Measurement of Microkelvin Temperature Differences in a Critical Point Thermostat

R.F. Berg
Physical and Chemical Properties Division
National Institute of Standards and Technology
Gaithersburg, MD 20899 USA

G.A. Zimmerli
Engineering Services Division
NYMA, Incorporated
Brook Park, OH 44142 USA

The density of a pure fluid near its critical point is extremely sensitive to temperature gradients. In the absence of gravity, this effect limits the fluid's homogeneity. For example, at 0.6 mK above the critical temperature, the microgravity experiment Critical Viscosity of Xenon (CVX) can allow temperature differences no more than 0.2 µK, corresponding to a gradient of 10^{-5} K·m^{-1}.

The CVX thermostat, which consists of a thick-walled copper cell contained within three concentric aluminum shells, was designed to achieve such a small temperature gradient. However, asymmetries not included in the thermostat's model could degrade the thermostat's performance. Therefore we measured the temperature gradient directly with a miniature commercial thermoelectric cooler consisting of 66 semiconductor thermocouples. We checked the results with a half bridge consisting of two matched thermistors. The measurement was made along a thin-walled stainless steel cell whose conductance was much lower than that of the copper cell, thus "amplifying" the temperature differences by a factor of 60.

When the thermostat was controlled at constant temperature, the steel cell's static temperature difference was 5 ±1 µK. Ramping the thermostat's temperature at the rate of 1 x 10^{-5} K·s^{-1} increased the temperature difference to 0.36 mK. These results demonstrate the feasibility of achieving extremely low temperature gradients.