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Effects of metal protection coils on thermocouple EMF in multi-anvil high-pressure experiments

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Abstract

Metallic coils (in most cases Cu coils) are often used in high-pressure experiments to protect thermocouple wires. In this paper we show that these coils have important influences on thermocouple EMF and therefore on the temperature measurements. We tested this effect by measuring EMF from Cu coiled single wires of chromel and alumel, and, further, we conducted experiments to compare the EMF from W5Re-W26Re thermocouples with and without Cu coils attached to them. The results show systematic differences in thermocouple readings; the EMFs from W-Re thermocouples with Cu coils give systematically lower values than EMFs from thermocouples without Cu coils. The results were analyzed using a simple model. The difference in thermocouple EMFs between thermocouples with and without protection coils is given by

$$\Delta E_{\mathrm{TC}} = \frac{E_2 - E_{1+}}{1 + \dfrac{R_2}{R_{1+}}} - \frac{E_2 - E_{1-}}{1 + \dfrac{R_2}{R_{1-}}}$$

where E_i and R_i are the EMF and the electrical resistance of metal i in the portion of the Cu coil, and the subscripts 1+, 1–, and 2 indicate positive thermocouple metal, negative thermocouple metal, and coil metal, respectively. The addition of a coil with different metal has a large effect — the ΔE_{TC} will be close to $-(E_{1+} - E_{1-}) < 0$ when the resistance of the coil is significantly smaller than that of a thermocouple wire. For a Cu coil and W-Re thermocouple, $R_{1+,\,1-} >> R_2$ and therefore thermocouple readings with a Cu coil will lead to underestimation of the real temperature. Under common experimental conditions with a multi-anvil apparatus, the error in the temperature estimate caused by Cu protection coils is ~100–150 K for a peak temperature of 1600–2000 K.

Keywords: High-pressure and high-temperature studies, thermocouple EMF, electrical properties, tungsten-rhenium alloy, chromel-alumel