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Performance of the G^0 Superconducting Magnet System

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Abstract. At the heart of the G^0 Spectrometer is the toroidal superconducting magnet system (SMS). The SMS has been in use at Jefferson Lab since the fall of 2002. Experience with the operation and reliability of the magnet over that period is reported. Some measured performance parameters are compared the magnet specification.

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The G^0 superconducting magnet system (SMS) is an iron-free toroid with zero magnification optics. Its field, peaking at 3.5 T (3 T in conductor) is generated by eight coils, each with 144 turns (4X36 windings), in a common cryostat. The stored energy is 6.6 MJ at the normal operating current of 5 kA.

Coil locations were measured at room temperature after installation at Jefferson Lab using photogrammetry to locate 128 targets (16 on each coil). Design and measured target locations were compared, while adjusting the overall position and orientation of the magnet for a best fit. The average deviation of measurements from the ideal was found to be 1.6 mm, less than the 2.0 mm specification. The locations of the coils, when cooled, were deduced from known coefficients of thermal expansion.

A measurement of the Q^2 associated with each focal plane detector was extracted[1] from the difference between the time-of-flight of elastic protons and of π^+ particles. This difference is sensitive to the particle trajectory through the magnet and thus to the magnetic field configuration. Measurements were compared to a simulation based on the design magnetic field and found to agree to a precision of 100 ps, which implies an uncertainty on Q^2 within the 1% requirement of the experiment.

The SMS cooldown, specified to take 7 days, actually required about 21 days. This rate was limited by the requirement that ΔT between inlet and coil average be < 75 K. Heat load to LHe was specified to be < 40 W, but boil-off studies indicate a load of about 107 W. The steady-state LHe requirement of the magnet at full power was found to be about 8 g/s, consistent with the measured heat load with some additional load from the supply lines.

During a fast dump of magnet stored energy, the current decays with a 10.4 s time constant into the 0.05 Ω dump resistor. This implies an inductance of 0.52 H which matches the design inductance of 0.53 H. Redundant quench protection systems, a "digital" system (DQP), which relied on the operation of the control system programmable logic controller (PLC), and an independent "analog" system (AQP), were used to trigger a fast dump when a quench was detected. The DQP initially suffered from the failure of series "safety" resistors on voltage taps due to thermal cycling. Circuitry was added to detect broken resistors. For each coil, a battery provided an isolated current, which circulated through the coil and adjacent voltage tap safety resistors. Diodes were used to ensure that the isolated current was only seen by the corresponding input stage to the DQP. Offsets voltages produced by the battery current were measured and subtracted by the PLC software. The absence of the offset voltage was the signature for a broken resistor. After the first commissioning run (October 2002 to January 2003), the safety resistors were re-located outside of the cryostat.

About 160 of the 3270 hours of available data collection time during commissioning and production running were lost due to magnet problems. This is about 48% of all lost data collection time. Most (70.3%) of the magnet problems were caused by radiation damage to control system components. A typical failure began with a halt of PLC program execution due to a radiation-related memory error, which caused the "heart-beat" interlock to open. This shut down the power supply. A transient at the start of the shut-down caused the AQP to erroneously detect a "quench" and initiate a fast-dump. Eddy-current heating then evaporated LHe in the coils and reservoir requiring a minimum 2.5-hour recovery time. LHe supply and return problems were the second largest cause (18.7%) of magnet related lost time.

References

1. G.Batigne, Proceedings of the Fourth International Conference on Perspectives in Hadronic Physics, Trieste, May 12-16, 2003.