# Strain Gage measurements

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A lot of help from

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# Strain Gage: Intro

Strain gage measure the strain

- $\varepsilon_{i} = \Delta L_{i} / L_{i}$
- $\Delta R_{i} / R_{i} = K \varepsilon_{i}$
- K ~ 2 is the gage factor
- $L_{i}$ ~ 7mm is the strain-gage length

$$\left(\frac{\Delta R}{R_0}\right)_{T/O} = \left[\beta_G + F_G\left(\frac{1+K_t}{1-\nu_0 K_t}\right)(\alpha_S - \alpha_G)\right]\Delta T \qquad (1)$$

where, in consistent units:

$\left(\frac{\Delta R}{R_0}\right)_{T/O}$ = unit change in resistance from the initial reference resistance, $R_0$, caused by change in temperature resulting in thermal output.

$\beta_G$ = temperature coefficient of resistance of the grid conductor.

$F_G$ = gage factor of the strain gage.†

$K_t$ = transverse sensitivity of the strain gage.

$\nu_0$ = Poisson's ratio (0.285) of the standard test material used in calibrating the gage for its gage factor.

**TABLE 1—NOMINAL THERMAL EXPANSION COEFFICIENTS OF ENGINEERING MATERIALS**

| MATERIAL DESCRIPTION | EXPANSION COEFFICIENTS** Per °F | [Per °C] | RECOMMENDED S-T-C NUMBER |
|---|---|---|---|
| **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 (17-4PH) | 6.0 | [10.8] | 06 |
| **STEEL, Stainless**, Age Hardenable (17-7PH) | 5.7 | [10.3] | 06 |
| **STEEL, Stainless**, Age Hardenable (PH15-7Mo) | 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 | 0.0 | [0.0] | 00* |
| **TUNGSTEN**, pure | 2.4 | [4.3] | 03 |
| **ZIRCONIUM**, pure | 3.1 | [5.6] | 03 |

* Indicates type of material used in determining thermal output

# Strain Gage: Methodology

In our samples thermal output vs T given for Steel 1018

$$\epsilon_{T/O} = \left( \frac{\beta_G}{F_G} - \alpha_G \right) \Delta T + \alpha_S \Delta T \qquad \varepsilon = \Delta L \ / \ L$$

For Another material X:

$$\epsilon_X = \left( \frac{\beta_G}{F_G} - \alpha_G \right) \Delta T + \alpha_X \Delta T$$

- $\varepsilon_X - \varepsilon_{T/O} = (\alpha_X - \alpha_{steel}) \, \Delta T$
  - The subtraction removes the thermal response of the strain gage and leaves just the part that depends on the substrate

- Measure $\varepsilon_X$ as a function of T
- Fit $\varepsilon_X - \varepsilon_{T/O}$ vs T

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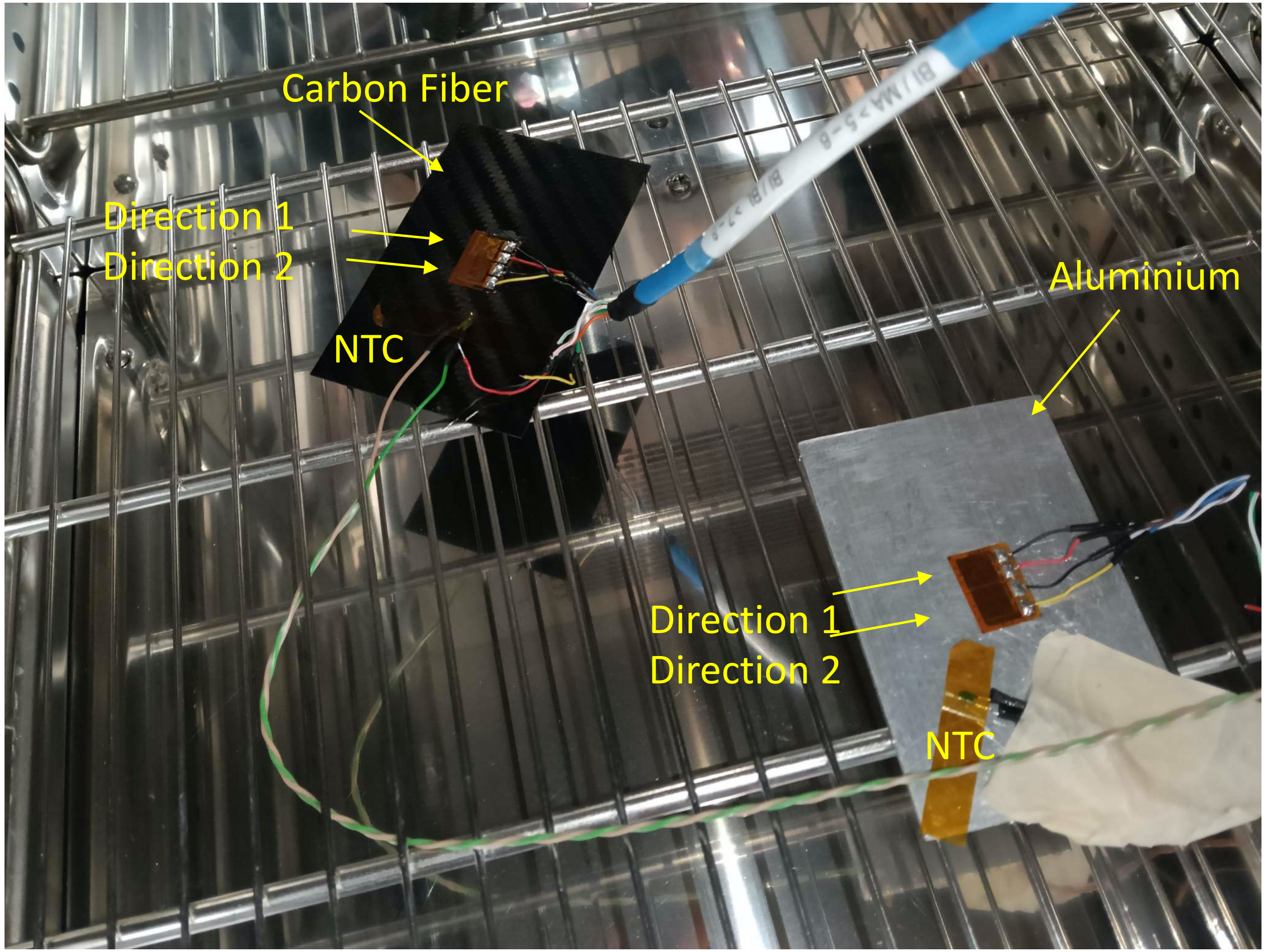
| **ZIRCONIUM**, pure | 3.1 | [5.6] | 03 |

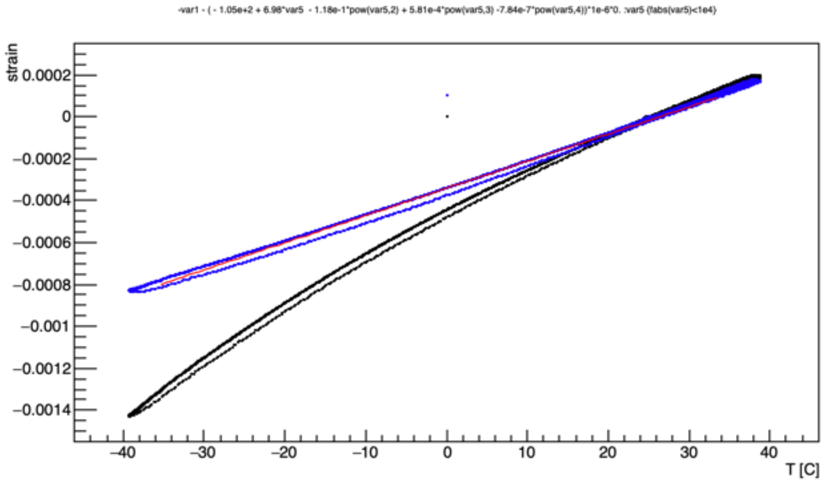
* Indicates type of material used in determining thermal output

# Experimental setup



Blue points and Fit: : after thermal correction

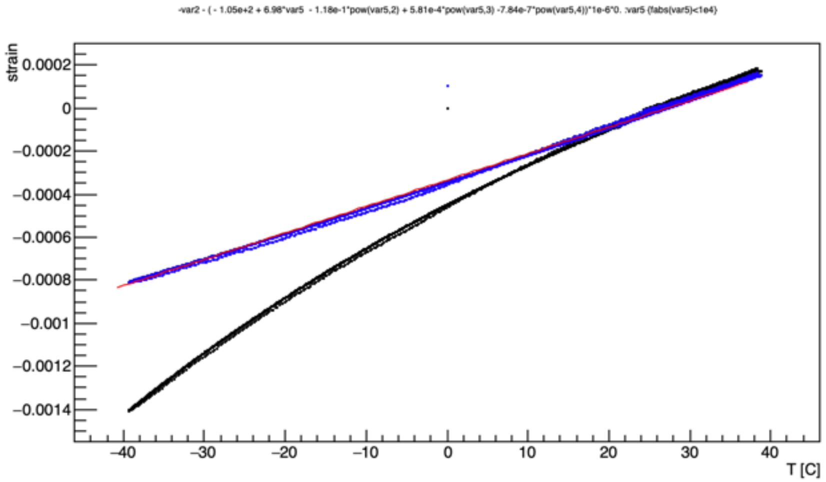
## Strain-gage 1 Al




slope_measured ~ 13.0 e-6 / C

$\alpha_{Al}$ = slope_measured + $\alpha_{steel}$ ~ 25.1 e-6 / C

## Strain-gage 2 Al



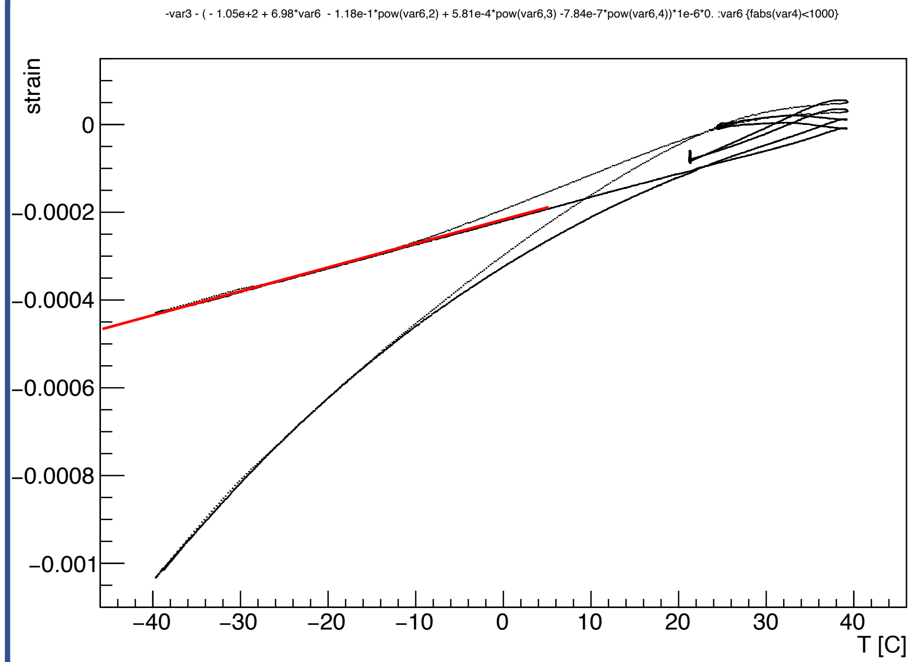

slope_measured ~ 12.3 e-6 / C

$\alpha_{Al}$ = slope_measured + $\alpha_{steel}$ ~ 24.5 e-6 / C

For both sensors decent agreement with expected CTE of Aluminium

## Blue points and Fit: after thermal correction

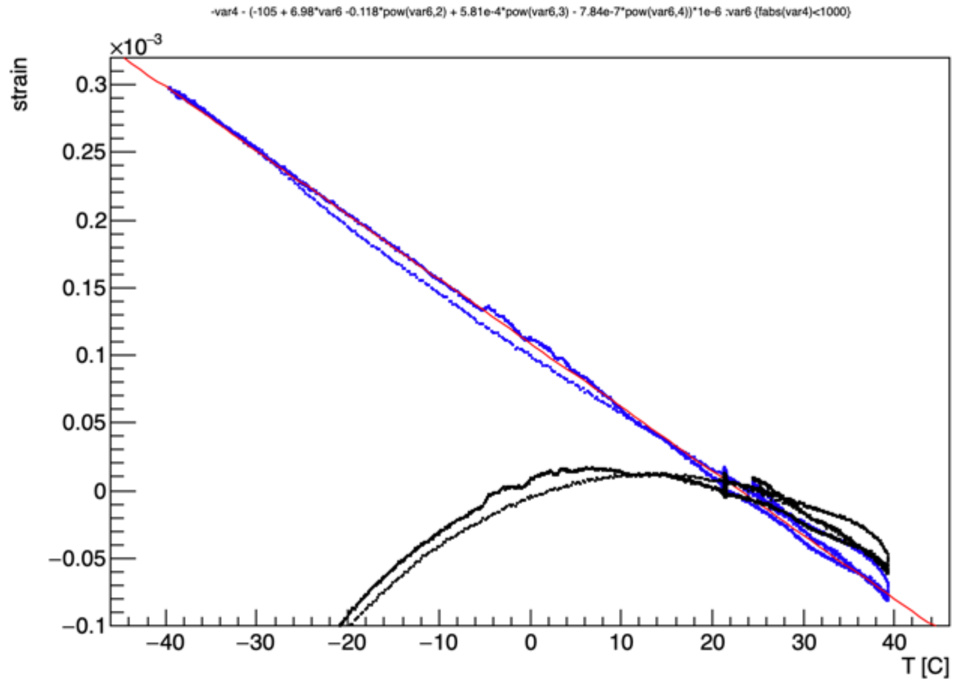
### Strain-gage 1 CF




slope_measured ~ 5.2 e-6 / C

$\alpha_{CF,1}$ = slope_measured + $\alpha_{steel}$ ~ 17.3 e-6 / C

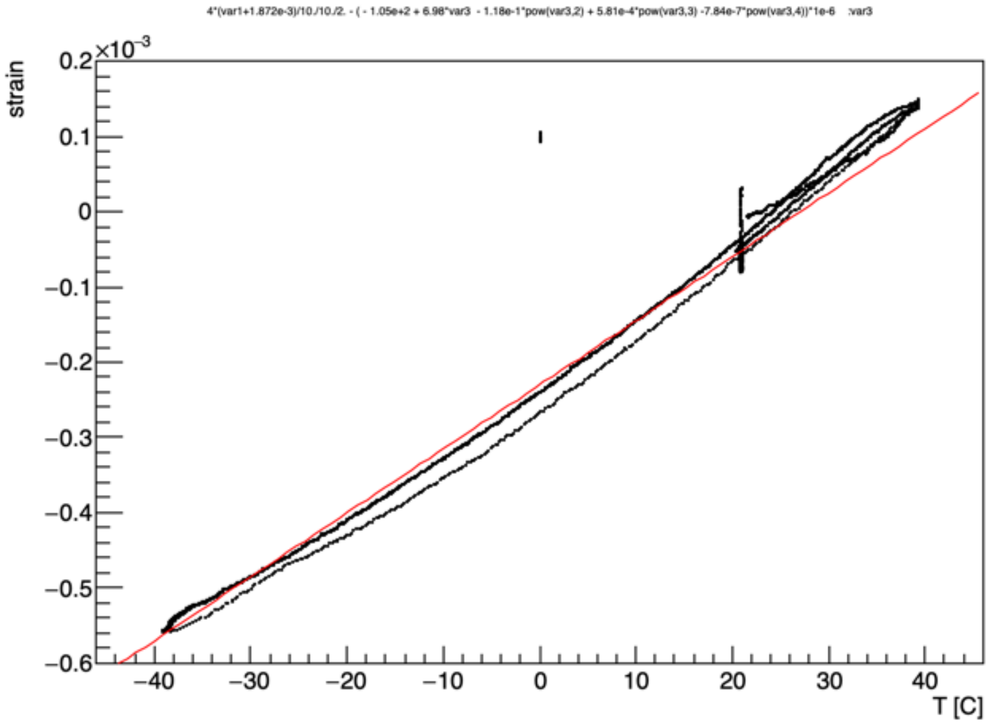
### Strain-gage 2 CF




- slope_measured ~ - 4.8 e-6 / C
- $\alpha_{CF,2}$ = slope_measured + $\alpha_{steel}$ ~ 7.3 e-6 / C
- decent agreement with Tim measurement of 4.94 ppm/C. He used calibration with low CTE material

# Backup

Strain 1 Lega Al




```
Chi2                      =  6.15966e-07
NDf                       =         6321
p0                        = -0.000334009   +/-   1.35577e-07
p1                        =  1.22829e-05   +/-   5.49233e-09
```