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C2Po1E-06: Helium Flow Meter for Measuring SRF Cavity Power Dissipation

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We present a helium gas flow meter designed to measure power dissipation in Superconducting Radio Frequency (SRF) cavities by quantifying the evaporation rate of helium vapor. The meter operates in the 3–7 K temperature range, measuring helium flow rates with a resolution of 0.05 g/s (˜1 W) and functioning at gas velocities from 1 to 14 m/s.

At the Thomas Jefferson National Accelerator Facility (JLab), the flow meter is installed in the return U-tube of an 8-cavity SRF cryomodule. It enables precise power dissipation measurements, identifying individual cavity losses (˜30 W range) and total cryomodule heat loads (˜200 W with beam on). This capability is critical for detecting contaminated cavities and optimizing cryogenic system performance.

The meter's exceptional sensitivity stems from a niobium-titanium sensor element (critical temperature 9.2 K) paired with a resistive heater. In "hot-wire anemometer" mode, the heater current is dynamically adjusted to maintain a partially normal conducting state, maximizing sensitivity to helium flow changes. An alternative "sawtooth" mode averages heater current over cyclic operations, compensating for minor variations in helium supply conditions.

To ensure accuracy, each flow meter reading is calibrated using cryomodule heaters while the cavity is off. The meter's control and data processing are managed via a Linux-based system and a LabJack T7 interface. This system has streamlined SRF cavity performance assessments, replacing labor-intensive methods previously used for LCLS-II-HE cryomodule qualification.

The flow meter is currently installed in 19 of 52 positions in CEBAF, with integration into operations underway. It enables real-time monitoring of cavity dissipation, optimizes cryogenic heat management, and supports long-term performance tracking, correlating cavity degradation with environmental or hardware factors.

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