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Calibration of a Resistance Thermometer Down to 0.04°K

The problem:

To develop a method for calibrating resistance thermometers between 0.4°K and 4°K. The temperature calibration of such thermometers below the He^3 vapor pressure range is usually done by extrapolating the inverse temperature behavior of the magnetic susceptibility of an appropriate paramagnetic salt. However, the necessary equipment for measuring the magnetic temperature at such low temperatures is not readily available.

The solution:

By extrapolating the specific heat of a simple metal to low temperatures, a germanium-resistance thermometer has been calibrated down to 0.4°K. This provides an accurate and convenient method for calibrating stable germanium-resistance thermometers in cryostats for specific heat measurements below the He^3 vapor pressure range, where a magnetic thermometer is not available. No other measuring equipment inside or outside the cryostat is needed other than the equipment required to measure specific heat. Also, there are no corrections to be made to the temperatures as directly calculated from the extrapolation. The calibration has been checked by measuring the specific heat of a 1965 Calorimetric Conference Standard Copper sample and a high purity silver sample.

How it's done:

The temperature dependence of the specific heat, C_p, of a nonmagnetic metal can be given as:

$$C_p = \gamma T + \alpha T^3;$$

if $T < \theta_D/100$ (θ_D is the Debye temperature at 0°K.) and there is no nuclear specific heat. If a charge of heat ΔQ is put into such a thermally isolated metal sample, originally at T_i, it will come to equilibrium at a temperaütre T_f, determined by the equation:

$$\Delta Q + \int_{T_i}^{T_f} C_p \, dT = \frac{\gamma}{2}(T_f^2 - T_i^2) + \frac{\alpha}{4}(T_f^4 - T_i^4).$$

Thus the temperature T_i can be calculated if ΔQ, T_f, γ, and α are known. In this experiment α and γ are determined by specific heat measurements above 0.75°K, where He^3 and He^4 vapor pressures can be used to calibrate the thermometer. ΔQ is determined from the electrical power used to heat a resistor on the sample and the measured background heat leak to the sample. T_f is known either because it has been determined by vapor pressure measurements or because it has already been determined by the extrapolation of C_p.

The detailed calibration procedure is available.

The thermometer calibrated is a germanium-resistance thermometer with a nominal resistance range of 133 ohms at 4.2°K to 9,400 ohms at 0.4°K. The metal sample used for the calibration is a 99.999% pure platinum cylinder, one inch in diameter and three inches long. Spectrochemical analysis of the sample showed ~5ppm of both silver and magnesium and 24ppm of sodium. Platinum was picked for its large low-temperature heat capacity due mostly to the electronic specific heat.

Notes:

1. The information may be of interest to persons concerned with low temperature calorimetry.
2. Reference: Additional details contained in *Cryogenics* 8, 386, 1968.

(continued overleaf)

3. Inquiries may be directed to:
   Office of Industrial Cooperation
   Argonne National Laboratory
   9700 South Cass Avenue
   Argonne, Illinois 60439
   Reference: B69-10149

Source: H. V. Culbert and Z. Sungaila
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The problem:

Inquiries concerning rights for commercial use of this innovation may be made to:

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