Heater Control and Monitoring for the Hall A Electron Calorimeter Test Stand

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The Hall A Electron Calorimeter (ECAL) detector consists of 188 supermodules [1]. Each supermodule consists of nine ~1" x ~1" x ~13" lead crystals, each wrapped in aluminum foil and copper strips, stacked in a 3 x 3 array. To counteract possible radiation damage during beam operations, thermal annealing of the crystals is required. This note describes the prototype design, development, and testing of the silicone pads with wire-wound heaters, which are capable of continuously heating the crystals during beam operations.

Continuously supplying heat to the lead crystals during beam operation is an effective way to reduce the effects of radiation [2].

Based on the design and performance specifications provided, a prototype silicone heater with adhesive backing, Fig. 1, which can be affixed to the front flange of the supermodule, was developed by Custom Heaters and Research. The heater was required to produce 125 W at 120 V for continuous use at 250ºC.

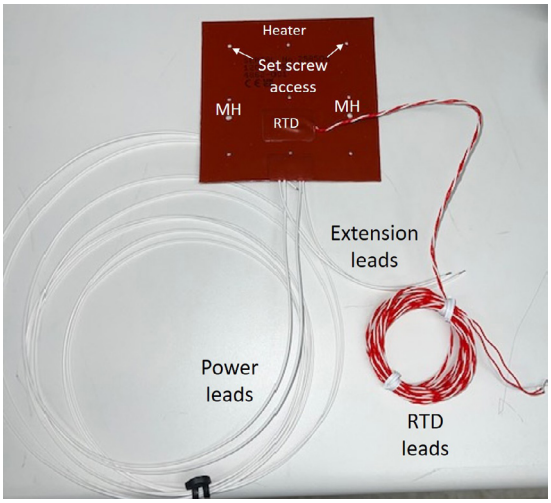

FIG. 1. Custom Heaters and Research's silicone heater.

The test stand uses eight RTD module channels to measure the temperature in six locations on the supermodule, Fig. 2, and two for the ambient temperature of the enclosure.

The control and monitoring system uses a National Instruments cRIO 9045, eight-slot, programmable automation controller with LabVIEW software. One digital output channel controls the voltage to the COTO relay coil. Lastly, an analog input channel verifies the voltage to the heater. Since the heater voltage exceeds the rating of the analog input module, a 9:1 voltage divider circuit is used to measure the heater voltage.

To test the heating of the test stand, an industrial oven rated for use at 350ºC was used as an enclosure, Fig. 3. All RTD and power cables are routed through a port at the top of the oven to connect to the controls system. The oven has a ventilation system to remove any fumes produced by heating the supermodule.

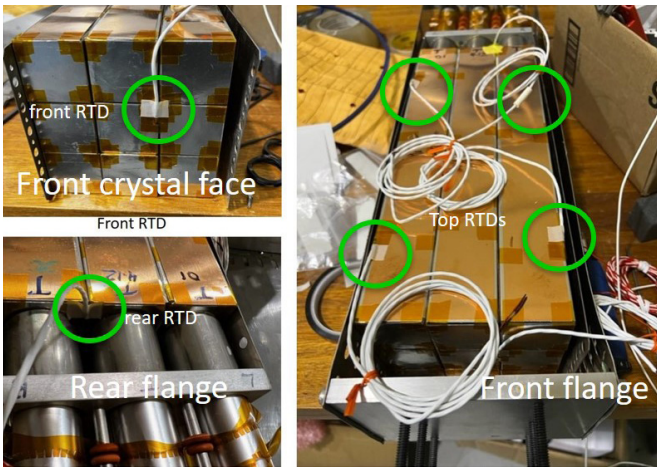

FIG. 2. Supermodule test stand with RTD locations in green circles.

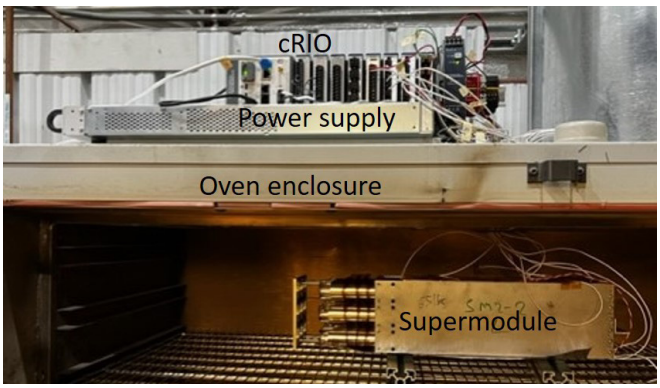

FIG. 3. ECAL module inside the EEL industrial oven.

The control and monitoring system, Fig. 4, uses an Agilent N6700B, four-channel power supply. Each channel of the power supply can provide 50 V and source 5 A. To produce the voltage required for the test stand, three channels were configured in series. The coil for the relay is powered by the fourth channel of the power supply, which provides 12 V.

To operate the software, the user inputs the set voltage of the supply and the temperature set point, and sets the power supply output-enable to "enable". The software monitors the RTDs and provides power until the temperature reaches the set point on the heater RTD, at which point the relay opens, and power to the heater stops until the heater's RTD measures a 0.5% drop in the temperature of the heater, the relay closes, and the heating cycle starts.

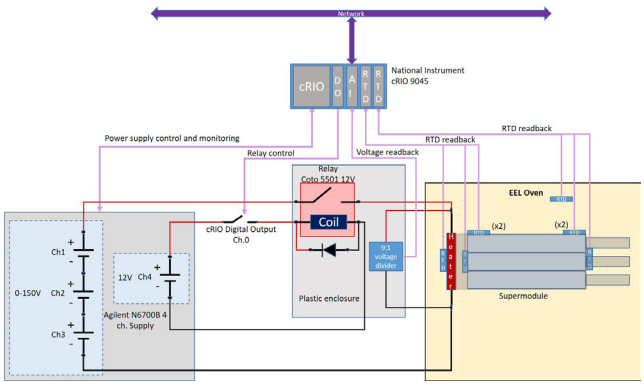

FIG. 4. ECAL heater controls test stand diagram.

Each loop of the control software takes a second. Every other loop, the software records all temperatures, the status of the power supplies' enable output, the power supply voltage and current, along with the time stamp to a text file. The text file closes every day at 23:59:59 and a new file starts, Fig. 5.

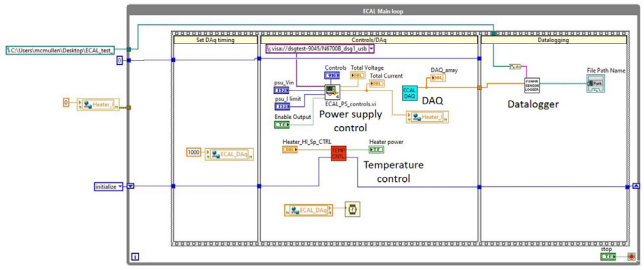

FIG. 5. LabVIEW-based controls software main loop.

During the initial testing, the test stand heater was set to produce 76 W to verify that the instrumentation was working properly. The heater temperature peaked at 155ºC [3], which was due to the enclosure size (24 cubic feet)—too large a volume for the heater to reach the target temperature of 250ºC.

To reduce the volume, an enclosure for the supermodule was made by wrapping it in a 1" thickness of mineral wool, which has R value of between three and four. A Teflon frame was used to support the mineral wool so that it would keep the shape of the supermodule, and not touch the edge of the front flange, Fig 6.

After the addition of the insulation, the front flange reached 222ºC with 76 W of power. When the heater power was increased to 96 W, the heater RTD temperature reached 250ºC and was controlled at that temperature for several hours, Fig. 7 [4].

In conclusion, a test stand and control system to power a a supermodule to the target temperature of 250ºC was designed, developed, and assembled. The results of this test will help with the specification of an appropriate heater, and the selection of the power supply and controls components for the ECAL detector.

FIG. 6. Front end view of supermodule with heater in the insulated enclosure.

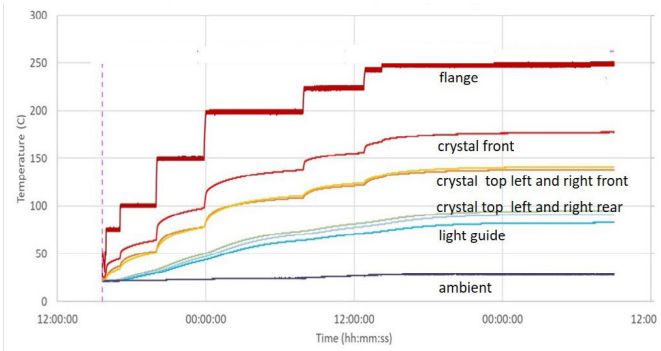

FIG. 7. Heater controls test at 92 W.

[1] M. McMullen, et al., *Tests for the Hall A Electromagnetic Calorimeter Supermodule Heater*, DSG Note 2022-13, 2022.
[2] G. Niculescu, et al., *An Update on the SBS ECal*, 2017.
[3] M. McMullen, et al., *ECAL Heater Controls Functionality Test*, DSG Talk 203-03, 2023.
[4] M. McMullen, et al., *ECAL Heater Controls Insulated Heater Test*, DSG Talk 2023-04, 2023.