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The Strain Gauge

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What is Strain?

- Strain is elongation or deformation of a solid body due to forces applied to it
- Physical units of strain or delta length over length
- Practical units of strain for stretching or compression stress is microstrains, or parts per million of elongation
- Compression is denoted by negative strain

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What is a Strain Gauge?

- Uses resistance of magnet wire
- Resistance increases as it stretches
- Resistance of a medium:

$$R_0 = \frac{\sigma \cdot \text{Length}}{\text{Area}} = \frac{\sigma \cdot \text{Length}^2}{\text{Volume}}$$

- If the volume stays constant as the wire is stretched an incremental amount δL , the resistance increases

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Resistance vs. Stretching

- Resistance increases as it stretches

$$R = \frac{\sigma \cdot (\text{Length} + \delta L)^2}{\text{Area}}$$

$$\approx \frac{\sigma \cdot (\text{Length}^2 + 2 \cdot \text{Length} \cdot \delta L)}{\text{Area}}$$

$$= \left(1 + 2 \cdot \frac{\delta L}{\text{Length}} \right) \cdot R_0$$

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The Gauge Factor

- Actual strain gauge resistance is

$$R = \left(1 + K \cdot \frac{\delta L}{\text{Length}} \right) \cdot R_0$$

- The factor K is the *gauge factor*
 - Theoretical value is 2
 - Actual value can vary due to
 - Physics of stretching
 - Temperature
 - Backing, adhesive
 - Small differences during manufacturing
- Calibration of the gauge factor is necessary for best accuracy

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Practical Aspects of Strain Gauge Configuration

- Requirements
 - Must easy to apply to material
 - Must be easy to use
 - Must have minimal effect on the strain being measured
- Configuration
 - Make very small
 - Physically weak compared to most materials
 - Satisfy ease of application and minimal effect on strain
 - Use folded configuration instead of straight wire
 - Keep total strain gauge size small
 - Measure the strain over a small area
 - Addresses all three requirements

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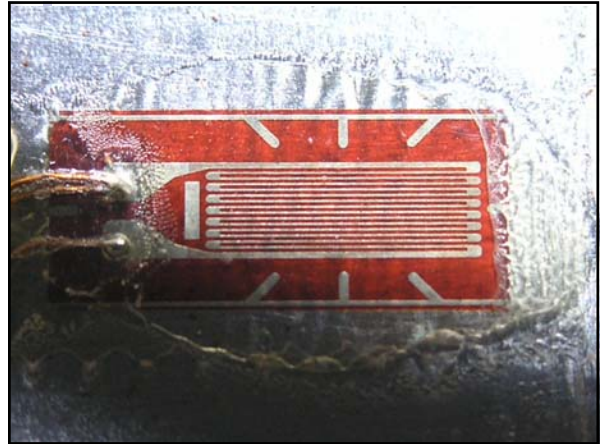
How Strain Gauges are Used

- Apply so that strain-measuring wires are in the direction of the strain being measured
- Connect the strain gauge in a Wheatstone bridge circuit
- Measure the differential resistance
- Convert the differential resistance to strain for recording the measurement

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The P-3500 Strain Indicator



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Usage of the P-3500

- We have two for Sophomore Clinic
- Use will be under supervision of a faculty member
- Today we present strain gauges and the P-3500
 - How a strain indicator works
 - How they are hooked to the P-3500
 - How the P-3500 is used

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What the Strain Indicator Is

- Battery-powered
- Electronics to
 - Put the strain gauge in a Wheatstone bridge
 - Balance the bridge for zero strain
 - Measure the output of the Wheatstone bridge
 - Calibrate a four-digit display to read strain in microstrains
 - Provide a ground-referenced analog output

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How a Strain Gauge Indicator Works

- Provides a Wheatstone bridge
 - Resistance is the nominal resistance of the strain gauge
 - One of the other resistors is varied to balance the bridge for zero strain
- A differential amplifier captures the output of the Wheatstone bridge
- A variable gain calibrates the output to microstrains
- A display provides recordable data in microstrains
- An analog output provides data for oscilloscopes, data loggers, or other purposes

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Strain Indicator

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Wheatstone Bridge

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Differential Amplifier

$$Gain = \left(1 + \frac{2 \cdot R}{R_G}\right) \cdot (e_+ - e_-)$$

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How to Operate

- Instructions on the inside of the lid
- We use four buttons
 - Power off
 - Zero amp
 - Gage factor
 - Run

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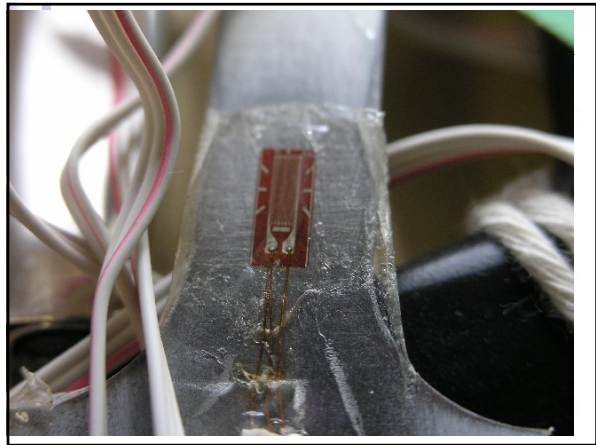
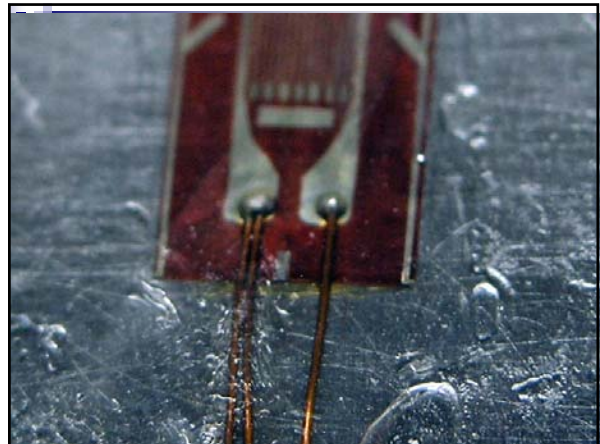
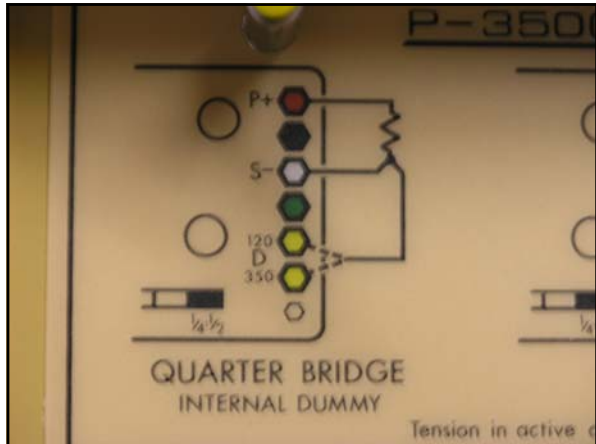
P-3500 STRAIN INDICATOR

*Sensor in active form. A = air compressor in form. C gives positive reading.

1. Connect gauges as shown. Set BRIDGE pushbutton to proper position.
2. Display AMP ZERO pushbutton. Set AMP ZERO control for reading of $\times 0000$.
3. Display GAGE FACTOR pushbutton. Set GAGE FACTOR controls in accordance with gauges in use. Lock GAGE FACTOR knob.
4. Display RUN pushbutton. Set BALANCE controls for reading of $\times 0000$ lock BALANCE knob.
5. Load gauge system as desired. Meter reads in microstrain ($\mu\epsilon$).
6. CAL pushbutton contacts $\pm 5000\mu\epsilon$ (short resistor across internal dummy. (See manual for optional uses of CAL pushbutton).
7. BRKCT OFF pushbutton removes excitation from bridge circuit. (Not normally used with "remote sensor" feature. See manual).
8. MULT pushbutton extends measurements range to $\pm 199990\mu\epsilon$. (Meter reads in increments of $10\mu\epsilon$).

TRANSDUCER CONNECTOR

(E+) (E-)
(I+) (I-)
(I) (CAL)
(SEE MANUAL)



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In Use

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For the Hoistinator

- Carefully select a spar for instrumentation
- Carefully select a point on the spar for a strain gauge
- Attach a strain gauge to the spar
- Relate measured strain to spar performance
 - Strain versus load
 - Failure strength
 - Failure load
- Relate measured strain to Hoistinator performance
 - Maximum safe load
 - Failure load

REMEMBER ENGINEERING SAFETY MARGINS

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