, with thermal output determined at the temperatures of interest. Temperatures should be measured by a thermocouple(s) mounted immediately adjacent to the strain gage.

NOTE 11—Thermal output and hysteresis of a test are usually repeatable under identical test conditions; however, even the slightest change in test conditions can result in a change of thermal output, hysteresis, or both.

6.3.2.2 To qualify the strain gage for thermal shock, laboratory tests should be made to determine the stability characteristics and the limits of thermal compensation.

6.3.3 *Electrical Requirements*—Bridge completion, as shown in Fig. 5, is required. While there are several standard strain measuring systems with bridge completion capability available, it is recommended that, for static strain measurement in the temperature range of this guide, an individual signal conditioning circuit having the following features be provided for each gage:

6.3.3 *Excitation Power Supply*—*Electrical Requirements*—A power supply for providing Bridge completion, as shown in Fig. 5 constant DC voltage, continuously variable from 1 V to 15 V across a 120-Ω external load, is required. Constant current excitation cannot be used with some of the compensation techniques generally used with this gage. If more than one bridge circuit is excited

by the same power supply, the electrical configuration must provide electrical isolation of each circuit to protect it in the event of a direct short of the excitation of any of the adjacent circuits, shall be made. While there are several standard strain gage systems with bridge completion capability available, for static strain measurement in the temperature range of this guide, an individual signal conditioning circuit should have the following features for each strain gage.

6.3.3.1 Excitation Power Supply—A power supply for providing constant DC voltage, continuously variable from 1 V to 15 V across a 120 Ω external load, shall be used. If more than one bridge circuit is excited by the same power supply, the electrical configuration shall provide electrical isolation of each circuit to protect it in the event of a direct short of the excitation of any of the adjacent circuits.

NOTE 12—Constant current excitation cannot be used with some of the thermal compensation techniques generally used with the hermetic weldable resistance strain gage.

6.3.3.2 Balance Control—Means shall be provided for balancing the bridge with a T balance resistor circuit across the completion half of the bridge. This means may be omitted if the data acquisition equipment automatically compensates for initial bridge unbalance.

6.3.3.3 Shunt Calibration—Shunt calibration capability should be provided on the completion half of the bridge. The active or compensating legs of the bridge should not be shunted, because of changes in the resistances of the lead wires with temperature. Multiple shunt calibration should be done.

6.3.3.4 Signal Conditioning Circuit—The signal conditioning circuit shall be capable of handling a half-bridge circuit with precision completion resistors, configured to permit the addition of series balance resistors to either leg. The signal conditioning circuit should be able to accommodate a half-bridge, five-wire configuration, with two additional leads, for remote sensing of the excitation voltage.

6.3.3.5 Means shall be provided for continuous monitoring of bridge excitations and bridge output. An amplifier may be used or omitted, depending on the input capability of the strain gage system used. Amplifier requirements are not covered in this guide; however, a good quality, stable amplifier with true differential input, and input impedance of not less than 10 M Ω and shunted by 750 pF when DC-coupled should be used.

6.3.5 Balance Control—Means shall be provided for balancing the bridge with a T balance resistor network across the completion half of the bridge. This is not required in the event that the data acquisition equipment automatically compensates for initial bridge unbalance. [/standards.iteh.ai/catalog/standards/sist/8620aa86-2136-4ac4-9c82-742053b62b69/astm-e1319-21](https://standards.iteh.ai/catalog/standards/sist/8620aa86-2136-4ac4-9c82-742053b62b69/astm-e1319-21)

6.3.6 Shunt Calibration—Shunt calibration capability should be provided on the completion half of the bridge. Shunting of the active or compensating legs of the bridge is not recommended because of changes in the resistances of the lead wires with temperature. Multiple shunt calibration is recommended.

6.3.7 Circuit—The signal conditioner must be capable of handling a half bridge circuit with precision completion resistors, configured to permit the addition of series balance resistors to either leg. It is recommended that the signal conditioner be able to accommodate a half bridge, five wire hookup, with two additional leads, for remote sensing of the excitation voltage.

6.3.8 Means must be provided for continuous monitoring of bridge excitations and bridge output. An amplifier may or may not be required, depending on the input capability of the measuring system used. Amplifier requirements are not covered in this guide; however, a good quality, stable amplifier with true differential input, and input impedance of not less than 10 M Ω and shunted by 750 pF when DC-coupled, is recommended.

6.4 Differential Capacitance Strain Gage—Fig. 8 identifies major elements of the strain gage and shows principal dimensions. Fig. 9 shows an isometric view. The compensating rod (1) is usually made of the same material as the test article (specified by user). The cylindrical excitation plates (2) are mounted coaxially on, but are electrically insulated from, the compensating rod. The sensing ring (3) is mounted coaxially with the excitation plates but is separated from them by an air gap. The attachment ribbons (4) (see the isometric view in view, Fig. 9) provide means for welding the strain gage to the test article. The alignment flexures (5) (see the isometric view in Fig. 9), maintain the coaxial alignment of the sensing ring relative to the excitation plates and compensating rod. Leads from the three capacitor plates are brought to a terminal (6) (in Fig. 9) which is also attached to the test article by spot welding. The complete strain measuring gage system consists of a half-bridge-half-bridge differential capacitance strain gage, a capacitive signal conditioner, conditioning circuit, and the interconnecting leads.