MICRO MEASUREMENTS
A VPG Brand

Strain Sensor Reference Guide

STRAIN GAGE APPLICATION CHECKLIST

The “considerations” listed apply to relatively routine and conventional stress analysis situations, and do not embrace exotic applications involving nuclear radiation, intense magnetic fields, extreme centrifugal forces, and the like. The choice of adhesive and protective coating is based on the specific application’s requirements.

CONSIDERATIONS FOR PARAMETER SELECTION

Parameter 1:
Gage Series

- Type of strain measurement application (static, dynamic, post-yield, etc.)
- Operating temperature
- Test duration
- Cyclic endurance
- Accuracy required
- Ease of installation

Parameter 2:
S-T-C Number

- Test specimen material
- Operating temperature range
- Accuracy required

Parameter 3:
Gage Length

- Strain gradients
- Area of maximum strain
- Accuracy required
- Static strain stability
- Maximum elongation
- Cyclic endurance
- Heat dissipation
- Space for installation
- Ease of installation

Parameter 4:
Gage Pattern

- Strain gradients (in-plane and normal to surface)
- Biaxiality of stress
- Heat dissipation
- Space for installation
- Ease of installation
- Gage resistance availability

Parameter 5:
Gage Resistance

- Heat dissipation
- Leadwire desensitization
- Signal-to-noise ratio

Parameter 6:
Options

- Type of measurement (static, dynamic, post-yield, etc.)
- Installation environment — laboratory or field
- Stability requirements
- Soldering sensitivity of Substrate (plastic, bone, etc.)
- Space available for installation
- Installation time constraints

Parameter 7:
Bonding Adhesives

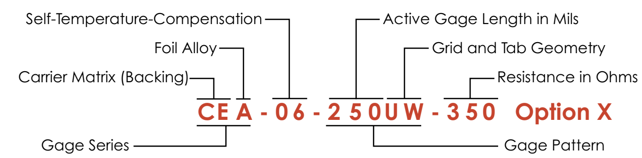
- Temperature range
- Elongation
- Cure temperature
- Clamping pressure

Parameter 8:
Environmental Protection

- Temperature range
- Contaminants encountered (water, steam, oil, grease, corrosive gases, etc.)
- Longevity of the installation
- Reinforcement

GAGE DESIGNATION SYSTEM

Example of Gage Designation Nomenclature



DON’T BLAME THE SENSOR!

Ten incredibly common strain measurement mistakes you really don’t want to make:

1. Failure to remove soldering flux (resistance drift will occur)
2. Failure to follow gage bonding adhesive instructions (gage un-bonding can occur)
3. Making the wrong wire connections to the instrument (cannot balance)
4. Inputting the incorrect gage factor value
5. Using the wrong shunt calibration resistor value
6. Applying excessive bridge excitation (causes drift)
7. Applying strain levels that produce yield in the structure (produces a zero shift in the strain gages)
8. Applying strain levels that are beyond the capability of the strain gage or bonding adhesive
9. Applying strain gages to bolted assemblies (bolted joints typically slip during loading, resulting in the strain gage’s poor return to zero after loading)
10. Not applying, or incorrectly applying, strain gage protective coatings (corrosive attack on the gage foil causes gage resistance drift over time)

FIVE SIGNS THAT SHOW YOUR CONFIDENCE WITH STRESS VS. STRAIN

1. The strain gage readings are stable from power-up and with no load applied.
2. The gage circuits have nearly infinite resistance to ground (>10k MΩ).
3. Under elastic loading conditions, the gages return to zero when unloaded.
4. Shunt calibration resistors have been used to verify that gage factor settings are correct; leadwire desensitization has been accounted for; and rosettes are used when strain directions are unknown.
5. The gages have been properly protected from the environment.

Parameter 1:
Gage Series
CEA-06-250UW-350 Option X

STANDARD GAGE SERIES SELECTION

GAGE SERIES	DESCRIPTION AND PRIMARY APPLICATION	TEMPERATURE RANGE	STRAIN RANGE
EA	Constantan foil in combination with a tough, flexible, polyimide backing. Wide range of options available. Primarily intended for general-purpose static and dynamic stress analysis. Not recommended for highest accuracy transducers.	Normal: –100° to +350°F (–75° to +175°C) Special or short term: –320° to +400°F (–195° to +205°C)	±3% for gage lengths under 1/8 in (3.2 mm) ±5% for 1/8 in and over
CEA	Universal general-purpose strain gages. Constantan grid completely encapsulated in polyimide, with large, rugged copper-coated tabs. Primarily used for general-purpose static and dynamic stress analysis.	Normal: –100° to +350°F (–75° to +175°C) Stacked rosettes limited to +150°F (+65°C)	±3% for gage lengths under 1/8 in (3.2 mm) ±5% for 1/8 in and over
C2A	General-purpose stress analysis strain gages. Supplied with preattached cables for direct connection to instrumentation.	–60° to +180°F (–50° to +80°C)	±3%
L2A	General-purpose stress analysis strain gages. Supplied with preattached leadwire ribbons.	–100° to +250°F (–75° to +120°C)	±3%
W2A IPX8S Rated	For water-exposure applications. Based on the CEA Series with Option P2 pre-attached cables, W2A strain gages are fully enclosed with a silicone rubber coating and tested to 10 GΩ insulation resistance, 1 meter water depth, 30 minutes duration. Other requirements can be addressed on demand.	–60° to +180°F (–50° to +80°C)	±3%
N2A	Open-faced constantan foil gages with a thin, laminated, polyimide-film backing. Primarily recommended for use in precision transducers, the N2A Series is characterized by low and repeatable creep performance. Also recommended for stress analysis applications employing large gage patterns, where the especially flat matrix eases gage installation.	Normal static transducer service: –100° to +200°F (–75° to +95°C)	±3%
WA	Fully encapsulated constantan gages with high-endurance leadwires. Useful over wider temperature ranges and in more extreme environments than EA Series. Option W available on some patterns, but reduces fatigue life to some extent.	Normal: –100° to +400°F (–75° to +205°C) Special or short term: –320° to +500°F (–195° to +260°C)	±2%
SA	Fully encapsulated constantan gages with solder dots. Same matrix as WA Series. Same uses as WA Series but derated somewhat in maximum temperature and operating environment because of solder dots.	Normal: –100° to +400°F (–75° to +205°C) Special or short-term: –320° to +450°F (–195° to +230°C)	±2%
EP	Specially annealed constantan foil with tough, high-elongation polyimide backing. Used primarily for measurements of large post-yield strains. Available with Options E, L, and LE (may restrict elongation capability).	–100° to +400°F (–75° to +205°C)	±10% for gage lengths under 1/8 in (3.2 mm) ±20% for 1/8 in and over
ED	Isoelastic foil in combination with tough, flexible polyimide film. High gage factor and extended fatigue life excellent for dynamic measurements. Not normally used in static measurements due to very high thermal-output characteristics.	Dynamic: –320° to +400°F (–195° to +205°C)	±2% Nonlinear at strain levels over ±0.5%
WD	Fully encapsulated isoelastic gages with high-endurance leadwires. Used in wide-range dynamic strain measurement applications in severe environments.	Dynamic: –320° to +500°F (–195° to +260°C)	±1.5% Nonlinear at strain levels over ±0.5%
SD	Equivalent to WD Series, but with solder dots instead of leadwires.	Dynamic: –320° to +400°F (–195° to +205°C)	±1.5% Nonlinear at strain levels over ±0.5%
EK	K-alloy foil in combination with a tough, flexible polyimide backing. Primarily used where a combination of higher grid resistances, stability at elevated temperature, and greatest backing flexibility are required. Supplied with Option DP.	Normal: –320° to +350°F (–195° to +175°C) Special or short term: –452° to +400°F (–269° to +205°C)	±1.5%
WK	Fully encapsulated K-alloy gages with high endurance leadwires. Widest temperature range and most extreme environmental capability of any general-purpose gage when self-temperature compensation is required. Option W available on some patterns, but restricts both fatigue life and maximum operating temperature.	Normal: –452° to +550°F (–269° to +290°C) Special or short term: –452° to +750°F (–269° to +400°C)	±1.5%
SK	Fully encapsulated K-alloy gages with solder dots. Same uses as WK Series, but derated in maximum temperature and operating environment because of solder dots.	Normal: –452° to +450°F (–269° to +230°C) Special or short term: –452° to +500°F (–269° to +260°C)	±1.5%
S2K	K-alloy foil laminated to 0.001 in (0.025 mm) thick, high-performance polyimide backing, with a laminated polyimide overlay fully encapsulating the grid and solder tabs. Provided with large solder dots for ease of leadwire attachment.	Normal: –100° to +250°F (–75° to +120°C) Special or short term: –300° to +300°F (–185° to +150°C)	±1.5%

Notes: The performance data given here are nominal, and apply primarily to gages of 0.125-in (3-mm) gage length or larger. Refer to Gage Series/Optional Feature data sheet for more detailed description and performance specifications.

Parameter 2:
S-T-C Number
CEA-**06**-250UW-350 Option X

NOMINAL THERMAL EXPANSION COEFFICIENTS OF ENGINEERING MATERIALS

MATERIAL DESCRIPTION	EXPANSION COEFFICIENTS**		RECOMMENDED S-T-C NUMBER
	Per °F	Per °C	
ALUMINA, fired	3.0	5.4	03
ALUMINUM Alloy, 2024-T4*, 7075-T6	12.9	23.2	13*
BERYLLIUM, pure	6.4	11.5	06
BERYLLIUM COPPER, Cu 75, Be 25	9.3	16.7	09
BRASS, **Cartridge**, Cu 70, Zn 30	11.1	20.0	13
BRONZE, **Phosphor**, Cu 90, Sn 10	10.2	18.4	09
CAST IRON, gray	6.0	10.8	06
COPPER, pure	9.2	16.5	09
GLASS, Soda, Lime, Silica	5.1	9.2	05
INCONEL, Ni-Cr-Fe alloy	7.0	12.6	06
INCONEL X, Ni-Cr-Fe alloy	6.7	12.1	06
INVAR, Fe-Ni alloy	0.8	1.4	00
MAGNESIUM Alloy*, AZ-31B	14.5	26.1	15*
MOLYBDENUM*, pure	2.7	4.9	03*
MONEL, Ni-Cu alloy	7.5	13.5	06
NICKEL-A, Cu-Zn-Ni alloy	6.6	11.9	06
QUARTZ, fused	0.3	0.5	00
STEEL Alloy, 4340	6.3	11.3	06
STEEL, **Carbon**, 1008, 1018*	6.7	12.1	06*
STEEL, **Stainless**, Age Hardenable (17-4 PH)	6.0	10.8	06
STEEL, **Stainless**, Age Hardenable (17-7 PH)	5.7	10.3	06
STEEL, **Stainless**, Age Hardenable (PH15-7 Mo)	5.0	9.0	05
STEEL, **Stainless**, Austenitic (304*)	9.6	17.3	09*
STEEL, **Stainless**, Austenitic (310)	8.0	14.4	09
STEEL, **Stainless**, Austenitic (316)	8.9	16.0	09
STEEL, **Stainless**, Ferritic (410)	5.5	9.9	05
TIN, pure	13.0	23.4	13
TITANIUM, pure	4.8	8.6	05
TITANIUM Alloy, 6AL-4V*	4.9	8.8	05*
TITANIUM SILICATE*, polycrystalline	0.017	0.03	00*
TUNGSTEN, pure	2.4	4.3	03
ZIRCONIUM, pure	**3.1**	**5.6**	**03**

* Indicates type of material used in determining thermal output data supplied with Micro-Measurements strain gages.
** Nominal values at or near room temperature for temperature coefficient of expansion values.

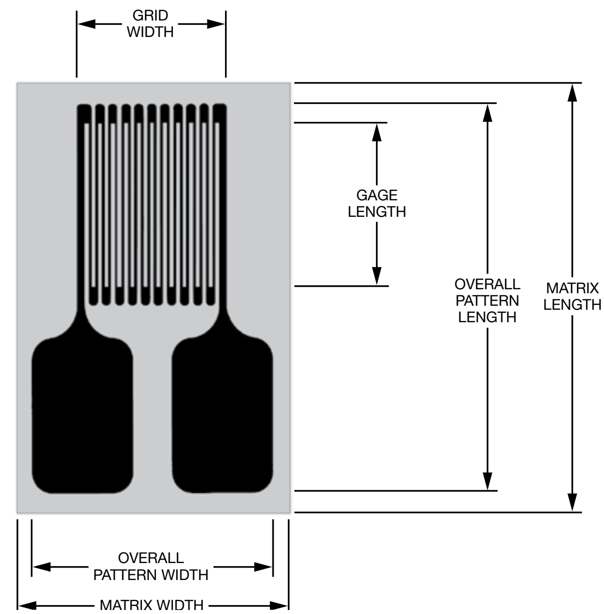
Parameter 3, 4:
Gage Length, Gage Pattern
CEA-06-**250UW**-350 Option X

GAGE LENGTH AND GRID/TAB GEOMETRY

Gage length is an important consideration in strain gage selection, and is usually the first parameter to be defined.

Dimensions listed for gage length (as measured inside the grid endloops) and grid width refer to active grid dimensions. Overall length and width refer to the actual foil pattern, not including alignment marks or backing.

The matrix size represents the approximate dimensions of the backing/matrix of the gage as shipped. Matrix dimensions are nominal, with a usual tolerance of ±0.015 in (±0.4 mm). If the gages are encapsulated, the matrix may be smaller by as much as 0.01 in (0.25 mm). Most patterns also include trim marks, and, for use in a restricted area, the backing/matrix may be field-trimmed on all sides to within 0.01 in (0.25 mm) of the foil pattern without affecting gage performance.



Parameter 5:
Gage Resistance
CEA-06-250UW-**350** Option X

120 Ω vs. 350 Ω vs. 1 kΩ

In the past, it was more common to use 120 Ω (instrumentation stability driven), but modern instrumentation has eliminated the need to use 120 Ω gages for stability.

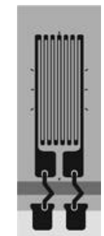
When a choice exists, the higher resistance strain sensor (gage) is preferable in that it reduces the heat generation rate by a significant factor. Higher gage resistance, such as 350 Ω and 1 kΩ, also have the advantage of decreasing leadwire effects such as gage factor desensitization due to leadwire resistance in series with the active gage. If the strain gage circuit is in an electrically noisy environment, the signal-to-noise ratio can be improved with higher resistance strain gages due to the ability to use a higher excitation without grid self-heating (zero instability).

Parameter 6:
Options
CEA-06-250UW-350 **Option X**

STANDARD OPTIONS

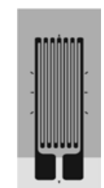
OPTION W — SERIES AVAILABILITY: EA, EP, WA, ED, WD, EK, WK

General Description: This option provides encapsulation, and thin, printed circuit terminals at the tab end of the gage. Beryllium copper jumpers connect the terminals to the gage tabs. The terminals are 0.0014 in (0.036 mm) thick copper on polyimide backing nominally 0.0015 in (0.038 mm) thick. Option W gages are rugged and well protected, and permit the direct attachment of larger leadwires than would be possible with open-faced gages. This option is primarily used on EA-Series gages for general-purpose applications. **Solder:** +430°F (+220°C) tin-silver alloy solder joints on E-backed gages, +570°F (+300°C) lead-tin-silver alloy solder joints on W-backed gages. **Temperature Limit:** +350°F (+175°C) for E-backed gages, +450°F (+230°C) for W-backed gages. **Grid Protection:** Entire grid and part of terminals are encapsulated with polyimide. **Fatigue Life:** Some loss in fatigue life unless strain levels at the terminal location are below ±1000με. **Size:** Option W extends from the soldering tab end of the gages and thereby increases gage size. With some patterns, width is slightly greater. **Strain Range:** With some gage series, notably E-backed gages, strain range will be reduced. This effect is greatest with EP gages, and Option W should be avoided with them if possible. **Flexibility:** Option W adds encapsulation, making gages slightly thicker and stiffer. Conformance to curved surfaces will be somewhat reduced. In the terminal area itself, stiffness is markedly increased. **Resistance Tolerance:** On E-backed gages, resistance tolerance is normally doubled.



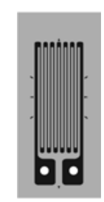
OPTION E — SERIES AVAILABILITY: EA, ED, EK, EP

General Description: Option E consists of a protective encapsulation of polyimide film approximately 0.001 in (0.025 mm) thick. This provides ruggedness and excellent grid protection, with little sacrifice in flexibility. Soldering is greatly simplified since the solder is prevented from tinning any more of the gage tab than is deliberately exposed for lead attachment. Option E protects the grid from fingerprints and other contaminating agents during installation and, therefore, contributes significantly to long-term gage stability. Heavier leads may be attached directly to the gage tabs for simple static load tests. Supplementary protective coatings should still be applied after lead attachment in most cases. **Temperature Limit:** No degradation. **Grid Protection:** Entire grid and part of tabs are encapsulated. **Fatigue Life:** When gages are properly wired with small jumpers, maximum endurance is easily obtained. **Size:** Gage size is not affected. **Strain Range:** Strain range of gages will be reduced because the additional reinforcement of the polyimide encapsulation can cause bond failure before the gage reaches its full strain capability. **Flexibility:** Option E gages are almost as conformable on curved surfaces as open-faced gages, since no internal leads or solder are present at the time of installation. **Resistance Tolerance:** Resistance tolerance is normally doubled when Option E is selected.



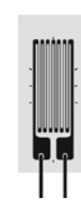
OPTION SE — SERIES AVAILABILITY: EA, ED, EK, EP

General Description: Option SE is the combination of solder dots on the gage tabs with a 0.001 in (0.025 mm) polyimide encapsulation layer that covers the entire gage. The encapsulation is removed over the solder dots providing access for lead attachment. These gages are very flexible, and well protected from handling damage during installation. Option SE is primarily intended for small gages that must be installed in restricted areas, since leadwires can be routed to the exposed solder dots from any direction. The option does not increase overall gage dimensions, so the matrix may be field-trimmed very close to the actual pattern size. Option SE is sometimes useful on miniature transducers of medium- or low-accuracy class, or in stress analysis work on miniature parts. **Solder:** +570°F (+300°C) lead-tin-silver alloy. To prevent loss of long-term stability, gages with Option SE must be soldered with noncorrosive (rosin) flux, and all flux residue should be carefully removed with *M-LINE* Rosin Solvent after wiring. Protective coatings should then be used. **Temperature Limit:** No degradation. **Grid Protection:** Entire gage is encapsulated. **Fatigue Life:** When gages are properly wired with small jumpers, maximum endurance is easily obtained. **Size:** Gage size is not affected. **Strain Range:** Strain range of gages will be reduced because the additional reinforcement of the polyimide encapsulation can cause bond failure before the gage reaches its full strain capability. **Flexibility:** Option SE gages are almost as conformable on curved surfaces as open-faced gages. **Resistance Tolerance:** Resistance tolerance is normally doubled when Option SE is selected.



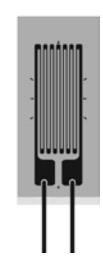
OPTION L — SERIES AVAILABILITY: EA, ED, EK, EP

General Description: Option L is the addition of soft copper lead ribbons to open-faced polyimide-backed gages. The use of this type of ribbon results in a thinner and more conformable gage than would be the case with round wires of equivalent cross section. At the same time, the ribbon is so designed that it forms almost as readily in any desired direction. **Leads:** Nominal ribbon size for most gages is 0.012 wide x 0.004 in thick (0.30 x 0.10 mm). Leads are approximately 0.8 in (20 mm) long. **Solder:** +430°F (+220°C) tin-silver alloy. **Temperature Limit:** +400°F (+200°C). **Fatigue Life:** Fatigue life will normally be degraded by Option L. This occurs primarily because the copper ribbon has limited cyclic endurance. When it is possible to carefully dress the leads so that they are not bonded in a high strain field, the performance limitation will not apply. Option L is not often recommended for very high endurance gages such as the ED Series. **Size:** Matrix size is unchanged. **Strain Range:** Strain range will usually be reduced by the addition of Option L. **Flexibility:** Gages with Option L are not as conformable as standard gages. **Resistance Tolerance:** Not affected.



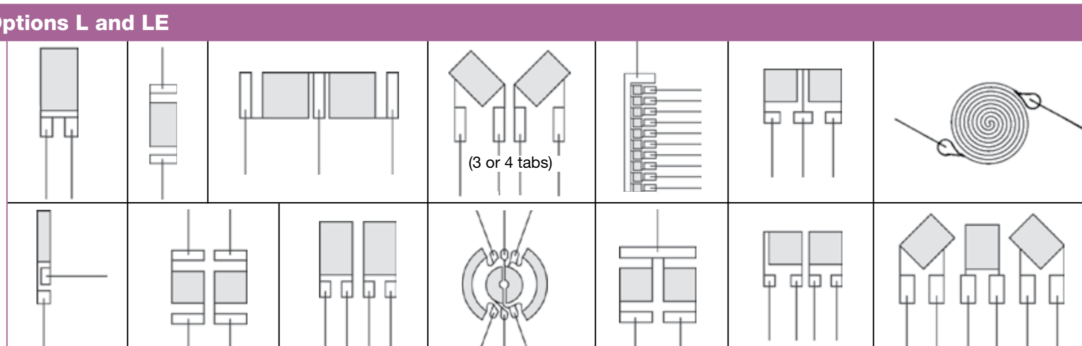
OPTION LE — SERIES AVAILABILITY: EA, ED, EK, EP

General Description: This option provides the same conformable soft copper lead ribbons as used in Option L, but with the addition of a 0.001 in (0.025 mm) thick encapsulation layer of polyimide film. The encapsulation layer provides excellent protection for the gage during handling and installation. It also contributes greatly to environmental protection, though supplementary coatings are still recommended for field use. Gages with Option LE will normally show better long-term stability than open-faced gages which are "waterproofed" only after installation. A good part of the reason for this is that the encapsulation layer prevents contamination of the grid surface from fingerprints or other agents during handling and installation. The presence of such contaminants will cause some loss in gage stability, even though the gage is subsequently coated with protective compounds. **Leads:** Nominal ribbon size for most gages is 0.012 wide x 0.004 in thick (0.30 x 0.10 mm) copper ribbons. Leads are approximately 0.8 in (20 mm) long. **Solder:** +430°F (+220°C) tin-silver alloy. **Temperature Limit:** +400°F (+200°C). **Grid Protection:** Entire gage is encapsulated. A short extension of the backing is left uncovered at the leadwire end to prevent contact between the leadwires and the specimen surface. **Fatigue Life:** Fatigue life will normally be degraded by Option LE. This occurs primarily because the copper ribbon has limited cyclic endurance. Option LE is not often recommended for very high endurance gages such as the ED Series. **Size:** Matrix size is unchanged. **Strain Range:** Strain range will usually be reduced by the addition of Option LE. **Flexibility:** Gages with Option LE are not as conformable as standard gages. **Resistance Tolerance:** Resistance tolerance is normally doubled by the addition of Option LE.



Leadwire Orientation for Options L and LE

These illustrations show the standard orientation of leadwires relative to the gage pattern geometry for Options L and LE. The general rule is that the leads are parallel to the longest dimension of the pattern. The illustrations also apply to leadwire orientation for WA-, WK- and WD-Series gages, when the pattern shown is available in one of these series.



Parameter 6:
Options
CEA-06-250UW-350 **Option X** (cont.)

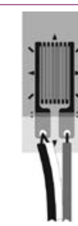
STANDARD OPTIONS

OPTION P	SERIES AVAILABILITY: EA, N2A

General Description: Option P is the addition of preattached leadwire cables to many patterns of EA Series strain gages. Encapsulation seals small "jumper" leadwires at gage end, and cable insulation protects solder joints at cable end. Option P virtually eliminates need for soldering during gage installation. **Leads:** A pair of 1 in (25 mm) *M-LINE* 134-AWP (solid copper, polyurethane enamel) single conductor "jumper" leadwires. **Cable:** 10 ft (3.1 m) of color-coded, flat, three-conductor 26-gauge (0.404 mm dia.), stranded, tinned copper with vinyl insulation (similar to M-LINE 326-DFV). Solder: +430°F (+220°C) tin-silver alloy solder joints, "jumper" to gage. Cable conductors and "jumpers" joined with +361°F solder beneath cable insulation. Exposed leadwires on unattached end of cable are pretinned for ease of hookup. **Temperature Limit:** –60° to +180°F (–50° to +80°C); limited by vinyl insulation on cable. **Grid Encapsulation:** Entire grid and tabs are encapsulated. **Fatigue Life:** Fatigue life will normally be degraded by Option P, primarily because the copper "jumper" wires have limited cyclic endurance. **Pattern Availability:** Most EA-Series single-grid patterns that are 0.062 in (1.5 mm) or greater gage length, with parallel solder tabs on one end of the grid, and suitable for encapsulation. (Consult our Applications Engineering Department for availability of Option P on other gage series/patterns, and for nonstandard cable lengths.) **Size:** Matrix size is unchanged. **Strain Range:** Strain range will usually be reduced by the addition of Option P. **Flexibility:** E-backed gages with Option P are not as conformable as standard gages. **Resistance Considerations:** Each conductor of the cable has a nominal resistance of 0.04 ohm/ft (0.13 ohm/m). Gage resistance is measured at gage tabs. **Gage Factor:** Gage factor is determined for gages without preattached cable. **Resistance Tolerance:** Resistance tolerance is normally ±0.5% for single-element gages, and ±0.6% for multiple-grid gages.

OPTION P2	SERIES AVAILABILITY: CEA

General Description: Option P2 is the addition of preattached leadwire cables to CEA-Series strain gages. Option P2 virtually eliminates need for soldering during gage installation. **Cable:** 10 ft (3.1 m) of color-coded, flat, three-conductor 30-gauge (0.255 mm), stranded, tinned copper with vinyl insulation (similar to *M-LINE* 330-DFV). Solder: +361°F (+180°C) tin-lead alloy solder joints. Exposed leadwires on unattached end of cable are pretinned for ease of hookup. **Temperature Limit:** –60° to +180°F (–50° to +80°C); limited by vinyl insulation on cable. **Grid Encapsulation:** Entire grid is encapsulated. (Solder tabs are not encapsulated.) **Fatigue Life:** Fatigue life will normally be unchanged by Option P2. **Pattern Availability:** Most CEA-Series single- and multiple-grid patterns. **Size:** Matrix size is unchanged. **Strain Range:** Standard for CEA-Series gages. **Flexibility:** No appreciable increase in stiffness. **Resistance Considerations:** Each conductor of the cable has a nominal resistance of 0.1 ohm/ft (0.35 ohm/m). Gage resistance is measured at gage tabs. **Gage Factor:** Gage factor is determined for gages without preattached cable. **Resistance Tolerance:** Not affected.



OPTION S	SERIES AVAILABILITY: EA, ED, EP

Precisely formed hemispherical solder dots are installed in the center of each solder tab. This feature facilitates soldering by providing a pretinned area for lead attachment. A film of adhesive or appropriate protective coating is normally applied over the gage before soldering, and this prevents the solder from spreading on the tab when leads are reinstalled. After the top coating has been cured, the solder dot is easily exposed for soldering by scraping with a scalpel or by simply post-tinning. Solder used for the dots is +570°F (+300°C) lead-tin-silver alloy. Dot diameter varies somewhat with tab size but is usually about 0.02 in (0.5 mm). Temperature limit for this feature is +500°F (+260°C). Because the solder dots result in much greater soldering uniformity, the variable fatigue life factor, which results from excessive solder on the gage tabs, is eliminated. Solder dots are small and interfere very little with flexibility and conformability of strain gages.

OPTION W3	SERIES AVAILABILITY: EA, EP, WA, ED, EK, WK

This feature is identical to Standard Catalog Option W, except that the printed circuit wiring terminals have three solder pads, two of which are electrically common. These terminals facilitate the connection of three-conductor cable for single active gage circuits using the three-wire lead system. Many of the gage patterns which are marked as available with Option W in the General-Purpose Strain Gage Listings are available with three-pad terminals.

Parameter 7:
Bonding—Adhesives/Cements

STRAIN GAGE ADHESIVES AND CEMENTS

M-BOND 200	Most widely used general-purpose adhesive. Easiest to handle. Fast room-temperature curing.
M-BOND AE-10	General-purpose adhesive that is highly resistant to moisture and most chemicals. Room-temperature curing.
M-BOND AE-15	Similar to AE-10. Recommended for more critical applications, including transducer gaging. Moderately elevated-temperature curing.
M-BOND 610	Used primarily in stress analysis applications over a wide temperature range, and in precision transducers. Elevated-temperature curing.
M-BOND 600	Similar to 610, but faster reacting. Can be cured at somewhat lower temperatures than 610.
M-BOND 43-B	Normally used in precision transducers. Highly resistant to moisture and chemical attack. Elevated-temperature curing.
M-BOND GA-2	Special-purpose adhesive primarily used on very rough and irregular surfaces. Room-temperature curing.
M-BOND GA-61	Special-purpose adhesive with a higher operating temperature range than GA-2, and more viscous. Also used to fill irregular surfaces and to anchor leadwires. Elevated-temperature curing.
M-BOND A-12	Special-purpose, very high-elongation adhesive. Used only when other adhesives cannot meet elongation requirements. Elevated-temperature curing.

M-BOND 300	Special-purpose polyester adhesive used primarily when low-temperature curing is required. Sensitive to solvents. Not recommended as a general-purpose adhesive.
M-BOND 450	Special-purpose, high-performance epoxy for higher-temperature transducer applications.
DENEX #3 ADHESIVE	One-part epoxy for lab and transducer work requiring minimal creep. Elevated-temperature curing.
EPOXYLITE 813	Used for long term, high temperature applications requiring a filled glueline. Wider temperature range than GA-61.
P ADHESIVE	Single-part solvent thinned polyimide adhesive. Excellent for long-term high temperature applications.
GC CEMENT	Single-part ceramic cement used for free-filament gages. Recommended for use on low TCE materials, such as carbon.
PBX CEMENT	Two-part ceramic cement/coating used for free-filament strain gages. Good adhesion to most metals.
SAUEREISEN #8 CEMENT	Single-part chemical setting zircon-based cement used for free-filament strain gages. High electrical insulation and thermal conductivity.

Parameter 7:
Bonding—Adhesives/Cements
(cont.)

RECOMMENDED ADHESIVES/STRAIN GAGE SERIES

TYPE OF TEST OR APPLICATION	OPERATING TEMPERATURE RANGE	GAGE SERIES	M-BOND ADHESIVE
GENERAL STATIC OR STATIC-DYNAMIC STRESS ANALYSIS	–50° to +150°F (–45° to +65°C)	C2A, L2A, W2A, CEA, EA	200 or AE-10 or AE-15
		C2A, L2A, W2A, CEA, EA	AE-15 or 610
	–50° to +400°F (–45° to +205°C)	WA, SA, WK, SK	600 or 610
	–452° to +450°F (–269° to +230°C)	WK, SK	610
	<600°F (<315°C)	WK	610
HIGH ELONGATION (POST-YIELD)	–50° to +150°F (–45° to +65°C)	CEA, EA	200 or AE-10
		EP	AE-15 or A-12
DYNAMIC (CYCLIC) STRESS ANALYSIS	–100° to +150°F (–75° to +65°C)	ED	200 or AE-10
		WD	AE-10 or AE-15
	–320° to +500°F (–195° to +260°C)	WD	600 or 610
TRANSDUCER GAGING	–50° to +150°F (–45° to +65°C)	CEA, EA	AE-10 or AE-15
	–50° to +200°F (–45° to +95°C)	N2A, J2A	600 or 610 or 43-B
	–50° to +300°F (–45° to +150°C)	WA, SA, TA, TK, J5K	610, 450, P Adhesive
	–320° to +350°F (–195° to +175°C)	WK, SK, TK, J5K	610, 450, P Adhesive
HIGH TEMPERATURE GAGING	–452° to +700°F (–269° to +370°C)	WK, RK	P Adhesive
	–320° to +1600°F (–195° to +870°C)	ZC	GC Cement

Parameter 8:
Protection

COATINGS SELECTION GUIDE

ENVIRONMENT	PREFERRED	ALTERNATE
TYPICAL LABORATORY		
50%, or lower, relative humidity	M-Coat A	M-Coat C, or M-Coat D, or M-Coat F
FIELD APPLICATIONS		
Outdoor installations, shielded from rain and snow	M-Coat F	M-Coat JA
HIGH HUMIDITY, WATER SPLASH		
Laboratory and field applications under damp or wet conditions	**Short Term:** 3140 RTV **Long Term:** M-Coat W-1 Wax	**Short Term:** 3145 RTV **Long Term:** M-Coat F
WATER IMMERSION		
Short-term, fresh water or salt water	Teflon® + M-Coat B (on vinyl-insulated leadwires) + M-Coat JA	M-Coat W-1 Wax
Long-term, fresh water	M-Coat W-1 Wax	M-Coat W-1 Wax, or M-Coat F
Long-term, salt water	M-Coat W-1 Wax combined with M-Coat JA	None
High-pressure water	M-Coat W-1 Wax, M-Coat JA, M-Coat FA-2, followed by M-Coat B	M-Coat F, or M-Coat W-1 Wax for short-term
STEAM		
+212°F (+100°C), long-term installation	Hermetically sealed metal cap, and conduit for leadwires	None
CONCRETE SURFACES		
Long-term	M-Coat JA	M-Bond GA-61 to seal concrete surface
OILS AND GASOLINE		
Commercial oils, to +180°F (+80°C), gasoline, and kerosene	M-Coat D + two or three layers of M-Coat B	3145 RTV + M-Coat B
Synthetic oils, to +200°F (+95°C)	Two or three layers of M-Bond 43B	M-Bond GA-61
HIGH-TEMPERATURE AIR		
To +500°F (+260°C), with good mechanical protection	**Short Term:** M-Bond GA-61	3145 RTV