High-Temperature Strain Measurements

Applications Engineering Department
Vishay Micro-Measurements, Inc.

Introduction

Products Available for High-Temperature Strain Measurement

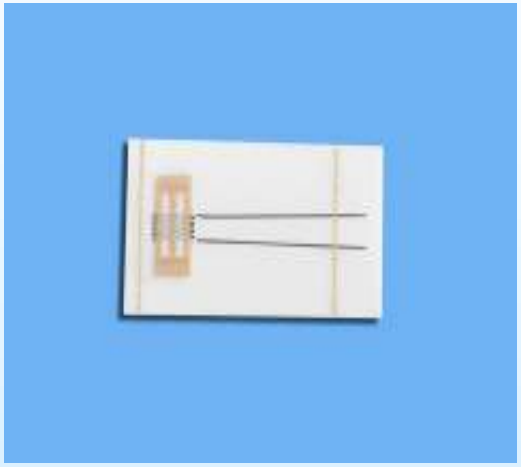
Instrumentation

Installation Techniques

ZC-Series Strain Gages

Etched Kanthal Alloy grids

1. Available in quarter-bridge and half-bridge configurations (for temperature compensation).
2. Designed for applications from 500 to 2100 ºF.
3. Nominal Gage Factor of 2.6 at room temp.
4. Strain Limit of +/- 0.5% (5000 microstrain).



Ceramic Based Adhesives

H Cement -Single part ceramic cement/coating that provides excellent insulating properties, even at 1600 ºF. Good adhesion to most metals. Thermal Expansion Coefficient = 7.0 ppm/ ºF.

PBX Cement -Two part ceramic cement/coating. Excellent insulating properties, even at 1200 ºF. Good adhesion to most metals. Thermal Expansion Coefficient = 7.0 ppm/ ºF.

GC Cement -Single part ceramic cement. Good for installation on low TCE materials such as carbon. +2000 ºF rating. Thermal Expansion Coefficient = 1.5 ppm/ ºF.

Wire

326-GJF Solid nickel-clad copper wire, 3-conductor twisted cable, fiberglass braid insulation and jacket. To +480 ºC.

Nichrome Ribbon Used for welded connection of strain gage tabs to leadwire.

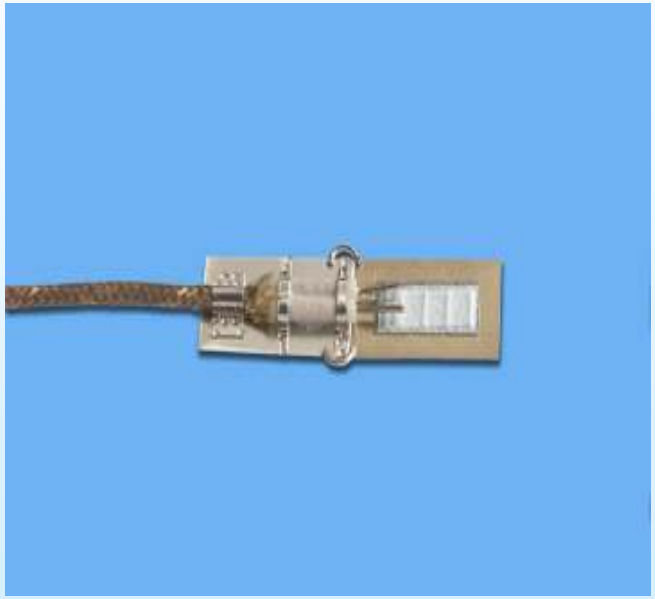
C-50671 Not available from Vishay Micro-Measurements. 347SS sheath, Oxygen-free copper conductors (0.010-inch diameter), Magnesium-Oxide mineral insulation, 3-conductor or 4-conductor.

LZN-Series Weldable Strain Gages

Nichrome V sensor alloy.

F-Series Leadwire: Chromel-Alumel conductors, 2-conductor, fiberglass braid insulation. +650 ºC

M-Series Leadwire: Chromel-Alumel conductors, 2-conductor, inconel jacket. +870 ºC



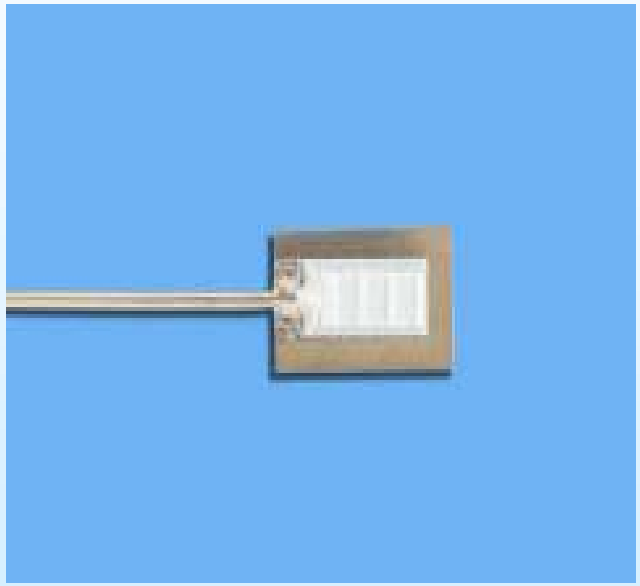
F-Series Leadwire

LZE-Series Weldable Strain Gages

Pt8W sensor alloy.

F-Series Leadwire: Chromel-Alumel conductors, 2-conductor, fiberglass braid insulation. +650 ºC

M-Series Leadwire: Chromel-Alumel conductors, 2-conductor, inconel jacket. +980 ºC



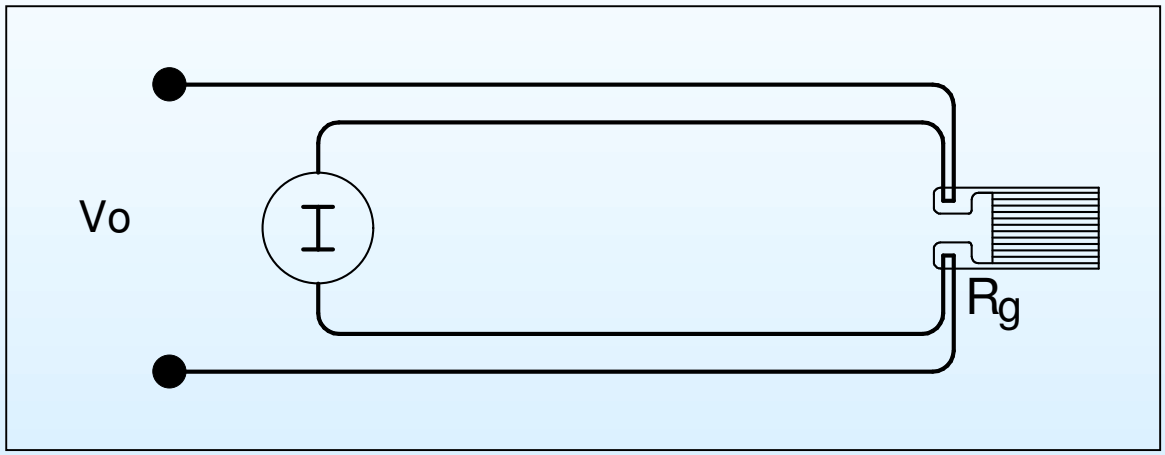
M-Series Leadwire

Instrumentation

4-Wire Constant Current

- Used when there exists significant leadwire resistance or where the overall resistance of the leadwire will change significantly at high temperature.
- Cannot be used for static testing.
- Must be AC coupled to instrumentation.

Constant-Current Connections



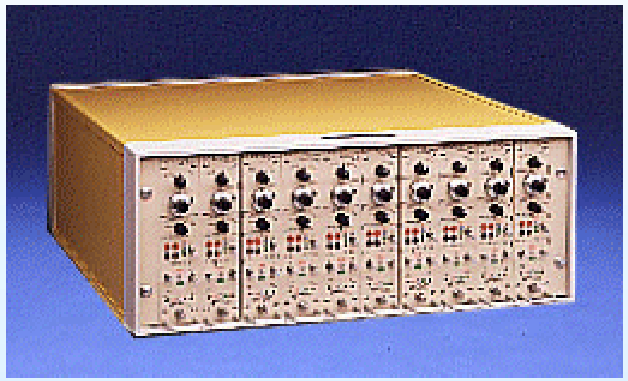
$$V_o = I \times R_g$$

$$V_o = 10mA \times 120\Omega = 1.2V \rightarrow$$

$$\Delta V_o = 10mA \times 0.24\Omega(\Delta) = 0.0024Volts$$

Instrumentation

Vishay Micro-Measurements 2200 System is a signal conditioning amplifier capable of constant-current excitation.

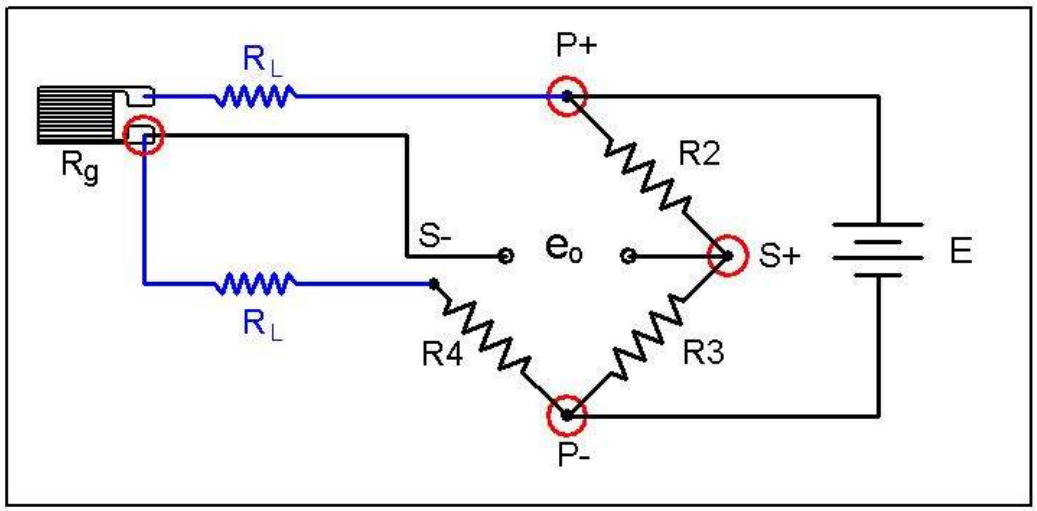


Instrumentation

3-Wire Constant Voltage

- Cannot be used when there exists significant leadwire resistance or where the overall resistance of the leadwire will change significantly at high temperature.
- Static or dynamic testing.
- AC coupling to instrumentation to eliminate thermal output.

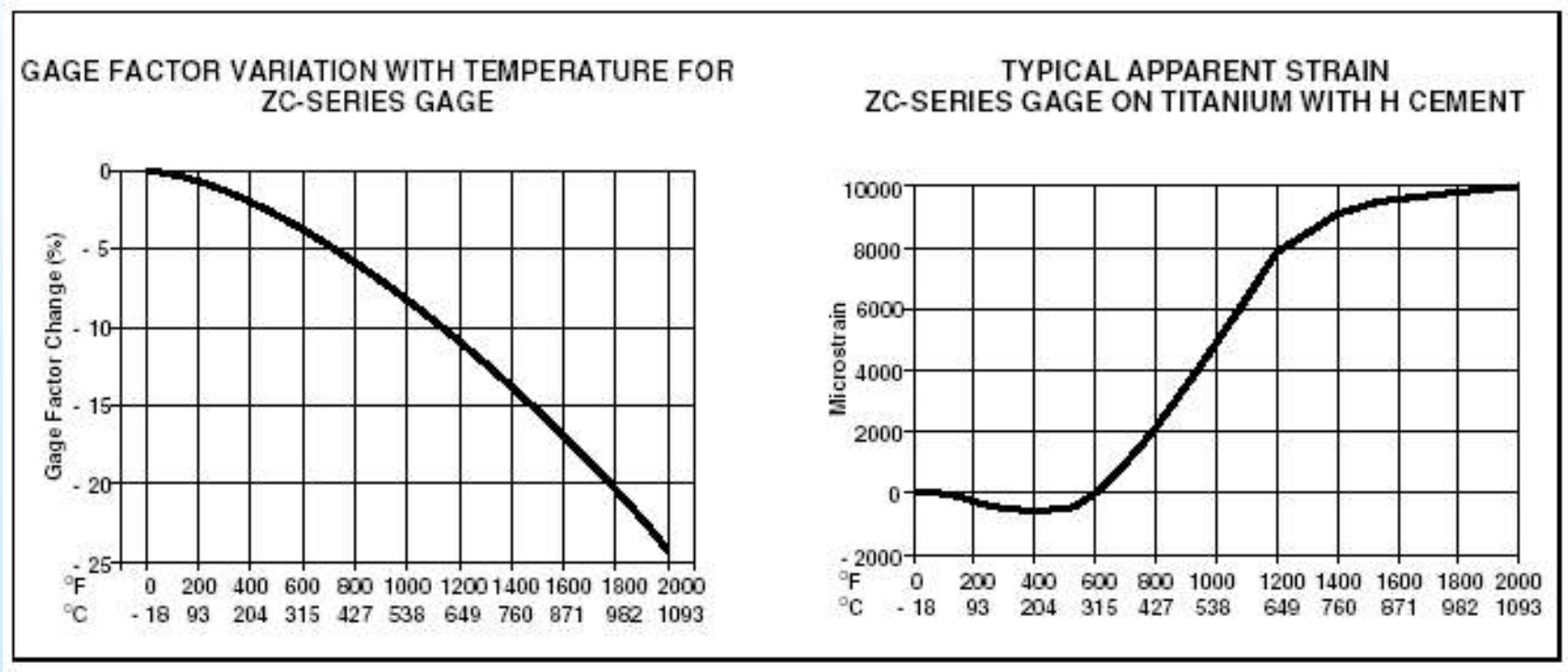
Constant-Voltage Connections



Bridge Balance Equation

$$\frac{R_G + R_L}{R_4 + R_L} = \frac{R_2}{R_3}$$

Thermal Output and Gage Factor Variation with Temperature



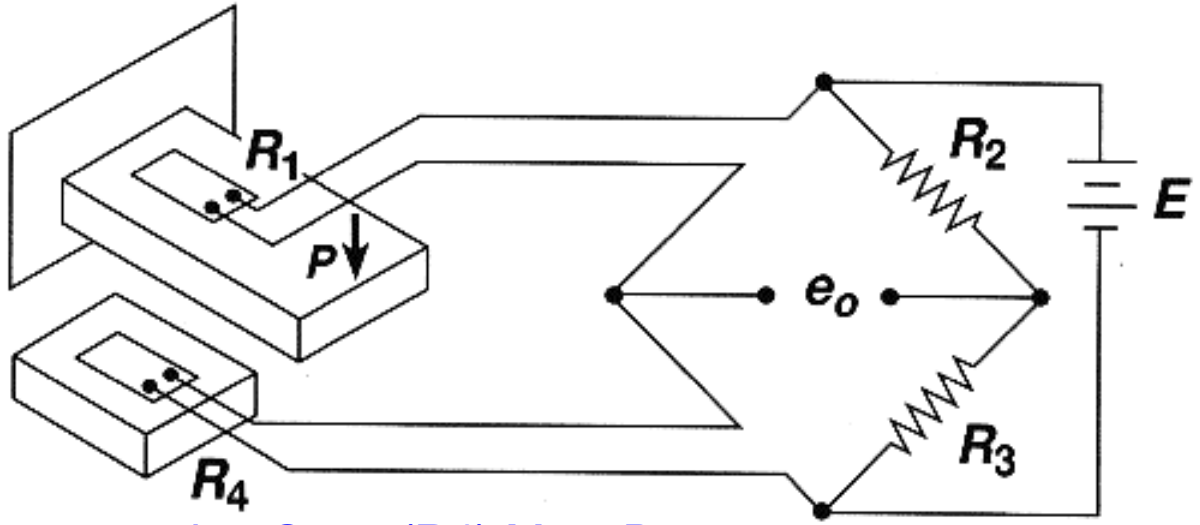
Thermal Output and Gage Factor Variation with Temperature

For dynamic measurements, thermal output may be eliminated by AC coupling to the instrument.

For static measurements, thermal output must be reduced by the use of a compensating strain gage.

Gage factor variation may be corrected after the data is acquired, but requires knowledge of the temperature as a function of time.

Half-Bridge Compensating Gage



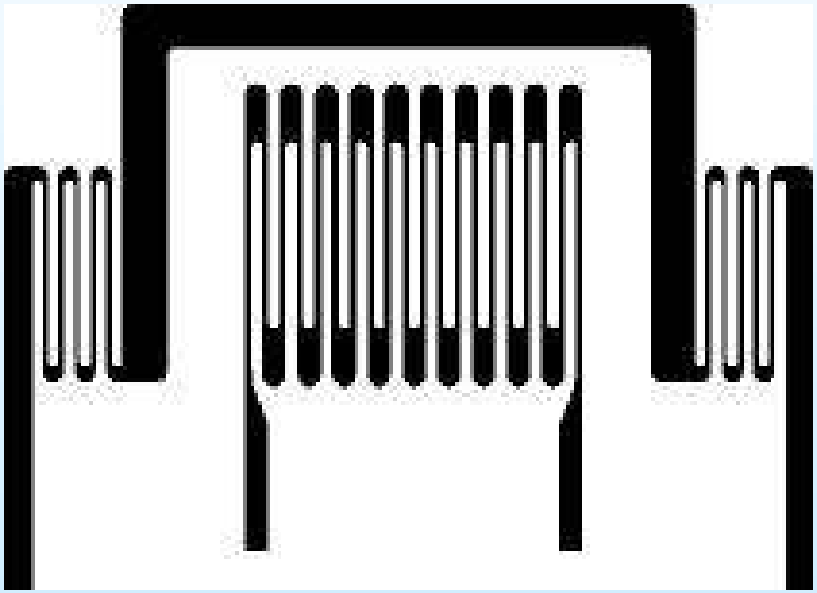
Compensating Gage (R4) Must Be:

- Same Temperature as Active Gage
- On same material as active gage that is unstrained and allowed free thermal expansion.

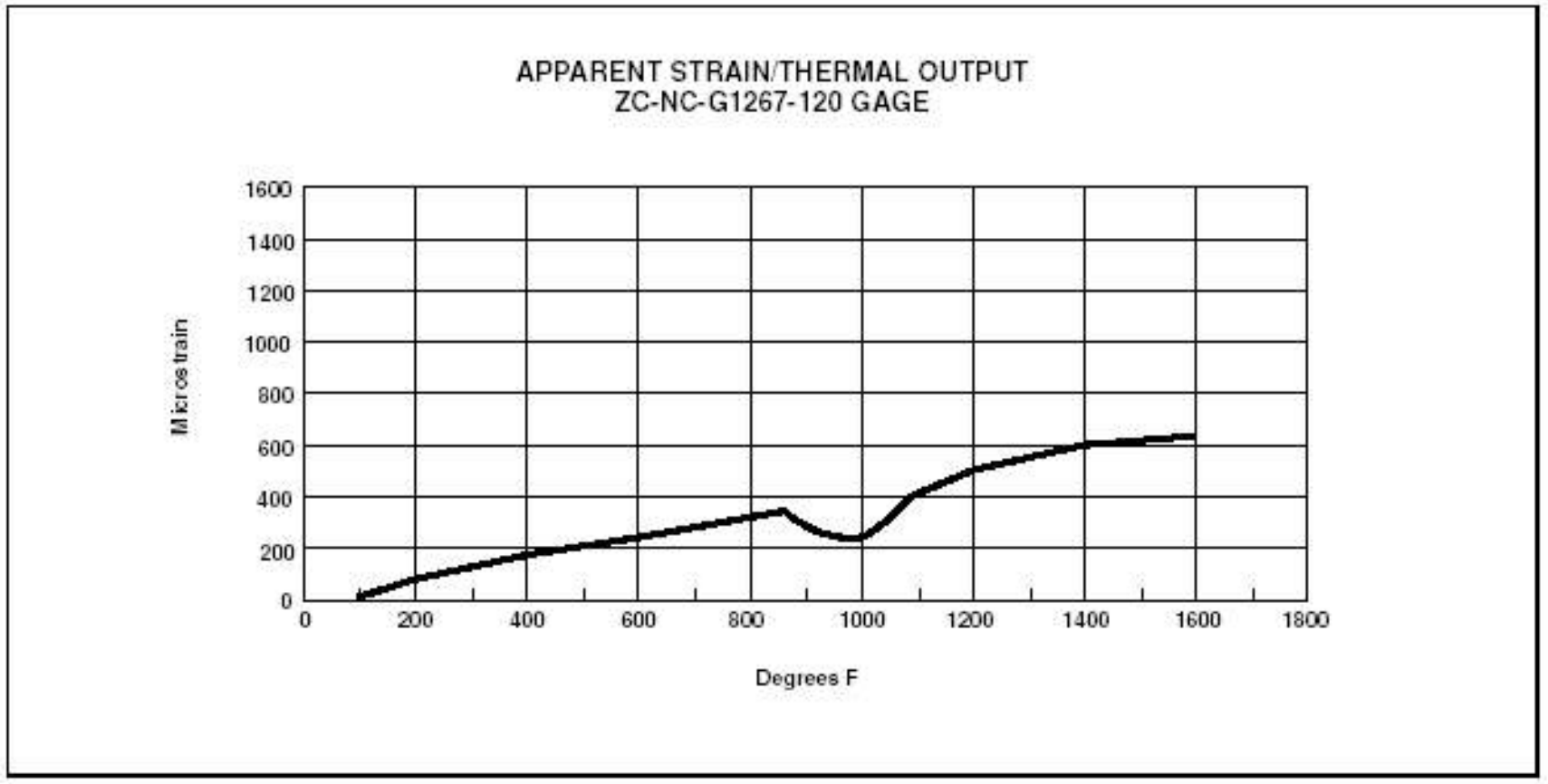
ZC series with compensating grids

- NASA developed
- Permits static measurements by use of unstrained compensating grids.

ZC-NC-G1267-120



ZC series with compensating grids



Installation Techniques

Phase I- Insulation Layer of Ceramic Cement

Phase II- Bond Layer of Ceramic Cement

Phase III- Prepare the Lead Ribbons

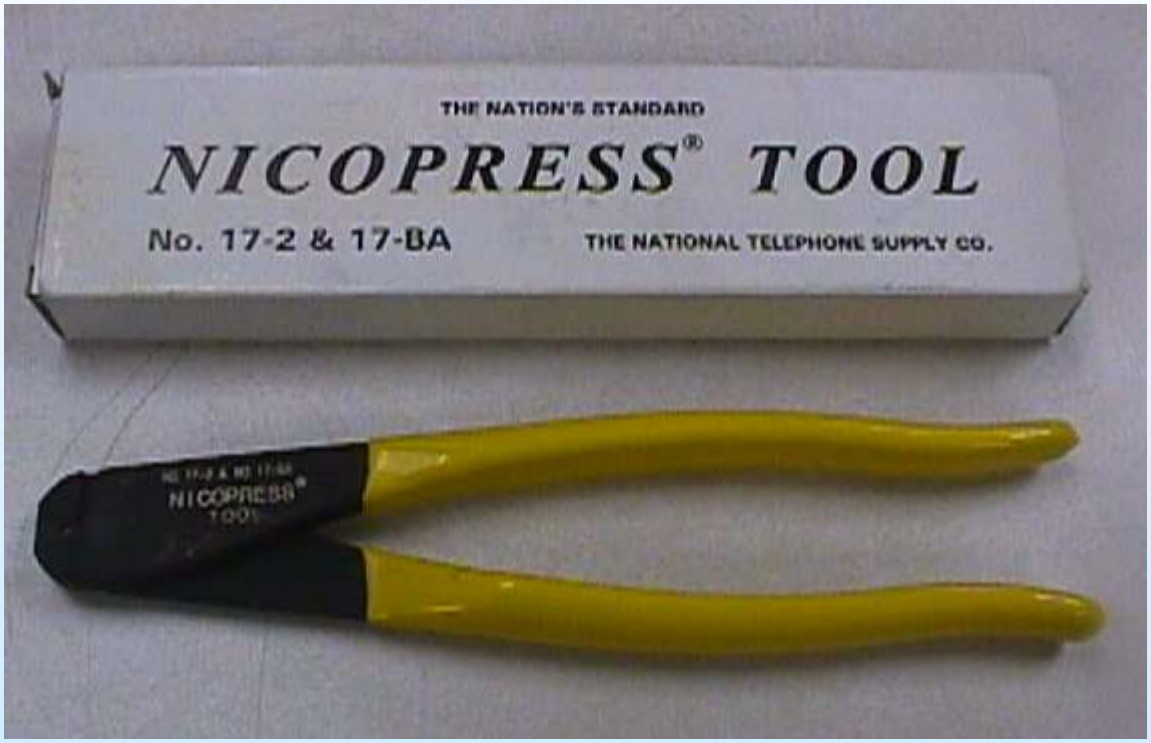
Phase IV- Weld the Lead Ribbons

Phase V- Final Protective Layer of Ceramic Cement

List of Materials for Strain Gage Bonding

1. H Cement
2. Tweezers BTW-1
3. Small, Camel's Hair Brush
4. Spatula
5. Single-Edge Razor Blade
6. Deionized water
7. M-Prep Conditioner A
8. M-Prep Neutralizer 5A
9. CSM-2 Degreaser
10. 220- and 320-Grit Silicon Carbide Paper
11. ZC Series Strain Gage
12. Glass stirring rod
13. 3-mil Kapton or Mylar Tape

Nicopress Tool for Leadwire



Stripping Tool for Metal-Sheathed Leadwire

Model 700 Welder with Tweezers

Close-up of Welding Tweezers

Phase I- Insulation Layer of Ceramic Cement

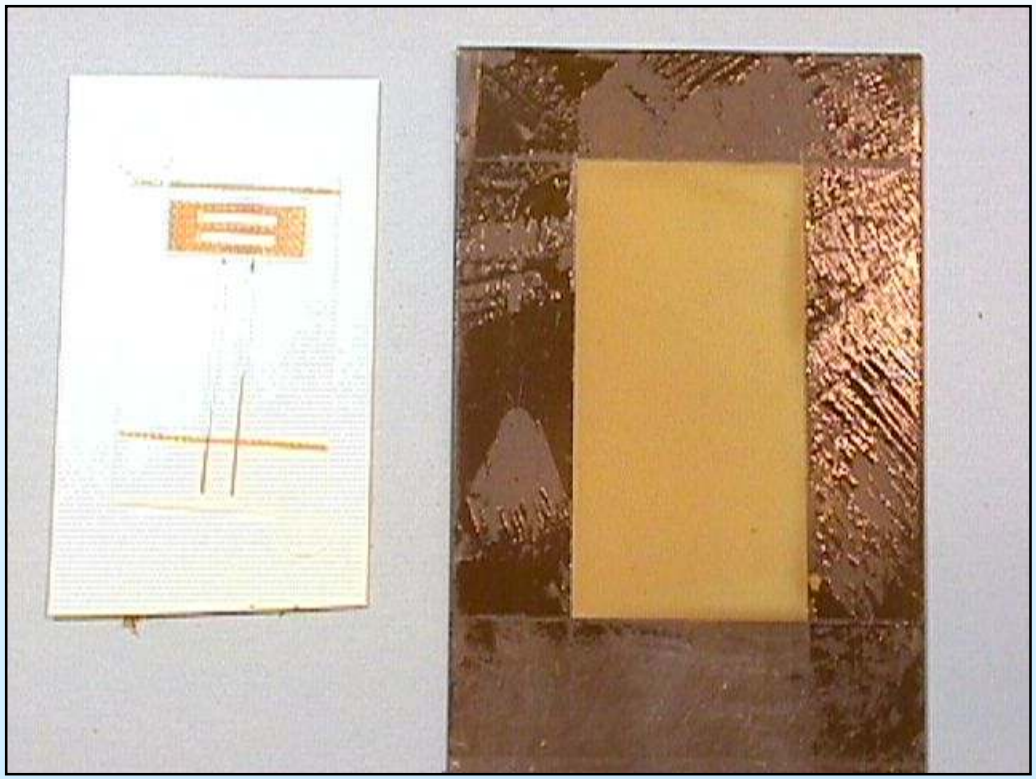
Step 1. Prepare the surface for bonding in accordance with our Instruction Bulletin B-129 “Surface Preparation for Strain Gage Bonding”.

Step 2. Apply 0.003 inch thick Kapton Tape for a boundary for ceramic cement.

Step 3. Apply the H Cement and level using a straight edge spatula or razor. Pull the spatula evenly across the tape creating a layer of ceramic cement that is no more than 0.003 inch thick.

Step 4. Air dry for 30 minutes, then cure at 200 ºF for 30 min, and then at 350 ºF for 30 minutes.

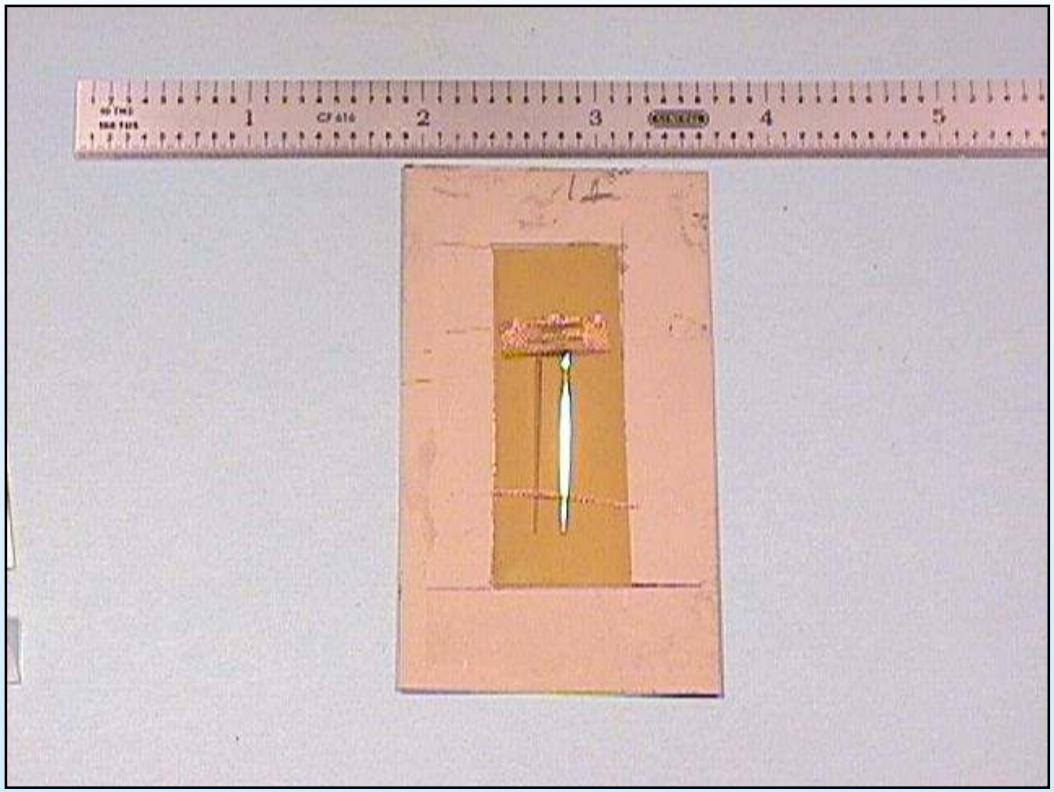
ZC Strain Gage with H Series Cement Insulating Layer



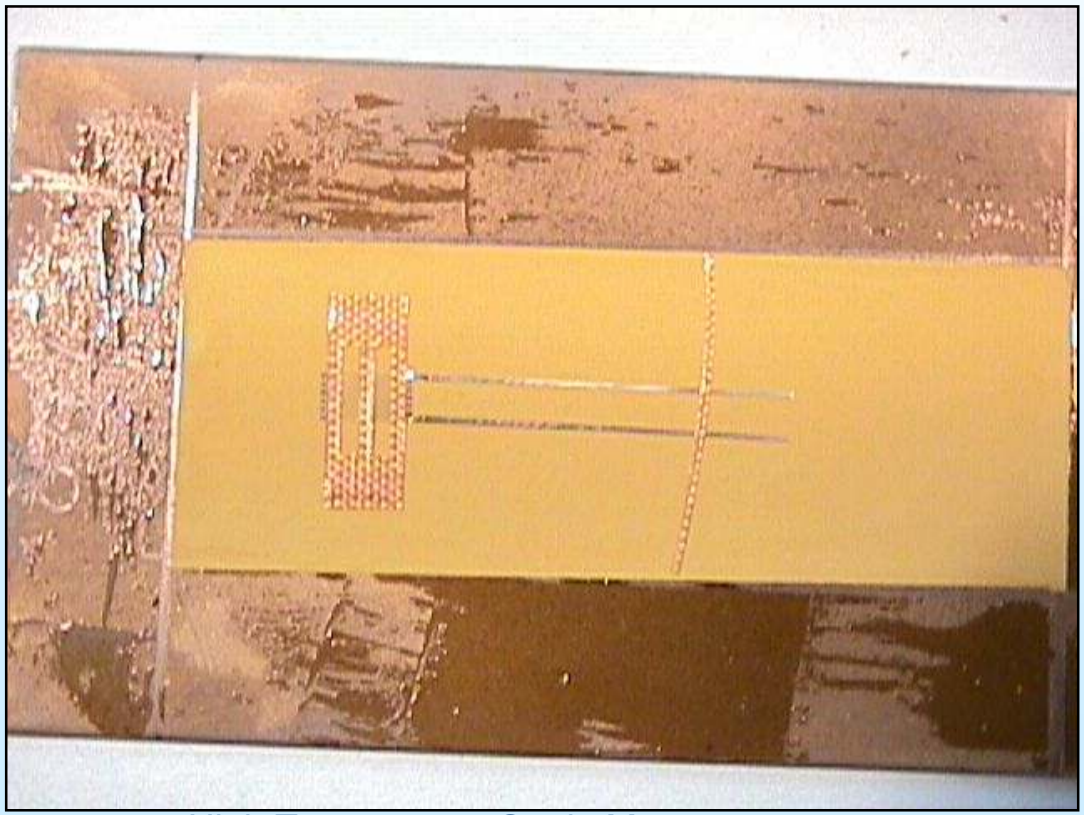
High Temperature Strain Measurement

Phase II- Bond Layer of Ceramic Cement

ZC Strain Gage After Removing Fiberglass Teflon Carrier

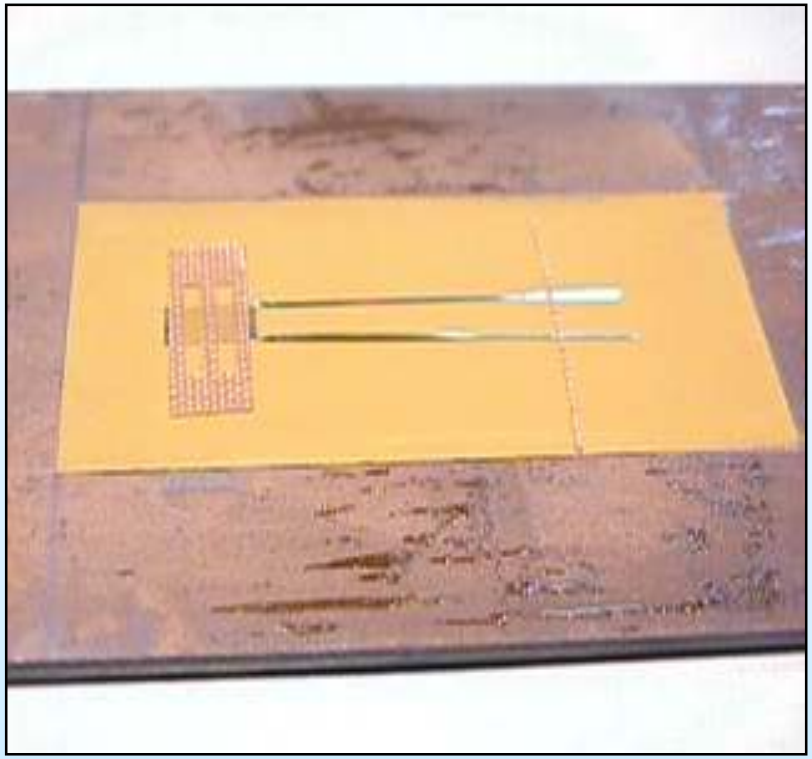


Closeup of ZC Strain Gage Ready for H Series Cement



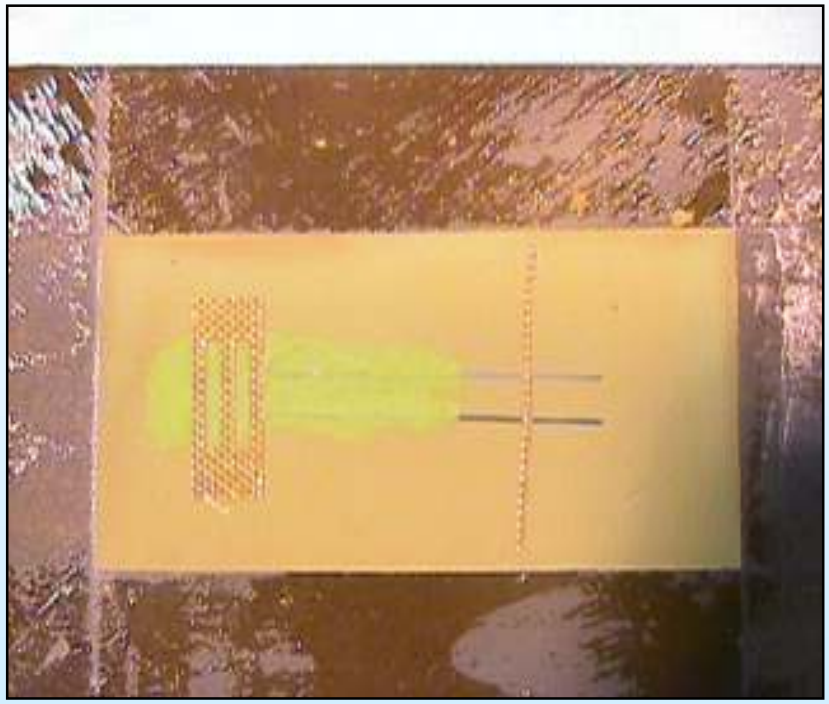
High Temperature Strain Measurement

ZC Series Strain Gage Before Application of H Cement



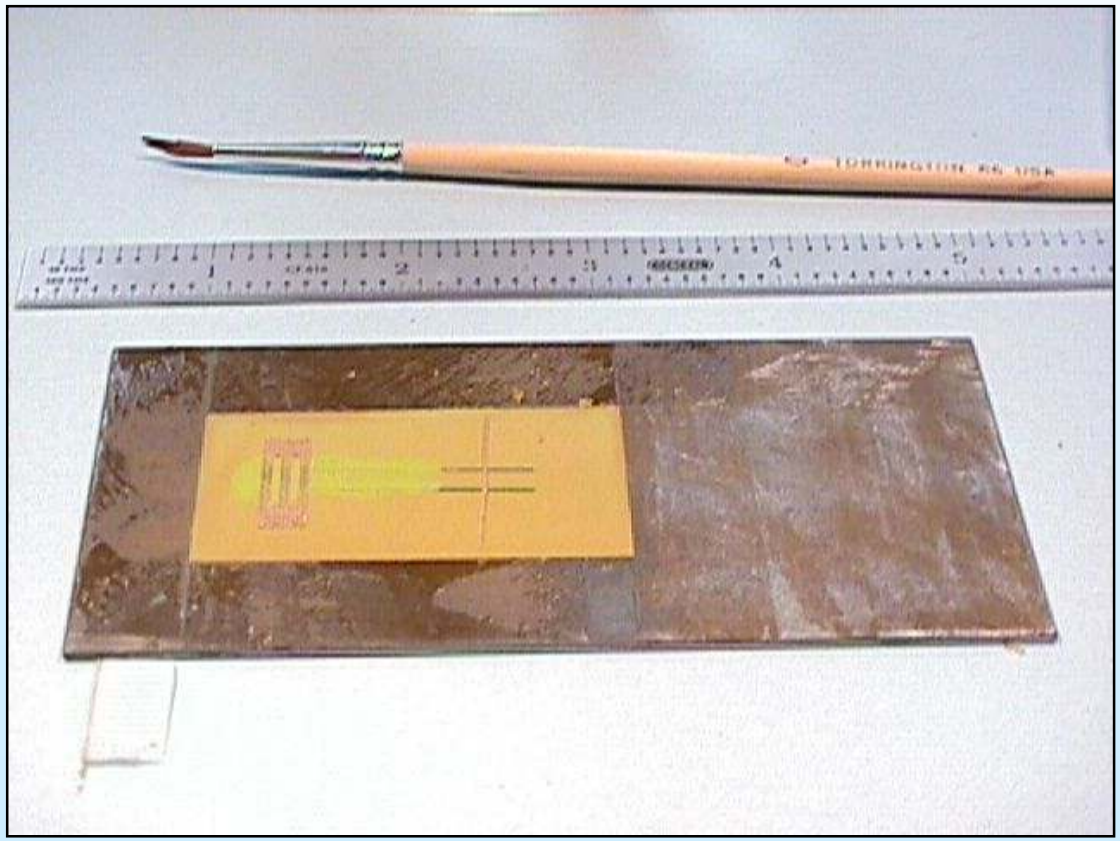
1. Notice the Teflon impregnated fiberglass tape is left in place over the grid and the leads.
2. The grid is laying flat against the ceramic insulator.

ZC Strain Gage After Application of H Cement



1. Notice the application of H Cement over end loops, in between openings in the tape, and about 1/2 down the leads.
2. H Cement should not exceed thickness of the tape.

ZC Strain Gage with Brush for Application of H Cement



High Temperature Strain Measurement

ZC Strain Gage Ready for the Oven

The gage is ready for second stage of oven curing which includes a 30 minute air dry, 30 minutes at 200 degrees F and then 30 minutes at 350 degrees F.

Phase III- Prepare the Lead Ribbons

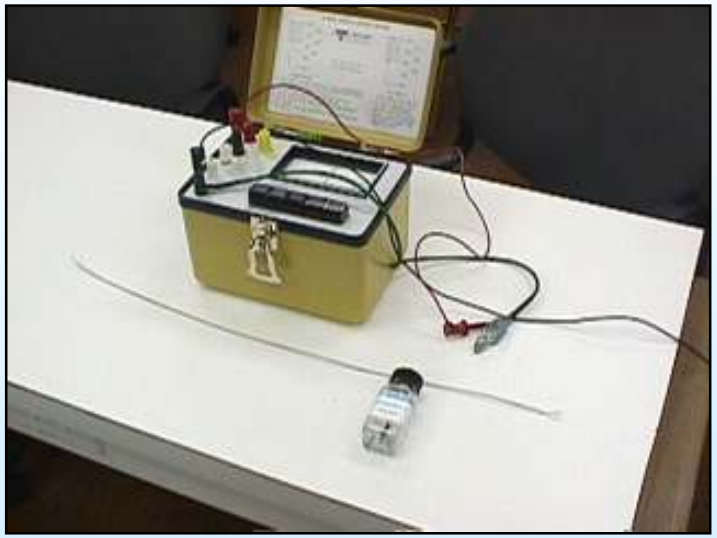
Wire Types for ZC Strain Gages

1. Three conductor cable with stainless steel jacket and magnesium oxide ceramic insulator. Rated for 1600 degrees F.
2. Three conductor cable with fiberglass jacket and rated for 1200 degrees F.

Tools for Wire Preparation

- Wire Cutter is used to slice through the stainless steel jacket to expose the copper conductors.
- Double ended pin vise is best for holding during the cutting and stripping of the sheath.

Checking Insulation Resistance with GIT-1300

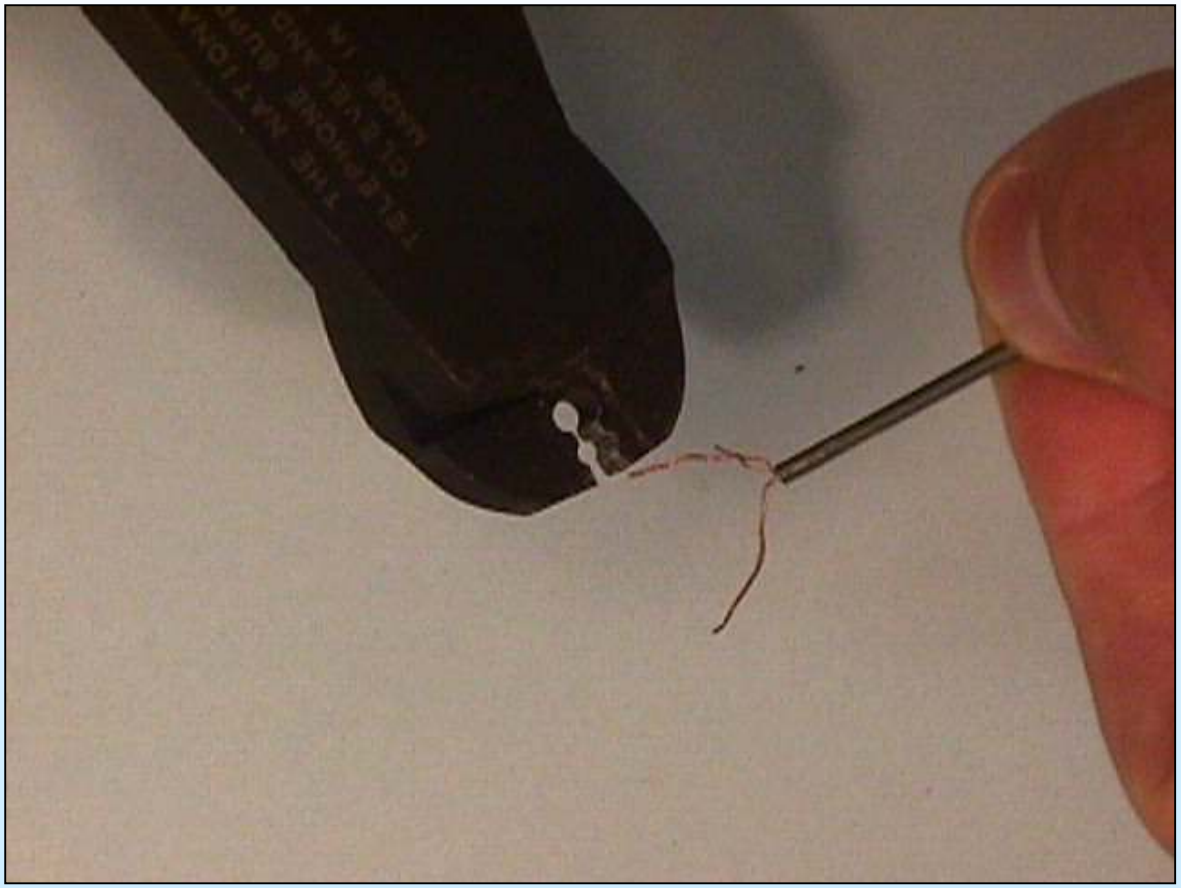


1. Check resistance between stainless jacket and copper conductors after baking the wire at 200 degrees F for 2 hours.
2. Resistance should be 100 Megohm or higher.

ZC Strain Gage Wire Preparation

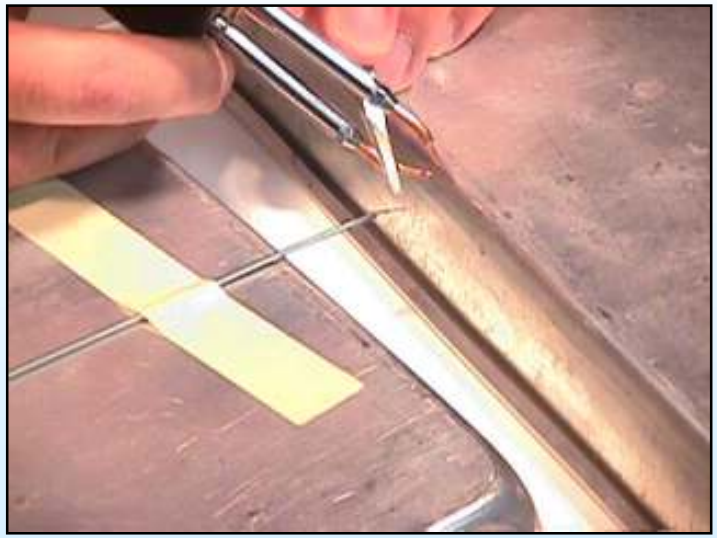
1. Wire is being sealed to prevent moisture contamination using GageKote #11.
2. Resistance to ground should be higher than 100 Megohm

Copper conductors are flattened for Nichrome V



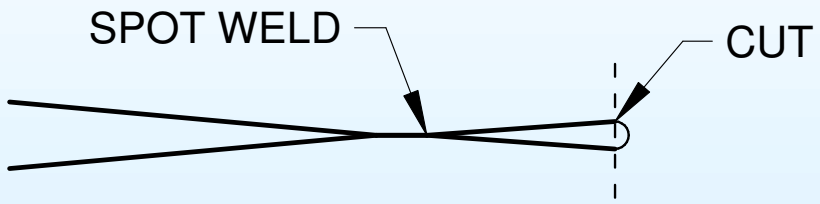
Phase IV- Weld the Lead Ribbons

Preparing wire to add Nichrome V straps using Model 700 Welder



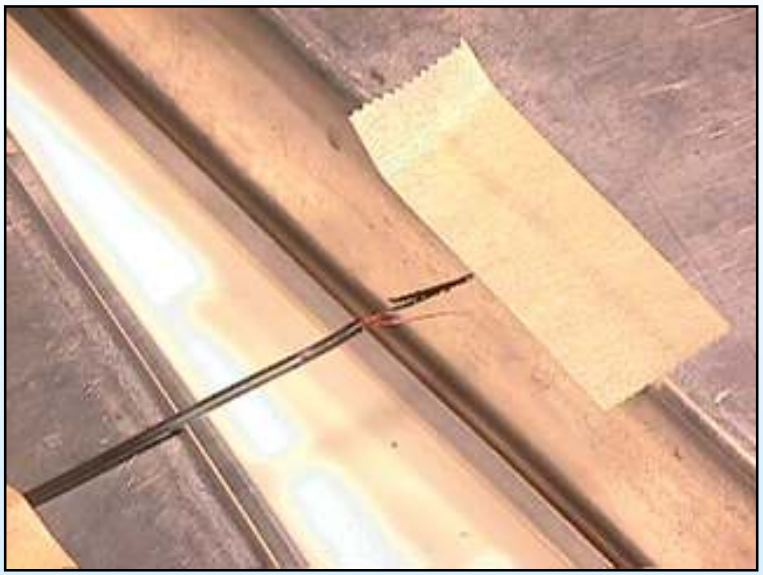
1. Wire is taped in place and the Nichrome V is added to the flattened ends of wire.
2. 4 spots welds on each conductor is desired.

Preparing Nichrome V straps using Model 700 Welder



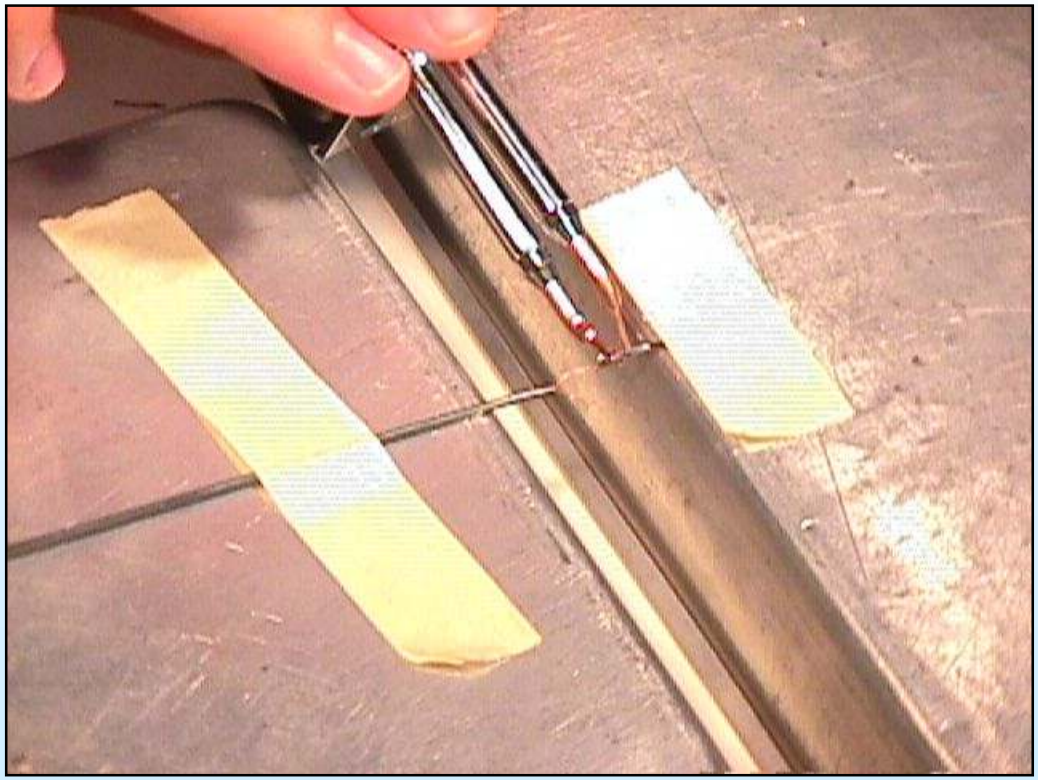
1. Nichrome V ribbon is folded as shown, spot welded, and then the folded end is cut.

Nichrome V about to be added

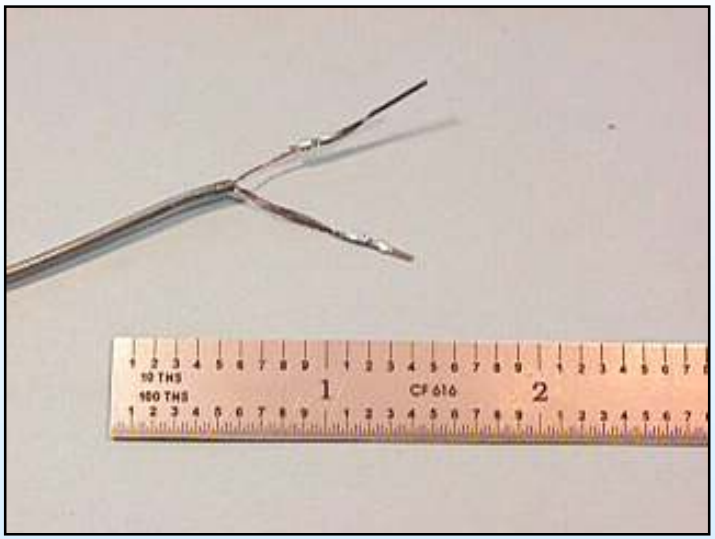


A small loop of Nichrome V was created and the ends will be spot welded to the copper conductor.

Spot welding Nichrome V with special handpiece for Model 700

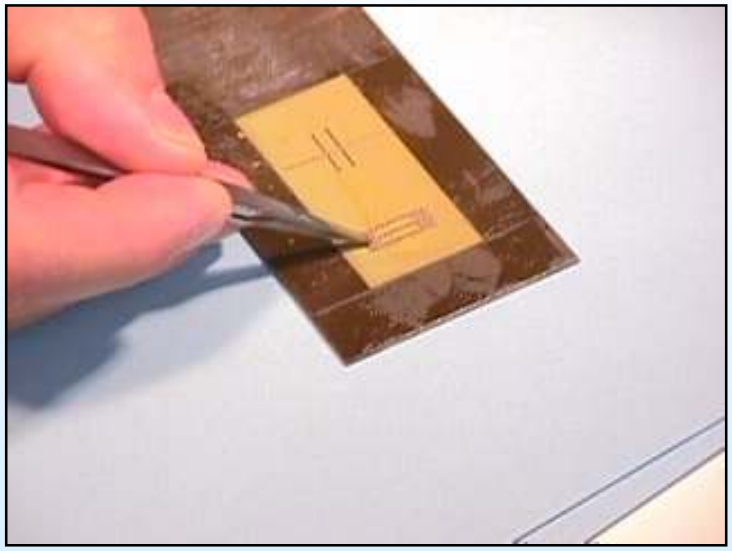


Wire after Nichrome V is added



Nichrome extensions about 3/4 inch long.

Preparing Strain Gage for Lead Attachment

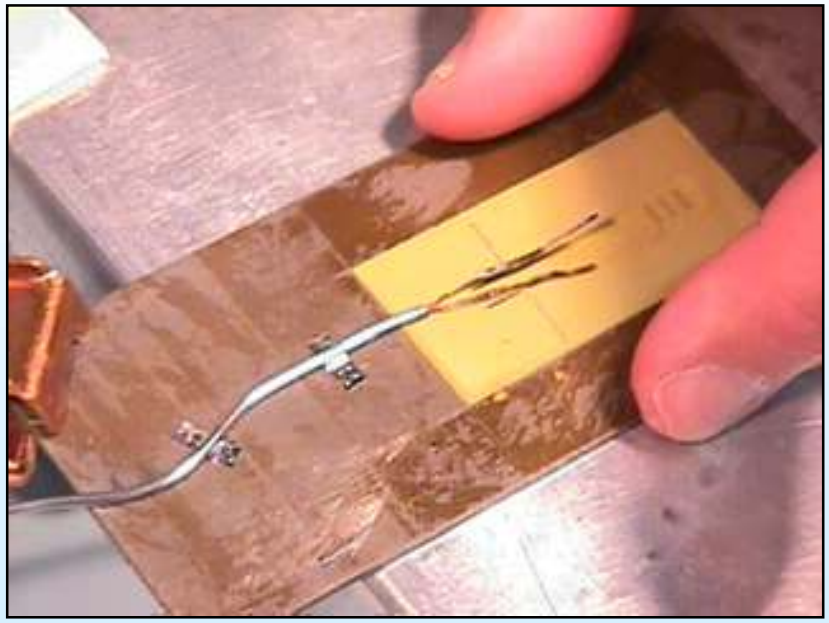


Teflon impregnated fiberglass tape carefully peeled up from the gage grid and leads.

Strain Relief of Stainless Jacketed Cable

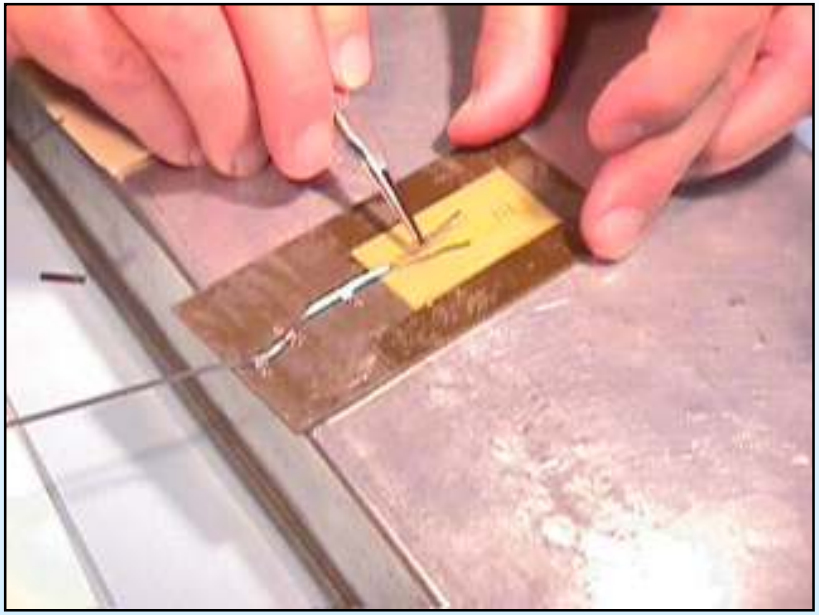
1. 0.005 inch strapping is spot welded over jacketed cable to hold in place.
2. Cable is curved to provide minimize pull on the gage leads.

Strain Relief Complete



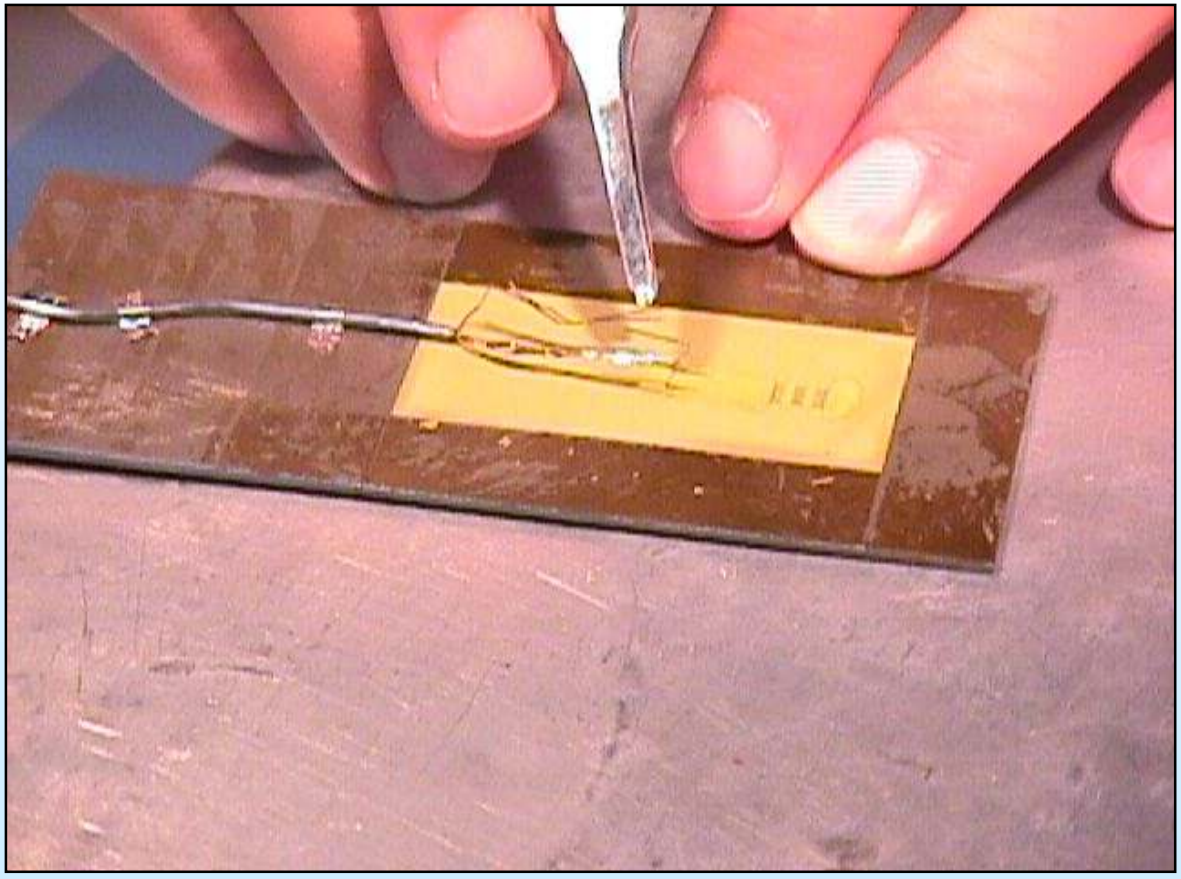
1. Completed strain relief and ready for welding to leads of the strain gage.
2. Notice the curvature to minimize forces on the gage leads and the multiple tie down points.

Preparation of Strain Gage Leads



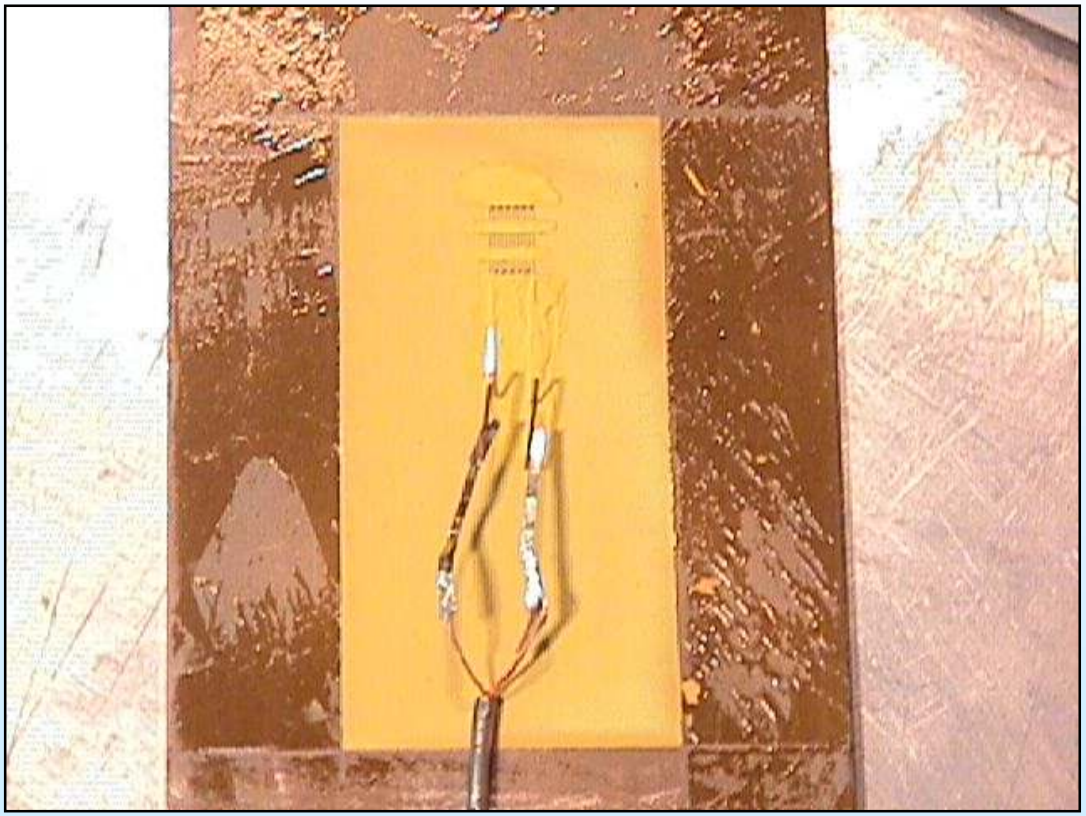
1. Strapping is cut to length.
2. Leads of the strain gage are placed into the Nichrome V strapping that was added to the wire.

Handling of Leads With Tweezers



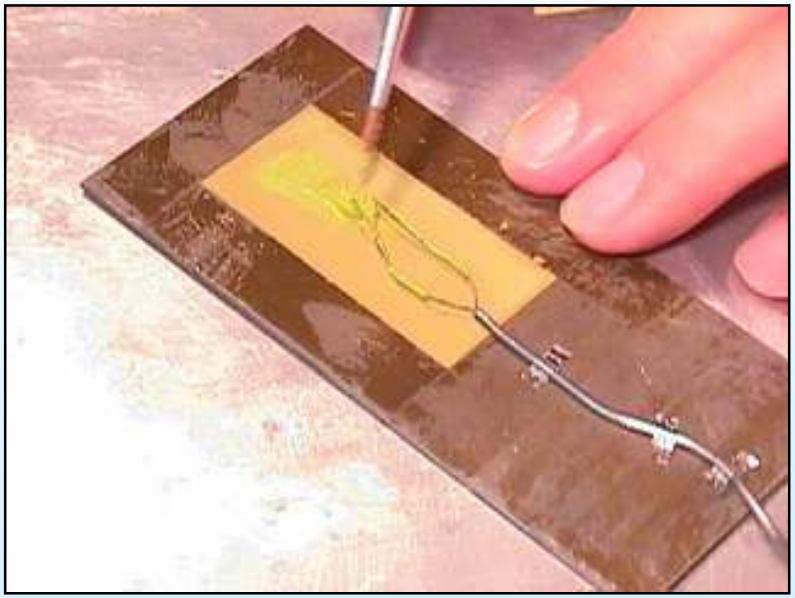
High Temperature Strain Measurement

Top View of Completed Wiring



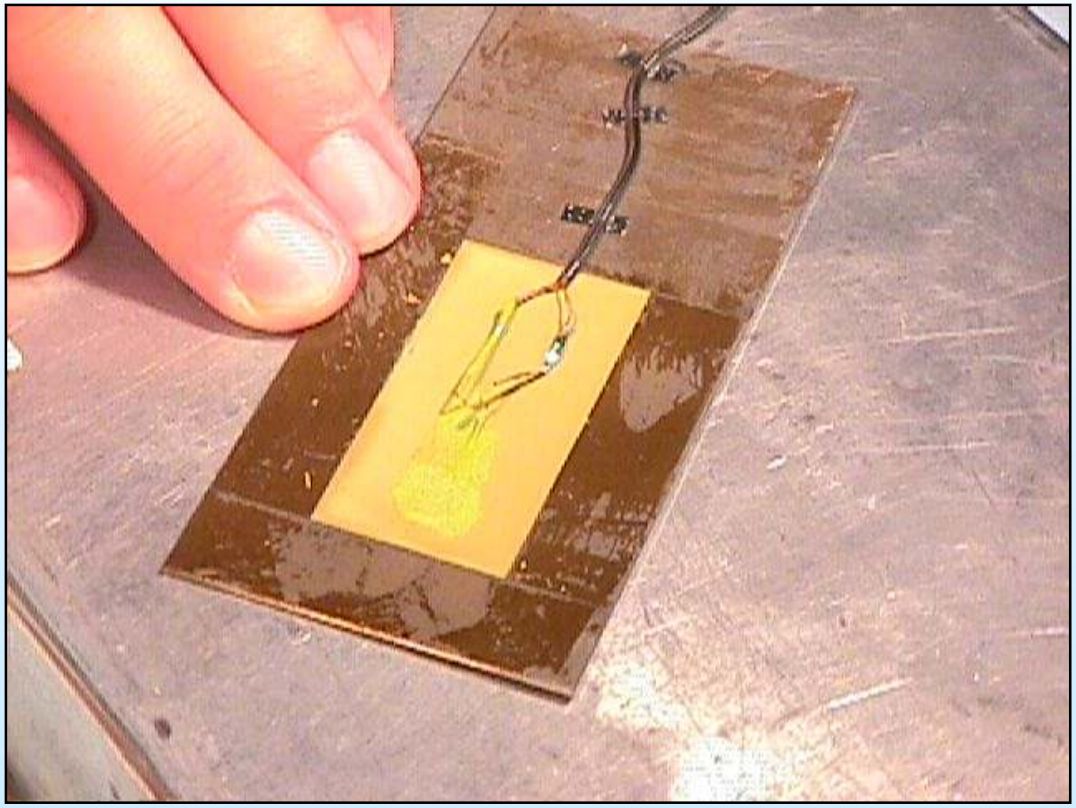
Phase V- Final Protective Layer of Ceramic Cement

Application of H Cement as a Protective Coating



1. Brushing the H Cement over the exposed grid and leads.
2. All conductive areas should be covered for protection.

Complete Wiring with H Cement Overcoat- Ready for Final Cure

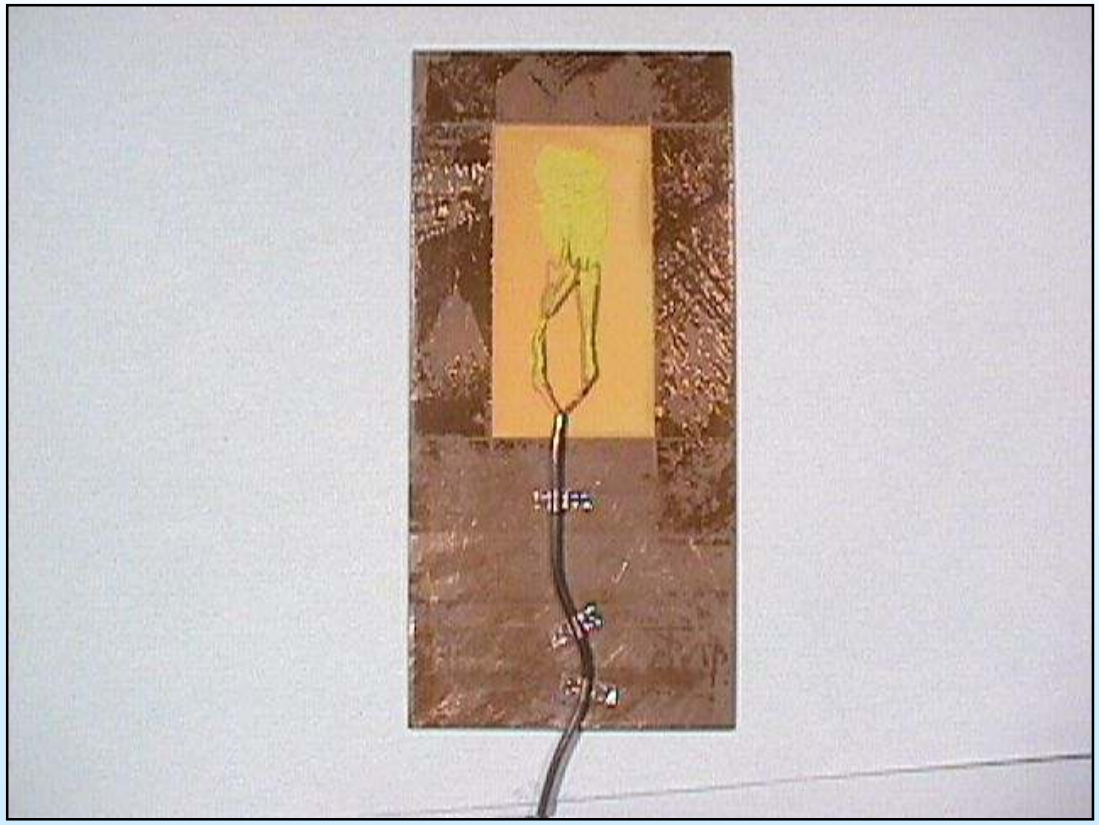


High Temperature Strain Measurement

Final Cure

1. Air dry coating of H-Cement for 30 minutes.
2. Bake 30 minutes @ 200 ºF.
3. Bake 30 minutes @ 350 ºF.
4. Bake 1 hour @ 600 ºF.

Complete Installation Ready for Use



High Temperature Strain Measurement

Rockide Flame Spray- An Alternate Method of Installation

1. Oxy-acetylene torch.
2. Propelled by compressed nitrogen.
3. Molten alumina-oxide is sprayed onto the surface.
4. Much faster than ceramic cements, but the equipment is expensive.
5. Necessary if strain gages are to be installed on compound-curved surfaces.

Rockide Flame Spray- An Alternate Method of Installation

High Temperature Strain Measurement

Feedback

- Let's discuss questions/comments….