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Prototyping a new, high-temperature SQUID magnetometer system

J. Michael Grappone, John Shaw, and Andrew J. Biggin
Geomagnetics Laboratory, University of Liverpool, Liverpool L69 7ZE UK (grappone@liverpool.ac.uk)

High-sensitivity Superconducting Quantum Inference Devices (SQUIDs) and μ-metal shielding have largely solved paleomagnetic noise problems. Combing the two allows successful measurements of previously unusable samples, generally sediments with very weak ($<$10 pAm^2) magnetizations. The improved sensitivity increases the fidelity of magnetic field variation surveys, but surveys continue to be somewhat slow. SQUIDs have historically been expensive to buy and operate, but technological advances now allow them to operate at liquid nitrogen temperatures (77 K), drastically reducing their costs. Step-wise thermal paleomagnetics studies cause large lag times during later steps as a result of heating from and cooling to room temperature for measurements. If the cooling step is removed entirely, however, the lag time drops by at least half. Available magnetometers currently provide either SQUID-level (0.1 - 1 pAm^2) sensitivity or continuous heating. Combining a SQUID magnetometer with a high temperature oven is the logical next step to uncover the mysteries of the paleofield. However, the few that currently offer high temperature capabilities with noise levels approaching 10 pAm^2 require either spinning or vibrating the sample, necessitating additional handling and potentially causing damage to the sample.

Two primary factors have plagued previous developments: noise levels and temperature gradients. Our entire system is shielded from the environment using 4 layers of μ-metal. Our sample oven (designed for 7 mm diameter samples) sits inside a copper pipe and operates at high-frequency AC voltages. High frequency (10 kHz) AC current reduces the skin depth of radio frequency (RF) electromagnetic noise, which allows the 2 mm-thick copper shielding to reduce RF noise by $\sim$94%, leaving a residual field of $\sim$1.5 nT at the SQUID's location, 14.9 mm from the oven. A computer-controlled Eurotherm 3216 thermal controller regulates the temperature within $\pm$ 0.5 ˚C. To reach 700 ˚C, just above the Curie temperature of Hematite, a temperature difference of nearly 900 ˚C between the sample and the SQUID is required. Since dipole fields decay rapidly with distance ($\propto$ r $^{-3}$), the equipment is designed to handle temperature gradients above 500 ˚C cm^{-1} for maximum sensitivity using a passive double-vacuum separation system. All the parts used are commercially available to help reduce the operating costs and increase versatility.