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THIRD ANGLE PROJECTION	CUSTODIAN ENGINEERING MANAGEMENT COMMITTEE	REVISION 3
PROCUREMENT SPECIFICATION NONE	TITLE STRAIN GAGES, BONDED RESISTANCE	CLASSIFICATION SPECIFICATION ③



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1000 WILSON BLVD.
ARLINGTON, VA 22209

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1. SCOPE

1.1 Purpose

The purpose of this document is to provide a standard for specifying bonded resistance strain gages.

In accomplishing the purpose of this document, it is necessary to:

- (a) Establish standard nomenclature for describing bonded resistance strain gages in this specification.
- (b) Prescribe the minimum amount and kind of qualification and quality control tests to be performed by strain gage manufacturers, and to standardize the manner in which the data are furnished.
- (c) Define the minimum capabilities of the test equipment to be used to perform the qualification and quality control tests.
- (d) Set forth the methods to be used to perform the qualifications and quality control tests.
- (e) Establish criteria for classification of strain gages with respect to performance.
- (f) Classify strain gages with respect to performance.

1.2 Intended Use

The specifications in this document provide a means for comparing and selecting strain gages on a preliminary basis. This document will require manufacturers to furnish that minimum information which the user or purchaser needs to make a selection for a particular application. This document is not intended to provide information to be used for the calibration of a specific strain gage installation, except in the cases of gage factor, resistance, and the thermal output coefficient. This document will also provide the purchaser and the manufacturer with a standard means of specifying strain gage characteristics.

1.3 Summary

A summary, with an emphasis on intent, is presented below:

- (a) Section 1 presents the purpose, intent and other details that aid in understanding and using this document.
- (b) Section 2 lists the documents which form a part of this specification.
- (c) Section 3 establishes a grading system for strain gage performance characteristics, and specifies the quality requirements for each grade.
- (d) Section 4 describes the equipment, strain gage attachment methods, and test procedures which must be used in determining the fourteen performance characteristics used to specify strain gages. This section has two major divisions – the first major division is concerned with the minimum qualification tests, while the second is concerned with quality control tests.
- (e) Section 5 describes the requirements which pertain to the dissemination of the information obtained in Section 4.
- (f) Section 6 contains definitions of terms used in this document.

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1.4 Classification

1.4.1 Performance Characteristics

The fourteen performance characteristics listed below in 1.4.1.1 through 1.4.1.14 are used to classify strain gage performance characteristics with respect to five quality grades. The test procedures for evaluating gages with respect to these performance characteristics are described in Section 4. The performance characteristics are defined in Section 6. (Note that the first six performance characteristics are room temperature characteristics while the last eight involve imposed temperature conditions.)

1.4.1.1 Gage resistance at room temperature

1.4.1.2 Gage factor at room temperature

1.4.1.3 Mechanical hysteresis at room temperature

1.4.1.4 Fatigue life at room temperature

1.4.1.5 Transverse sensitivity at room temperature

1.4.1.6 Strain limit at room temperature

1.4.1.7 Strain limit at extreme temperature

1.4.1.8 Thermal output

1.4.1.9 Thermal hysteresis

1.4.1.10 Drift

1.4.1.11 Leakage resistance

1.4.1.12 Transient temperature response

1.4.1.13 Gage factor change with temperature

1.4.1.14 Creep

1.4.2 Quality

Five grades (A through E) are used to indicate the quality of each of fourteen strain gage performance characteristics. A quality grade, therefore, refers to a single performance characteristic. The quality requirements which determine the grades of gage performance characteristics are given in Table I of Section 3. Table III in Section 5 exemplifies the grading of the performance characteristics of a typical gage installation.

1.4.3 Nominal Characteristics

1.4.3.1 General

Nominal characteristics describe strain gages but are not necessarily the result of specific tests or measurements. (Note that average nominal characteristic values are the result of specific tests or measurements on a specified minimum number of gages.)

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1.4.3.2 Gage Resistance

Standard nominal gage resistance values are as follows:

- (a) 60 ohms
- (b) 120 ohms
- (c) 240 ohms
- (d) 350 ohms
- (e) 500 ohms
- (f) 1,000 ohms

1.4.3.3 Gage Factor

An average nominal gage factor value is determined and stated by the manufacturer in accordance with procedures in this specification.

1.4.3.4 Extreme Operating Temperature

The testing procedures in this specification are, in certain cases, dependent on the maximum or minimum operating temperature of the gage. The maximum or minimum operating temperature of each gage type is designated by the manufacturer as the extreme operating temperature. The choice of this value is left to the discretion of the manufacturer. Gages intended for use below room temperature shall be assigned both a maximum and a minimum operating temperature.

1.4.3.5 Thermal Output

Any one of six different materials maybe chosen by the manufacturer as the specimen on which a strain gage is installed for the determination of the thermal output. Each of the six materials has a different linear thermal expansion coefficient. The six materials, in order of magnitude of their approximate linear thermal expansion coefficients, are listed below:

- | | |
|----------------------------------|---|
| (a) Amorphous Quartz | Approximate linear thermal expansion coefficient equals $.2 \mu\epsilon/^{\circ}\text{F}$ |
| (b) Molybdenum | Approximate linear thermal expansion coefficient equals $3 \mu\epsilon/^{\circ}\text{F}$ |
| (c) 1018 Cold-worked Steel | Approximate linear thermal expansion coefficient equals $6 \mu\epsilon/^{\circ}\text{F}$ |
| (d) 316 Stainless Steel | Approximate linear thermal expansion coefficient equals $9 \mu\epsilon/^{\circ}\text{F}$ |
| (e) 2024-T4 Aluminum | Approximate linear thermal expansion coefficient equals $13 \mu\epsilon/^{\circ}\text{F}$ |
| (f) HK 31A-H24 Magnesium Thorium | Approximate linear thermal expansion coefficient equals $15 \mu\epsilon/^{\circ}\text{F}$ |

Gages which are evaluated for thermal output on amorphous quartz specimens have a standard thermal output coefficient of zero. The indicated strain output, in this case only, will have to be corrected for the specimen thermal strain.

With the exception of those gages mounted on amorphous quartz specimens, the magnitude of the standard thermal output coefficient of a gage is the magnitude of the linear thermal expansion coefficient (as determined to a specified accuracy) of the specimen on which the strain gage was installed during the thermal output evaluation. The standard thermal output coefficient is always negative (or zero).

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1.4.3.6 Physical Dimensions and Configuration

Differences in the dimensions and configurations of strain gages result in differences in gage performance characteristics. For this reason, the manufacturer will be required to designate these differences. The manner in which this designation is carried out is left to the manufacturer. However, for the purpose of selection and use, the manufacturer is specifically required to relate the following in increments of .01 inch:

- (a) Active gage length (foil gages measured to inside of loops)
- (b) Minimum trim length
- (c) Active gage width
- (d) Minimum trim width

1.4.3.7 Combinations of Nominal Characteristics

Certain nominal characteristics are grouped in order to take advantage of known variations of strain gage performance with nominal characteristics. Grouping the gages in this manner reduces the required amount of testing. Three such groups are used in this specification and are introduced below:

- (a) The term "type" is used to refer to strain gages that are identical with respect to size, configuration, and composition.
- (b) The term "family" refers to strain gages that are identical with respect to configuration and composition.
- (c) The term "lot" is associated with the manufacturing process of the active grid element, and refers to strain gages with active grid elements from a common homogeneous melt or batch which have been subjected to the same mechanical and thermal treatments.

This specification requires that the manufacturer designate all strain gages so as to distinguish between various families, types, and lots.

1.4.3.8 Special Purpose

Strain gages designed to exhibit characteristics for unusual applications are termed special purpose gages. Special purpose gages may be classed and graded with other gages, but in addition, the special feature must be described.

2. **APPLICABLE DOCUMENTS**

There are no applicable documents.

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3. REQUIREMENTS

3.1 Qualification

A type of strain gage furnished under this specification shall be a product which has been tested in accordance with the qualification and quality control tests specified herein. Any exceptions to the procedures specified herein shall be noted.

3.2 Qualitative Requirements

3.2.1 General

3.2.1.1 It is required that each quantum of data, representing a particular characteristic of a strain gage, consist of the results of tests on at least five strain gage installations.

3.2.1.2 For Grade A and Grade B strain gages, it is required that 95% of the gages tested be within the tolerances described in Section 3.2.2. This means that if five gages are tested and one gage fails to fall within the tolerances desired, then in order to qualify this gage type (or kind or lot), it will be necessary to test an additional fifteen gages without any of the fifteen showing results outside the desired tolerances.

3.2.1.3 For Grade C and D strain gages, it is required that 90% of the gages tested be within the tolerances described in Section 3.2.2. This means that if five gages are tested and one gage fails to fall within the tolerances desired, then in order to qualify this gage type (or kind or lot) for a Grade C or Grade D quality, it will be necessary to test an additional five gages without any of the five showing results outside the desired tolerances.

3.2.1.4 There are no requirements for Grade E strain gages.

3.2.1.5 Only the requirements are listed in Section 3. An interpretation of the terms and methods used to describe these requirements is given in Section 4.

3.2.2 Individual Performance Characteristic Qualitative Requirements

The requirements necessary to class gages or gage characteristics into grades of quality are given in Table I. See also Section 1.4.2 and Table III in Section 5.

3.3 Quality Control Requirements

3.3.1 General

3.3.1.1 Quality control tests will be made on production line gages at specified intervals to insure that the values representing the performance characteristics (as determined from the qualification tests) have not changed.

3.3.1.2 All requirements set forth under qualification testing will apply to quality control testing except for the number of gages tested.

3.3.1.3 The testing of a single gage will be sufficient to represent a performance characteristic except in the event that the test results of the gage are not consistent with the test results of the qualification tests.

3.3.1.4 In the event that a gage tested for quality control has one or more performance characteristics which fall outside of the allowable tolerances established during the qualification tests, additional gages must be evaluated with respect to each of the intolerable performance characteristics (for Grade A and Grade B gages it would be necessary to test an additional nineteen gages). If the results of these additional tests are not consistent with those results used in qualifying the gage type (or family or lot), then action must be taken to insure that the production process is corrected and that those gages produced since the last successful quality check are appropriately down-graded.

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TABLE I – PERFORMANCE CHARACTERISTIC REQUIREMENTS

PERFORMANCE CHARACTERISTIC	DATA DESCRIPTION	GRADE			
		A	B	C	D
1. GAGE RESISTANCE	Deviation $\pm$ % of Std. Nom.	.5	2	5	10
	Tolerance % of Av. Nom.	.1	.2	.5	1.0
2. GAGE FACTOR	Tolerance % of Av. Nom.	1	2	3	5
3. MECH. HYSTERESIS	Δ in indicated strain in $\mu\epsilon$	25	50	100	200
4. FATIGUE LIFE	Required number of cycles	10^7	10^6	10^5	10^4
5. TRANSVERSE SENSITIVITY	Percentage indicated strain with 1,000 Trans. $\mu\epsilon$	.3	.5	2.0	5.0
6. STRAIN LIMIT AT R.T	Strain limit %	2	1	.5	.25
7. STRAIN LIMIT AT EXTREME OP. TEMP.	Strain limit %	2	1	.5	.25
8. THERMAL OUTPUT	Deviation from Std. Nom. in $\mu\epsilon$ /°F	.2	.5	1	2
	Tolerance from Av. Nom. in $\mu\epsilon$	25	100	500	1,000
9. THERMAL HYSTERESIS	Largest Difference in Apparent Strain in $\mu\epsilon$	5	10	50	100
10. DRIFT	70% Max. Op. Temp. in $\mu\epsilon$ /Hour	2	10	100	1,000
	At 100% Max. Op. Temp. in $\mu\epsilon$ /Hour	5	25	250	2,000
11. LEAKAGE RESISTANCE	Room Temp. in Megohms	50K	10K	2K	.5K
	70% Max. Op. Temp. in Megohms	20K	2K	500	100
	100% Max. Op. Temp. in Megohms	1K	200	30	5
12. TRANSIENT TEMPERATURE RESPONSE	Indicated Strain Difference at 10 °F/Sec in $\mu\epsilon$	5	100	300	500
	Indicated Strain Difference of 25 °F/Sec. in $\mu\epsilon$	10	200	500	1,000
	Indicated Strain Difference at 60 °F/Sec. in $\mu\epsilon$	25	500	1,500	2,500
13. GAGE FACTOR CHANGE WITH TEMPERATURE	Average Change %/100 °F at 70% Ext. Op. Temp.	.2	1	3	5
	Tol. %/°F Change in R.T. G.F. at 70% Ext. Op. Temp.	$\pm .05$	$\pm .2$	± 1.0	± 3.0
	Average Change %/100 °F at 100% Ext. Op. Temp.	.4	2	6	10
	Tol. %/°F Change in R.T. G.F. at 100% Ext. Op. Temp.	$\pm .05$	$\pm .2$	± 1.0	± 3.0
14. CREEP	Δ Indicated Strain at Room Temperature	Undetectable	5	10	25
	Δ Indicated Strain at 70% Ext. Op. Temp.	10	20	35	60
	Δ Indicated Strain at 100% Ext. Op. Temp.	20	30	50	100

3.3.2 Sampling Rate

The rates or intervals at which strain gages are to be taken from the production line are shown in Table II. This sample shall be taken from the production line in equal intervals dependent on the sequence in which the gages are produced. For example, suppose 1,000 gages are produced and that the sampling rate for a particular performance characteristic is 1%; one gage will be tested after every 100 is produced. If the first gage to be produced is called No. 1, and the second gage No. 2 and so on, then gages numbered 100, 200, 300, etc. should be taken for quality control testing. Gages removed from production for quality control testing will not be included in the interval or rate determination.

4. QUALITY ASSURANCE PROVISIONS

4.1 General

4.1.1 Unless otherwise specified herein, the manufacturer is responsible for the performance of all inspection requirements prior to submission for customer inspection and acceptance. Except as otherwise specified, the supplier may utilize his own facilities or any commercial laboratory acceptable to the customer. Inspection records of the examinations and tests shall be kept complete and available to the customer as specified in the contract or order.

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4.1.2 The choice of the strain gage extreme operating temperature has been left to the manufacturer. The procedures in this specification assume only one extreme operating temperature is assigned to each type of gage. Although the procedures are set up in this manner, no constraint is made to assigning more than one extreme operating temperature to a type of strain gage. In the event that a gage is assigned more than one extreme operating temperature, the testing and grading of the strain gage will be handled separately (as for a new type, family, or lot) for each extreme operating temperature.

4.1.3 Reliability requirements and test procedures have been included as an integral part of the qualification requirements. The requirement is made in Section 3.2.1 that test data used to represent a particular performance characteristic of a particular type, family, or lot of gage be the result of tests run on a minimum of five separate strain gage installations.

Ninety-five percent of the Grade A and Grade B gages and ninety percent of the Grade C and Grade D gages tested must be within the specified requirements; this, in combination with the sampling or quality control requirements, is intended to indicate the reliability of production strain gages which cannot, or have not, been tested.

The data representing performance characteristic tests will be composed of the results of tests on at least five gage installations. In the event that the data resulting from one of the five gage installations is out of tolerance and additional gage installations are tested as described in Section 3.2.1, then the data representing the particular performance characteristic being evaluated will be composed of the results of all gages tested, except those that were out of tolerance.

4.1.4 Except where otherwise noted, all stated accuracies shall refer to the actual measured value rather than to full scale values.

4.2 Gage Application

4.2.1 General

4.2.1.1 The gage application techniques must be consistent for all data representing a particular family, type, or lot of gage. A change in gage application techniques for a family, type, or lot of gages will require a new or additional set of data.

4.2.2 Surface Preparation

It is required that the step-by-step procedure used for the preparation of the surface to be gaged be recorded, as well as the materials used and their manufacturers.

4.2.3 Adhesion

4.2.3.1 The type of bond must be recorded.

- (a) When an adhesive is used, the manufacturer, manufacturer's type, and type of catalyst must be named.
- (b) When the gage is welded to the specimen, the name or description of the welding device used, a detailed description of the welding techniques, and the values of all control settings used must be recorded.
- (c) If a method other than (a) or (b) above is used, this method must be thoroughly described in a step-by-step manner.

4.2.3.2 The step-by-step procedure used in placing the gage on the prepared surface must be described.

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TABLE II – SAMPLING RATES

PERFORMANCE CHARACTERISTIC		SAMPLING RATE (ALL GRADES)
1.	GAGE RESISTANCE	100%
2.	GAGE FACTOR	Wire 5%
		Foil 1%
		Semi 100%
3.	MECHANICAL HYSTERESIS	.1%
4.	FATIGUE LIFE	.1%
5.	TRANSVERSE SENSITIVITY	Not Required
6.	STRAIN LIMIT AT R.T.	.01%
7.	STRAIN LIMIT AT EXT. OP. TEMP.	Not Required
8.	THERMAL OUTPUT	.1%
9.	THERMAL HYSTERESIS	.1%
10.	DRIFT	.01%
11.	LEAKAGE RESISTANCE	.01%
12.	TRANSIENT TEMPERATURE RESPONSE	Not Required
13.	GAGE FACTOR CHANGE WITH TEMP.	.01%
14.	CREEP	.01%

4.2.4 Cure

4.2.4.1 Time and Temperature Limitations

The gage characteristics vary with the cure time and cure temperature; in turn, cure time and cure temperature vary with intended use. Seven cure temperature and time combinations are listed below, but only four of the seven combinations are termed standard.

Class I, Class II, Class III, and Class IV time and temperature cure limitations listed below are standard for this specification. Class V, Class VI, and Class VII are optional cures. Testing and grading using these optional cures will be permitted only after a strain gage has first been tested and graded utilizing a standard cure.

Class I Cure – Less than one hour at room temperature (see Section 6 for definition of room temperature).

Class II Cure – From one to forty-eight hours at room temperature.

Class III Cure – Less than six hours and cured at no higher than 50 °F above the specified maximum operating temperature of the gage.

Class IV Cure – Less than sixteen hours and cured at a temperature no higher than 50 °F above the maximum operating temperature of the gage.

Class V Cure – Less than six hours and cured at a temperature higher than 50 °F above the maximum operating temperature of the gage.

Class VI – Less than sixteen hours and cured at a temperature greater than 50 °F above the maximum operating temperature of the gage.

Class VII – Less than thirty-two hours and cured at a temperature no higher than 50 °F above the maximum operating temperature of the gage.

It should be noted that the strain gage extreme operating temperature is an arbitrary and flexible value and might be varied for a particular type of gage by the manufacturer in order to classify the strain gage under different conditions.

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4.2.4.2 Cure Cycle

The temperature and clamping pressure in PSI (as a function of time), and the method of clamping must be recorded for each complete gage installation.

4.2.5 Lead Wire and Method of Attachment

4.2.5.1 The lead wire must be described as to its:

- (a) Conducting material
- (b) Conducting material cross-sectional area and whether solid or stranded
- (c) Size and shape, and plating (if any)
- (d) Type of insulation

4.2.5.2 The attachment must be described with respect to the following:

- (a) Number of lead wires.
- (b) A complete description of the type of connection (solder or weld) with material used, such as solder, fluxes and brazing. This description shall include the manufacturer's description of the materials or its chemical composition.
- (c) The step-by-step procedure used in making the connection including such details as the power used and size of heat transferring tool.

4.3 General Test Equipment

4.3.1 Certification

The calibration of test equipment used to obtain data required by this specification shall be traceable to the National Institute of Standards and Technology. A record of this traceability shall be maintained. In addition, a prescribed periodical calibration procedure shall be established and maintained by the manufacturer. This periodical calibration procedure shall cover all instruments and devices used herein and shall be available upon request. The following items are considered to be an essential part of the calibration record:

- (a) Method of calibration employed.
- (b) Serial numbers and names of the manufacturers of all apparatus used in verifying and calibrating.
- (c) A statement indicating how, by whom, and when the verification of apparatus used was made.
- (d) A statement of errors of the calibration apparatus.

4.3.2 Indicated Strain

The electrical equipment used to measure the change in resistance of a strain gage installation shall have an accuracy which will lead to an indicated strain accuracy of ± 5 microstrain. For example, the electrical equipment used to measure the change in resistance of a strain gage installation having a gage factor of 2.0 will be required to have an accuracy of at least ± 10 micro-ohms/ohm.

Corrections shall be incorporated to compensate for any de-sensitization caused by the measuring circuits used.

This specification requires that the change in resistance be measured; the direct measurement of unit resistance change will be permitted when it can be shown that the error introduced is less than .5%.

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4.3.3 Temperature Measuring Equipment

The strain gage manufacturer must maintain information describing the type of temperature sensor used and the type of measuring or recording equipment used. Temperatures shall be monitored with a resolution of 1 °F and an accuracy of ± 3 °F or $\pm 1\%$, whichever is greater.

4.3.4 Excitation Voltage

A voltage value of $2.0 \pm .25$ volts across the strain gage will be standard for the testing prescribed herein. If other voltage values are used, these values must be stated and accompanied by the reason for deviating from the standard.

The type of regulation (e.g. constant current or constant voltage) and the frequency of the excitation voltage must also be noted.

4.4 Qualification Test Procedure

4.4.1 Gage Resistance

4.4.1.1 Extent of Coverage

4.4.1.1.1 The resistance of each gage must be measured.

4.4.1.1.2 The measurement procedure is the same for all types of gages.

4.4.1.1.3 The gage resistance measurement made here represents the unbonded, or not installed, gage resistance only.

4.4.1.2 Testing Apparatus

The device used to measure the gage resistance must have an accuracy of at least $\pm .05\%$ and a resolution of $.01\%$.

4.4.1.3 Procedure

The resistance of the strain gage shall be measured and recorded. The ambient temperature and humidity will also be measured and recorded.

4.4.1.4 Test Results

4.4.1.4.1 The average nominal resistance will be computed by averaging the measured resistances. (Note in Section 4.1.3 that if more than five gages are tested, the test results might not consist of all the resistances measured).

4.4.1.4.2 The deviation is the difference between the standard nominal resistance value listed in Section 1.4.3.2; and the average nominal resistance as determined in Section 4.4.1.4.1. The deviation will be expressed as a percentage of the standard nominal resistance.

4.4.1.4.3 The tolerance is the difference between the average nominal resistance value and the resistance value of that gage (when less than ten gages are tested) which deviates the most from the average nominal resistance. This difference shall be expressed as a percentage of the average nominal resistance.

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4.4.2 Gage Factor and Mechanical Hysteresis

4.4.2.1 Extent of Coverage

4.4.2.1.1 The gage factor and mechanical hysteresis test must be made for each type of strain gage.

4.4.2.1.2 The testing procedure for determination of gage factor and mechanical hysteresis does not vary with the type of gage; however, the handling of the data does vary.

4.4.2.1.3 One value of gage factor will result from this test and it will represent both tension and compression.

4.4.2.2 Testing Apparatus

4.4.2.2.1 Specimen

The specimen shall consist of a constant moment beam conforming to the material, heat treat, and dimensions shown in Figure 1. The upper (compression) and the lower (tension) gage locations are shown on this drawing. Also shown are the loading and reaction points.

4.4.2.2.2 Loading and Calibration of Specimen

A mechanical strain measurement of the beam under the strain gage shall be made with an independent system. It will not be necessary, however, to directly measure the mechanical strain for each strain gage tested. A calibration may be made and maintained on the beam and loading device. Mechanical strain measurement (when made) must be made in the same area as the strain gage installation under test; strain measurements may be considered to be representative of other locations on the beam only if tests with the independent mechanical-strain measuring device prove that they are.

The loading or strain measuring system used must maintain a strain accuracy of ± 5 microstrain – with the following exception: gages with strain sensitive elements of resistivity greater than 10-3 ohm-centimeters which are intended to be classed as Grade A quality (with respect to gage factor) shall require a strain measuring system with an accuracy of ± 2 microstrain.

4.4.2.3 Procedure

The test specimen described in Section 4.4.2.2.1 bearing a previously unstrained strain gage installation, shall be installed in the loading system and test environment at zero strain. The beam will be loaded three times in tension (or compression) to a strain level of $3,000 \pm 90$ microstrain in 500 ± 15 microstrain incremental loads. The loaded beam shall be unloaded in decrements with the same tolerance. At each increment of load, the mechanical strain and the change in resistance shall be recorded. Upon returning to zero strain after loading, a final change in resistance will be measured before re-balancing and proceeding to the next load cycle. At least 40% of the gages shall be tested in compression and at least 40% in tension. The test specimen temperature shall be 75 ± 10 °F throughout the test. The temperature shall not vary more than ± 3 °F during the test.

4.4.2.4 Test Results

4.4.2.4.1 The data from the test procedure above shall be plotted on a graph (or graphs) as change in resistance (ordinate) versus mechanical strain (abscissa).

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4.4.2.4.2 A gage factor value will be determined for each of the three strain cycles (tension or compression) for each gage in accordance with the definition of gage factor found in Section 6. The gage factor value for gages with strain sensitive elements of resistivity less than 10^{-3} ohm-centimeters will be determined at 1,000 microstrain. The gage factor value for gages with strain sensitive elements of resistivity greater than 10^{-3} ohm-centimeters will be determined at 500 microstrain.

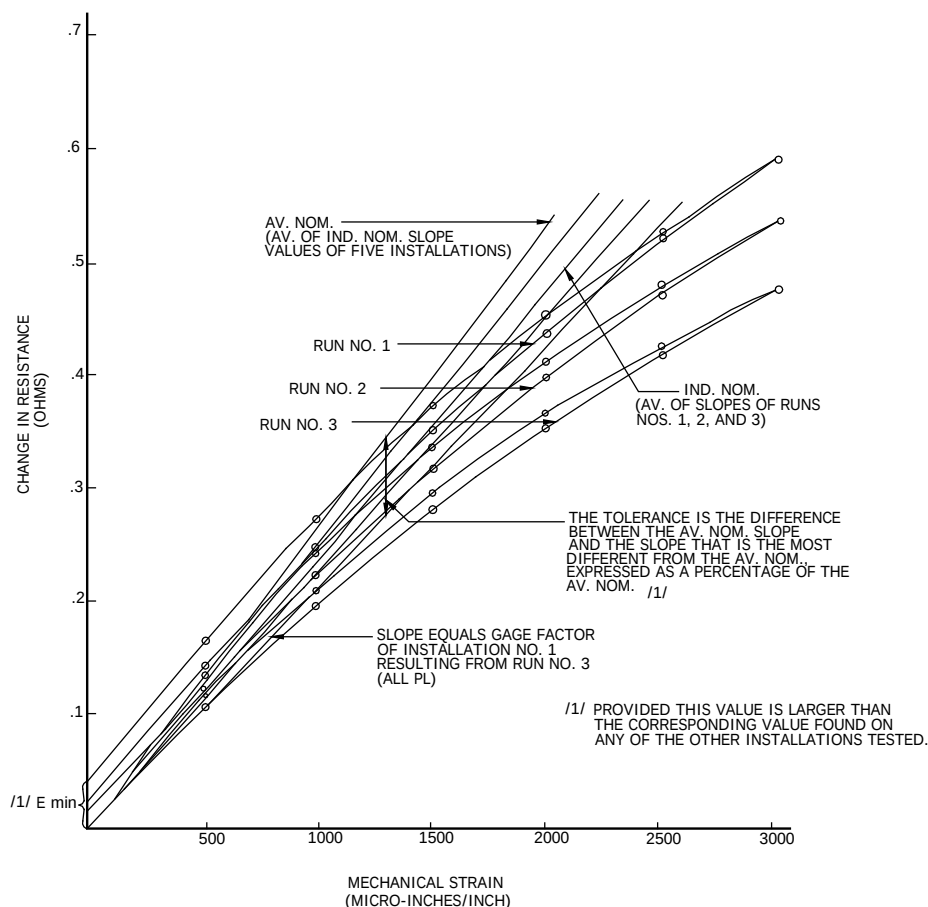
An individual gage factor value will be determined for each gage by averaging the three gage factor values for each of the three runs. The average nominal gage factor will be computed by averaging the individual gage factor values of all the strain gages used to represent the test results.

4.4.2.4.3 The differences between the average, nominal gage factor value and gage factor values of each run will be determined. The tolerance will be the largest difference, as determined above, expressed as a percentage of the average nominal gage factor value.

4.4.2.4.4 The mechanical hysteresis is the difference in indicated strain between an increasing and a decreasing strain cycle expressed as an indicted strain using the graphs from Section 4.4.2.4.1 and the average nominal gage factor as determined in Section 4.4.2.4.2. All data representing the test results must be considered. The largest value found will be reported as the mechanical hysteresis for this gage type.

4.4.2.4.5 Graph 1 shows the change in resistance as a function of mechanical strain.

GAGE INSTALLATION NO. 1
(INITIAL RESISTANCE = 121.3 Ω)



GRAPH 1 – GAGE FACTOR & MECHANICAL HYSTERESIS

4.4.3 Fatigue Life

4.4.3.1 Extent of Coverage

4.4.3.1.1 Fatigue life tests must be made for each family of gages. The data resulting from tests on one type of strain gage for fatigue life will represent data for all other types of strain gages that are of the same family.

4.4.3.1.2 A strain gage with an active gage length of .25 inches shall be used for this test. If a different active gage length is used, this length shall be stated along with the reason for deviating.

4.4.3.2 Testing Apparatus

4.4.3.2.1 Specimen

The specimen used for this testing is shown in Figure 2 (Sheet 50).

4.4.3.2.2 Loading Device

The loading device described in Figure 2 will be used.

4.4.3.2.3 Equipment

An automatic cycle-counter (or equivalent) with a resolution of 500 cycles or better shall be employed.

A provision shall be made to periodically display the varying output of each gage on an oscilloscope or in some equivalent manner.

4.4.3.2.4 Calibration

A mechanical strain calibration of the beam and loading device shall be made and maintained.

4.4.3.3 Procedure

The loading device shall be adjusted to apply an alternating strain of $\pm 1,500$ (+100 or -50) microstrain to the strain gage at the rate of 30 cycles/sec with zero mean load. The indicated strain shall be recorded at maximum positive, zero, and maximum negative strains after every 100,000 cycles. The gage outputs shall also be displayed on an oscilloscope at these same intervals to insure that short duration spike-like failures are not present at the interim strain levels.

All strain measurements shall be referenced to the initial zero. Cycling shall continue until the required number of cycles (see Section 3) have been applied, or until failure of the gage; failure of a gage for this testing procedure shall be defined as a change in indicated strain of 100 microstrain (with the first-cycle indicated strain values as reference), or the appearance of spikes on the oscilloscope display.

4.4.3.4 Test Results

A graphed curve shall be made for each gage showing the change in maximum positive, zero, and maximum negative indicated strains as a function of the number of load cycles.

An example graph is shown as Graph 2.

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4.4.4.2.2 Calibration of Test Specimen and Loading Jig

A calibration of mechanical strain on the two principal axes will be made and maintained on the specimen and associated loading system.

The measurement of the strains during testing may be performed through the use of single element strain gages which have been permanently attached to and calibrated on the specimen. The mechanical strain must be measured in the same area as the strain gage installation under test; these measurements may be considered to be representative of other locations and the test specimen only if tests prove that they are.

4.4.4.3 Test Procedure

The strain gage will be mounted on the test specimen such that the strain sensitive gage axis is 90° to the maximum principal strain. With the beam installed in the loading jig and at a temperature of 75 °F ± 10 °F, a strain of 1,000 ± 50 microstrain will be induced in the specimen beneath the gage. The change in resistance will be measured, after which the test specimen will be unloaded.

4.4.4.4 Test Results

The transverse sensitivity will be shown as a percentage value by dividing the indicated strain by the strain imposed on the transverse axis. The gage factor value determined in Section 4.4.2 will be used to compute the indicated strain. The largest transverse sensitivity percentage value computed from the above testing will be used to represent the transverse sensitivity of a type of gage.

4.4.5 Room Temperature Strain Limit

4.4.5.1 Extent of Coverage

4.4.5.1.1 Room temperature strain limit tests must be made for each family of gages. The data resulting from tests on one type of strain gage for room temperature strain limit will represent data for all other types of strain gages that are of the same family.

4.4.5.1.2 A strain gage with an active gage length of .25 inches shall be used for this test. If a length different from .25 inches is used, this length and the reason for deviating shall be reported.

4.4.5.1.3 The testing procedure used for determining the room temperature strain limit will not vary with the extreme operating temperature rating of the gage.

4.4.5.2 Testing Apparatus

4.4.5.2.1 Specimen

The test specimen used for this test shall be prepared in accordance with Figure 4.

4.4.5.2.2 Loading Equipment

The loading device must be capable of applying a uniform tensile load in increments of 10% or less of the expected strain limit. If the load is not applied in steps, the rate of loading must be slow enough to allow the simultaneous measurement of mechanical strain and electrical analog at approximately 10% increments of the expected strain limit.

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4.4.5.2.3 Measurement of Mechanical Strain

The general requirement of an accuracy of ± 5 microstrain for mechanical strain measurement will be waived for this test procedure. For the room temperature strain limit test, the real strain shall be measured with an independent system having an accuracy of ± 50 microstrain or 2% of the mechanical strain value, whichever is greater.

The extensometer used to measure the mechanical strain must have a gage length of four inches or less. The gage or gages being tested must lie within the gage length of the extensometer.

4.4.5.3 Procedure

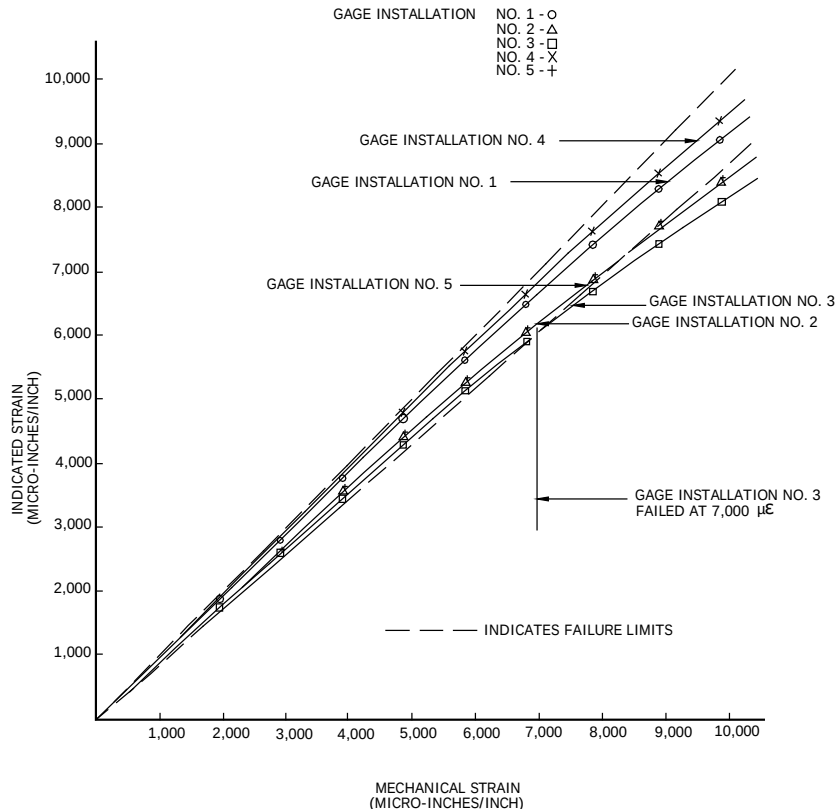
At $75^\circ\text{F} \pm 10^\circ\text{F}$ and zero strain the test specimen, with strain sensing devices attached, shall be installed in the loading system.

Tensile load shall be applied in increments of 10% or less of the expected strain limit. Measurements of mechanical strain and change in resistance shall be made simultaneously and shall be continued until failure of the strain gage or strain gage bond occurs. Failure of the strain gage for this test shall be defined as a difference between the indicated strain (using the gage factor value determined in Section 4.4.2) and the mechanical strain of more than 10% of the mechanical strain.

4.4.5.4 Test Results

Graphs of indicated strain (ordinate) versus mechanical strain (abscissa) shall be made for each gage installation. Considering all the gages tested, the strain limit will be that smallest value of mechanical strain at which a failure, as defined above, occurs.

An example of the above data is shown in Graph 3.



GRAPH 3 - ROOM TEMPERATURE STRAIN LIMIT

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4.4.6 Extreme Operating Temperature Strain Limit

4.4.6.1 Extent of Coverage

4.4.6.1.1 Extreme operating temperature strain limit tests must be made for each family of gages. The data resulting from tests on one type of strain gage for extreme operating temperature strain limit will represent data for all other types of strain gages that are of the same family.

4.4.6.1.2 The gages used for this test shall have an active gage length of .25 inches. If a gage with an active gage length other than .25 inches is used, the active gage length and the reason for deviating shall be reported.

4.4.6.2 Testing Apparatus

4.4.6.2.1 Specimen

The test specimen used for this test shall be prepared in accordance with Figure 4.

4.4.6.2.2 Load Equipment

The loading device must be capable of applying a uniform tensile load in increments of 10% or less of the expected strain limit. If the load is not applied in steps, the rate of loading must be slow enough to allow the simultaneous measurement of real strain and electrical analog, at approximately 10% increments of the expected strain limit.

4.4.6.2.3 Measurement of Mechanical Strain

The general requirement of an accuracy of ± 5 microstrain for real strain measurement will be waived here. For the extreme operating temperature strain limit test, the mechanical strain shall be measured with an independent system having an accuracy of ± 100 microstrain or 2% of the mechanical strain value, whichever is greater.

The extensometer used to measure the mechanical strain must have a gage length of four inches or less. The gage or gages being tested must lie within the gage length of the extensometer.

4.4.6.2.4 Environmental Chamber

The environmental chamber used must be capable of maintaining a constant specimen temperature within ± 3 °F or within $\pm 1\%$ of the measured test temperature in degrees Fahrenheit, whichever is larger.

4.4.6.3 Procedure

The test specimen shall be raised (or lowered) to the extreme operating temperature of the strain gage and brought to equilibrium. The temperature throughout the strain gaged area shall be maintained uniform within ± 3 °F, or within 1% of the measured Fahrenheit temperature, whichever is larger. The tensile load shall be applied in increments of 10% or less of the expected strain limit. Measurements of mechanical strain, indicated strain, and temperature shall be made simultaneously (starting at zero load) and shall be continued until failure of the strain gage which, for this test, will be defined as a change in the strain sensitivity (slope of the indicated strain versus mechanical strain curve) of more than 10%.

4.4.6.4 Test Results

Graphs of indicated strain (ordinate) versus real strain (abscissa) shall be made for each gage installation. The strain limit will be the sum of the mechanical strain at which failure, as defined above, occurs, and the thermal expansion of the specimen, which shall be computed using a value of 9.7 microstrain/°F for the linear thermal coefficient of expansion.

An example of the above data is shown in Graph 4.

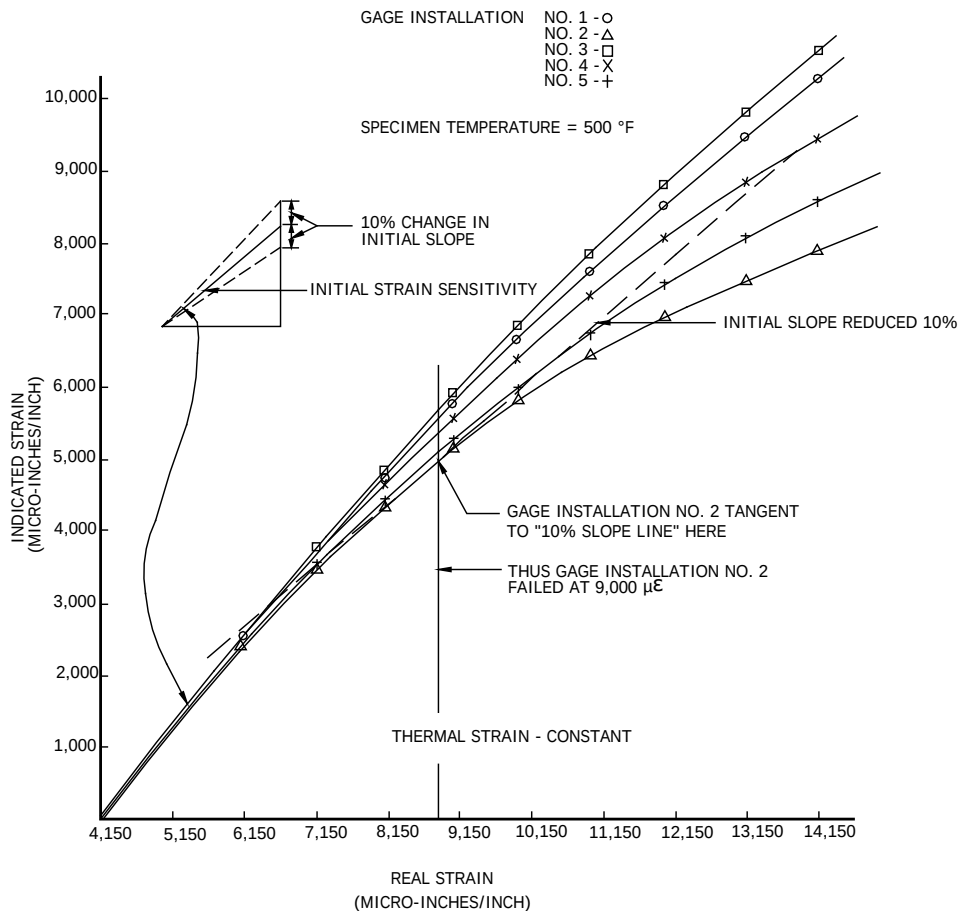
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GRAPH 4 – EXTREME OPERATING TEMPERATURE STRAIN LIMIT

4.4.7 Thermal Output and Thermal Hysteresis

4.4.7.1 Extent of Coverage

- 4.4.7.1.1 Thermal output and thermal hysteresis tests must be made for each lot of gages. The data resulting from tests on one type of strain gage for thermal output and thermal hysteresis will represent data for all other types of strain gages that are of the same lot.
- 4.4.7.1.2 A strain gage with an active gage length of .25 inches shall be used for this test. If a different active gage length is used, this length shall be stated along with the reason for deviating.
- 4.4.7.1.3 The testing apparatus and procedures for evaluating the thermal output performance characteristic vary and are dependent on the extreme operating temperature of the gage. Three test set-ups and procedures are directly allied with three temperature ranges, and the particular testing apparatus and procedure used to evaluate a gage is dictated by the corresponding temperature range within which the extreme operating temperature falls.

The three temperature ranges are as follows:

- (a) Below -75 °F
- (b) -75 °F to +100 °F
- (c) Above +100 °F

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