Spot-Weldable Strain Gauge

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Introduction

Strain, Stress, and Load

Strain is the change in length per unit length of a body when a force is applied to it. We measure strain in order to calculate stress and load.

Stress is the product of strain and Young's modulus of elasticity. Young's modulus is the ratio of stress to strain within limits of proportionality. It is a constant for each material and does not vary with the cross-sectional area of the material.

Load is the product of stress and the cross-sectional area of the body.

How Strain is Measured

The spot-weldable strain gauge consists of a steel wire held in tension inside a tube. The tube is mounted on a steel flange which is welded to the structural member.

Strain in the structural member is transferred through the flange to the tube and the wire inside. An increase in tensile strain increases tension in the wire, and a decrease in tensile strain decreases tension in the wire.

A sensor that is placed atop the wire is used to pluck the wire, causing it to vibrate at a frequency relative to its tension. The vibration of the wire within the magnetic field of the coil induces a frequency signal which is transmitted to the readout device.

The readout device processes the frequency signal using calibration factors that relate frequency to strain in the wire, and then displays a number, typically Hz, period, or microstrain.

A strain reading from a strain gauge does not represent the total strain in the member. There is strain in the member before the gauge is welded to it, and there is stain in the wire of the gauge, which must be tensioned in order to operate.

Therefore, a datum reading must be obtained after the strain gauge is installed. The datum is subtracted from any subsequent strain readings to find changes in strain.

Planning the Installation

Good Practices

The suggestions below will help your installation be successful.

Handle Carefully

- The spot-weldable strain gauge is a sensitive instrument. Do not drop or bend the gauge.
- Install the gauge on a flat surface that is clean, dry, and free of grease. If installing on reinforcing bar, create a flat surface with a grinder.
- If gauges are installed on a reinforcing cage, take care to minimize bending when lifting the cage. Bending may damage gauges or signal cable.

Protect Signal Cable

- Store the cable in a place that is dry and safe from rodents and other possible sources of damage.
- Protect the cable from nicks and cuts. Do not pull on cable to free it from obstructions.

Identify Cables

- Mark cables carefully for positive identification later. Attach identifying numbers with a durable, waterproof tape or use tape for color-coding. Mark the end of the cable three times at one foot intervals, then mark the rest of the cable at 6 to 10 foot intervals or as specified. If the cable is cut or spliced, mark the end three times as above.
- If your identification scheme differs from the instrument identification used on engineering drawings, note the differences in site log books and on the relevant drawings. For example: Strain Gauge 4-IA = Red and Brown.
- Make a record of the location of each strain gauge and its associated cable.

Testing the Strain Gauge

1. Connect signal cable from the strain gauge sensor to your indicator. See “Taking Readings” for connection diagram).
2. Turn the sensor over so that you can see the groove in its bottom surface. Place the tube of the strain gauge into the groove. Hold strain gauge in place firmly with your thumbnails.
3. The indicator should display approximately 1900 Hz for midrange gauges, 2100 Hz for gauge set to accomodate compression, and 1600 Hz for gauges set to accomodate tension.

Positioning Strain Gauges

Orientation: Position the strain gauge so that its long axis is parallel with the axis of loading.

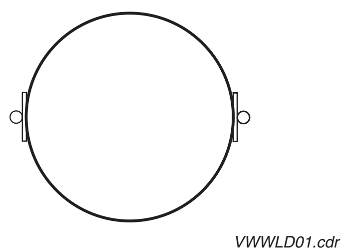
Bending: Bending will increase strain on one side of the neutral axis of the structural member and decrease strain on the opposite side. The strain gauge should be installed along the neutral axis when possible. This will eliminate false readings due to bending of the member along one plane. Eliminate false readings due to bending in the perpendicular plane by installing gauges on opposite sides of the member and averaging the change in strain reported by both gauges.

Irregularities: Avoid installing strain gauges near irregularities in the member or near the ends of the member since readings from these locations may not adequately represent strain in the whole member.

Sunlight: Try to shield gauges from direct sunlight. If the gauge is heated faster than the steel beneath it, it may report changes in strain that are not representative of the steel.

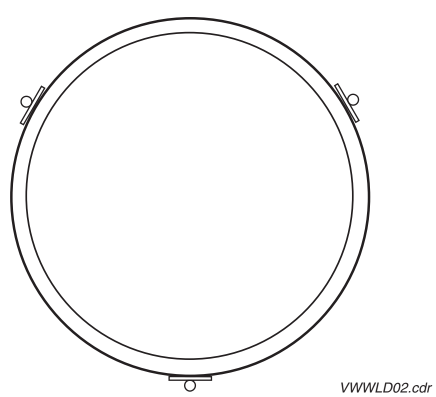
Threadbars

Install gauges on opposite sides of the bar.



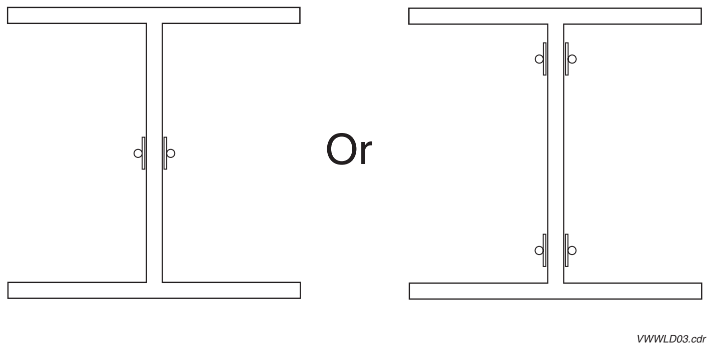
Pipe Piles or Struts

Install gauges 120 degrees apart.



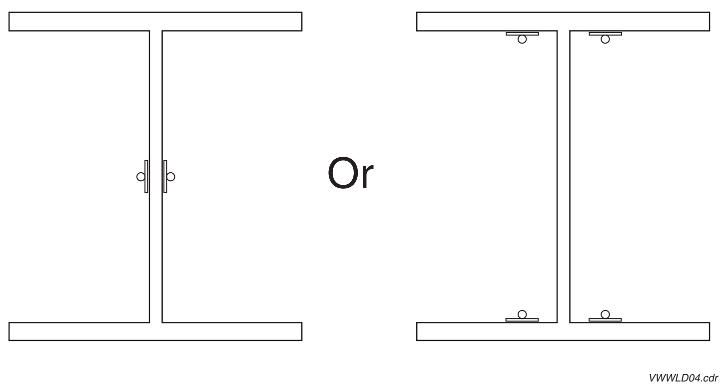
Driven H-Piles

Install gauges in the middle of the web. Add protective covering.



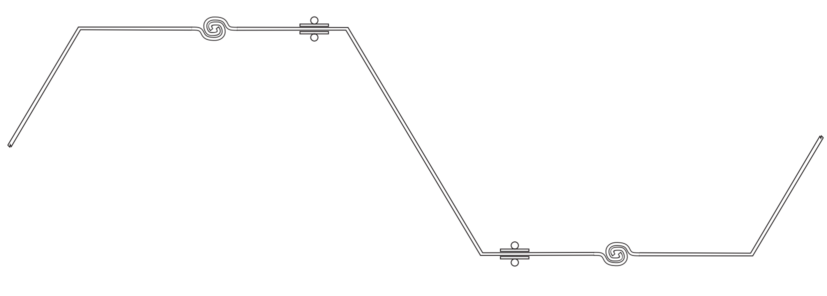
I-Beams

Install gauges in the middle of the web, or if installed on the flanges, as near to the web as possible.



Sheet Piles

Install gauges on both sides of the pile, away from the clutches.



Installing the Strain Gauges

Parts and Equipment

Check that you have these parts and materials.

Strain Gauge

- Spot-weldable strain gauge
- Strain gauge sensor
- Protective cover for strain gauge sensor

Tools and Materials

- Grinder and sander for surface preparation
- Spot-welding equipment
- Mica or similar material insulating card
- 100-grit emery paper
- Mastic pad
- Wire or tie-wraps for re-bar
- Self-vulcanizing tape for re-bar
- Stainless tie-down straps for beams
- 3M Skotchkote
- Degreaser for cleaning welding surface.

Prepare the Surface

1. Remove rust with sander. If necessary, create a flat surface with grinder. Gauge should lie flat on the surface with no wobble.
2. Surface must be clean, dry, and free of grease. A solvent such as MEK or Trichlor works well for removing grease.
3. Mark exact location for strain gauge.

Determine Welder Settings

Determine appropriate welder energy and force settings by testing with sample flange material (available from Slope Indicator Co). Start with an energy setting of 25 watt seconds and a force of 3 to 4 pounds.

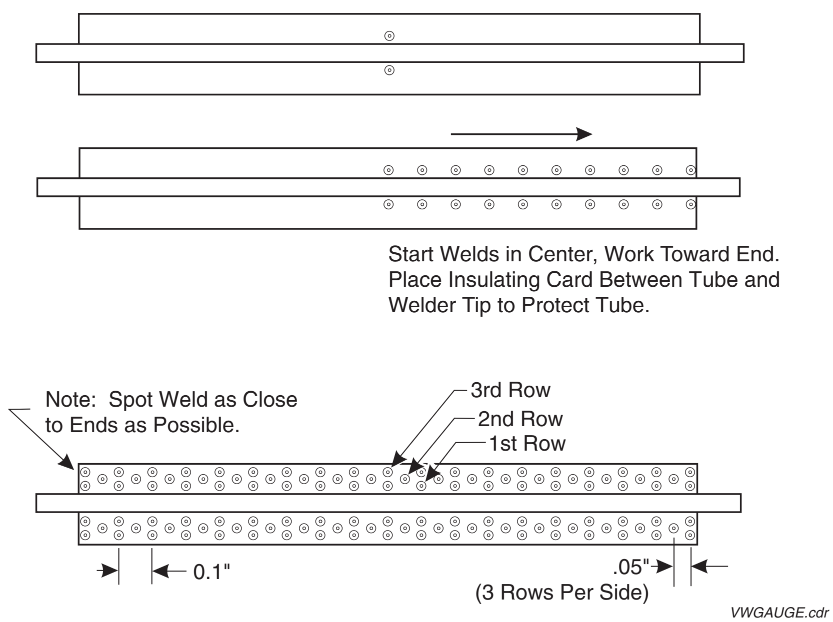
Modify only one factor at a time. Increase force, or increase energy, until a weld is made without expulsion of metal. If discoloration occurs, increase force or decrease energy to lower heat of weld. Decrease force and/or energy if excessive deformation occurs.

Check welds by attempting to peel sample material off structural member. Weld strength is satisfactory if welds tear off sample and remain on member.

Weld the Gauge

The majority of the welds should be slight, smooth depressions. Discoloration, excess or no deformation, or metal expulsion indicate a weak weld.

4. Tack the gauge in place with one spot weld centered on each side of the tube. First row should be placed close to tube, as shown below. Hold insulating card between welding tip and tube to avoid damaging the gauge.
5. Place welds alternately on each side, working from the center to the ends. Weld spacing should be approximately 0.1 inches (2.5 mm).
6. Apply a second row of welds staggered approximately 0.05 inch (1.25 mm) relative to the first row.
7. Apply a third row of welds staggered approximately 0.05 inch (1.25 mm) relative to the second row.



Apply Corrosion Protection

Apply corrosion protection to strain gauge and welds prior to installing sensor. Do not coat area where tie-down straps will be welded. We recommend use of 3M Skotchkote in the US.

Fixing the Sensor to the Strain Gauge

The strain gauge sensor should be mounted directly onto the strain gauge. Connect a readout to verify that the gauge works.

Fixing the Sensor onto a Bar

1. Place sensor over gauge so that gauge fits into groove in sensor. Connect sensor to a readout device and check that a stable reading is obtained.
2. Use wire or plastic tie-wraps to secure sensor.
3. Wrap sensor, gauge, and tie-wraps tightly with mastic pad.
4. Wrap self-vulcanizing tape over installation.

Fixing the Sensor to a Beam

1. Place sensor over gauge so that gauge fits into groove in sensor. Connect sensor to a readout device and check that a stable reading is obtained.
2. Hold sensor in position and weld tie-down straps to structural member. Do not touch welder tip to sensor.
3. Route electrical cable so that it is protected from physical damage.
4. Weld protective cover over installation. It is made of thicker material and may require a higher level of weld energy.
5. Fit mastic pad over protective cover and exit point of cable.

Terminate Signal Cable

For short term installations, identify the cable, and then strip the cable jacket back about three inches to expose wires. Strip some insulation from the wires for each connection to the readout. Protect the end of the cable from moisture.

For long term installation, connect the cable to a terminal box or data logger inside a weatherproof enclosure.

Function	Wire Color
Strain Gauge	Orange
	White and Orange
Temp Sensor	Blue
	White and Blue
Shield	Shield

Taking Readings

Introduction

These instructions tell how to read the strain gauge with Slope Indicator's portable readouts.

A datum strain reading is required to calculate changes in strain. A datum temperature reading is required to correct strain readings for changes in temperature.

Instructions for reading VW sensors with a Campbell Scientific CR10 can be found at www.slopeindicator.com. Go to Support - Tech Notes and click on the link titled "CR10-VW Sensors."

Reading with the VW Data Recorder

1. Connect signal cable to the data recorder as shown in the table below.
2. Choose Hz + Thermistor or Hz + RTD. You may also use the microstrain + RTD setting.
3. Select the 800-2000 Hz range. In general, the 800-2000 Hz range is suitable for measuring compression and the 1400-3500 range is suitable for measuring tension.
4. The recorder displays a sensor reading in Hz and a temperature reading in degrees C.

Binding Posts	Wire Colors	
VW	Orange	Red
VW	White & Orange	Black
TEMP	Blue	White
TEMP	White & Blue	Green
SHIELD	Shield	Shield

Reading with the VWP Indicator

1. Connect signal cable to the VWP indicator as shown in the tables below.
2. Select the 0.8 - 2.0 kHz sweep range if you are measuring compression. Select the 1.4 - 3.5 kHz range if you are measuring tension.
3. Use the Data key to select Hz or μεVW.
   Note: The VWP Indicator display zero microstrain when the wire vibrates at 1637 Hz.
4. Read the RTD: Select °C with the Data key.
   Note that the VWP Indicator reads RTDs only and cannot read thermistors.

Standard Jumper 52611950

Connect alligator clips as shown below:

Clips	Wire Colors		Function
Red	Orange	Red	VW
Red	White & Orange	Black	VW
Black	Blue	White	TEMP
Black	White & Blue	Green	TEMP

Universal Jumper 52611957

This cable has a universal connector and is supplied with a bare-wire adapter:

BWA	Wire Colors		Function
5	Blue	White	TEMP
6	White & Orange	Black	VW
7	White & Blue	Green	TEMP
8	Orange	Red	VW
10	Shield	Shield	Shield

Reading with the DataMate MP

The DataMate MP allows you to choose engineering units for your readings. However, for ease of data reduction, we recommend that you record readings in Hz.

Manual Mode

1. Connect signal cable as shown in the table below.
2. Switch on. Press (Manual Mode).
3. Scroll through the list to find “Vibrating Wire Hz.”
4. Press to excite the sensor and display a reading in Hz and a temperature reading in degrees C.

Universal Jumper and Bare-Wire Adapter

The DataMate jumper cable has a universal connector that connects directly to a universal terminal box or to signal cables that are terminated with a universal connector. A bare-wire adapter (BWA) is also supplied with the DataMate. It allows connection to wires of the signal cable as shown below:

Terminals on BWA or Terminal Box	Wire Colors		Function
5	Blue	White	TEMP
6	White & Orange	Black	VW
7	White & Blue	Green	TEMP
8	Orange	Red	VW
10	Shield	Shield	Shield

Data Reduction

Converting Hz to Microstrain

If your readings are in Hz, convert them to microstrain ($\mu\varepsilon$).

$$\mu\varepsilon = A(F^2) + C$$

where
F = Reading in Hz
A = 0.0007576
C= -2030.1

For example, suppose your reading is 2000 Hz.

$$\begin{aligned}\mu\varepsilon &= 0.0007576 \times 4000000 + (-2030.1) \\ &= 3030.4 - 2030.1 \\ &= 1000.3\end{aligned}$$

Calculating the Change in Strain

The reading from the strain gauge is now in microstrain, but it does not represent the total strain in the structural member. There was strain in the structural member before the gauge was attached, and there was strain in the wire inside the gauge, since it had to be tensioned in order to operate.

Therefore, a datum reading must be obtained after the strain gauge is installed. The datum is subtracted from any subsequent strain reading to find a change in strain.

$$\Delta\mu\varepsilon = \mu\varepsilon_{current} - \mu\varepsilon_{initial}$$

Positive or Negative Strain

Due to its design, the strain gauge reports larger numbers as the structural member lengthens and smaller numbers as the structural member shortens.

When a tensile load increases, successive strain readings will be greater than the initial reading, and the change in strain will be positive. In the same way, if a compressive load increases, successive strain values will be lower, and the change in strain will be negative.

Bending Effects

Bending increases strain on one side of the structural member and decreases strain on the opposite side. To minimize error due to bending, the strain gauge should be installed along the neutral axis of the member.

When a neutral axis is not available, strain gauges are installed on opposite sides of the member and the strain due to bending is eliminated by finding the average of the readings:

Temperature Effects

- We recommend that you always record temperature when you record strain readings. You can then use the temperature data in addition to strain data to characterize the behavior of the structure.
- The steel used for the wire in the strain gauge has a thermal coefficient of expansion similar to that of steel used in structures. Thus, if the gauge and the steel are at the same temperature, no correction for temperature corrections are required.
- If the temperature of the gauge and the temperature of the steel are not the same, you may see large changes in apparent strain. This is usually not a problem with the spot-weldable gauge.
- If there is a steel that has a very different coefficient of expansion from the steel in the gauge, the temperature correction might be appropriate.

$\Delta\mu\varepsilon$ corrected = $\Delta\mu\varepsilon - (TC_m - TC_g) \times (Temp_1 - Temp_0)$

Where

$\Delta\mu\varepsilon$ is the change in strain,

TC_m is the thermal coefficient of the member

TC_g is the TC of the gauge: 10.8 $\mu\varepsilon$/°C or 6$\mu\varepsilon$/ °F

$Temp_1$ is the current temperature

$Temp_0$ is the datum temperature