Control and Monitor Software for the Prototype Heaters of Hall A's Six-Supermodule Electromagnetic Calorimeter

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The Hall A Electromagnetic Calorimeter (ECAL) has 184 supermodules [1], each with two heaters. The supermodules are to be heated to 280°C to reduce radiation damage (clouding) of the lead crystals. To test whether the heating of the supermodules prevents clouding, an array of six supermodules was constructed to be tested in the beam. This note presents the heater controls.

Each ECAL supermodule consists of a 3×3 lead crystal array. The test stand's six supermodules, each with two 50-W heaters, are arranged in a 3×2 array. The left and right side aluminum bars of the array have ten heaters each.

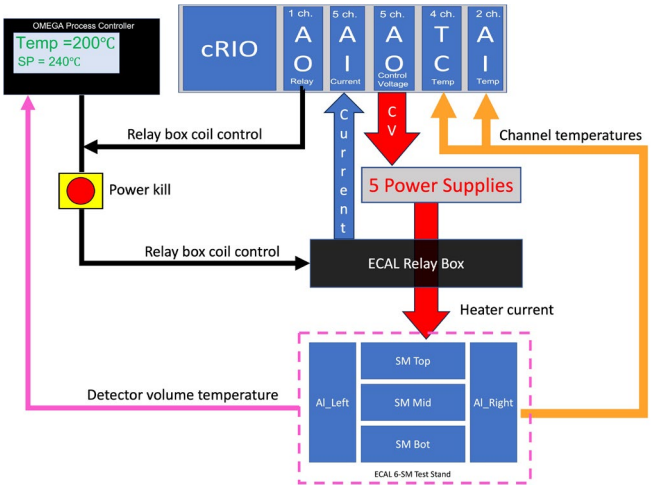

FIG. 1. A diagram of the cRIO connections to the test stands control elements and the five heater channels. The five elements are in contact with each other. The white spaces between the elements are boundaries of the elements.

There are five heater channels, one for each of the heater zones—SM_Top , SM_Mid, and SM_Bottom zones,with four heaters each (two per array element), and Al_left and Al_right zones, with 10 heaters each, Fig. 1. Each heater channel of a zone is powered by a Mean-Well 600-W supply [2] and their control voltage $\in$ [0.6 V, 10.0 V) to maintain their temperature is determined by the PID code developed in LabVIEW that runs on a cRIO programmable automation controller.

The cRIO uses five modules. There are two analog output (AO) modules, one to remove power to the heaters if the temperature limit is exceeded, the other for the heater supplies to provide the control voltage that determines how much current is to be supplied. Four of the five thermocouple sensors—one for each heater channel zone—are read by a four-channel thermocouple module (TC); the fifth thermocouple is read by an analog input (AI) module. The other AI module in the cRIO monitors the output of the five hall-effect sensors of the five Mean-Well power supplies.

Figure 2 shows the PID loop for a single channel. When the power supply is turned on, the initial error is the difference between the setpoints and the current temperatures measured by the thermocouples. This error is sent to the PID controls program, which based on the PID inputs, increases the current output of the power supplies to increase the temperature of the test stand elements. The new temperatures of the heater channels are read by the thermocouples and transmitted to the PID program, which determines the error and this process continues until the setpoint is reached (within the accepted range).

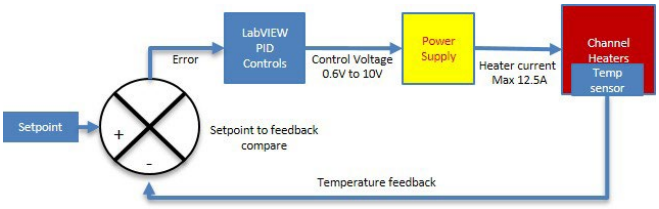

FIG. 2. PID loop of a single heater channel.

The Limits and PID tab of the user interface, Fig. 3, displays on the left side of the tab the PID gain settings for the five heater zones. Each heater channel's PID setting is individually settable to achieve the temperature setpoint [3].

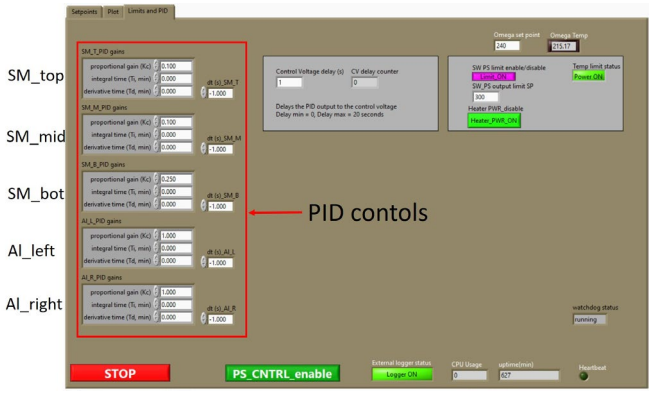

FIG. 3. User interface for limits and PID settings. The five channels of PID controls are shown in the red box.

To test that the heater controls reach the temperature setpoint with minimal over/undershoot, the proportional gain for each channel was varied between 0.4 and 0.6, the integral between 1.1 and 1.8, and the derivative was set at 0.

Figure 4 shows SM_Mid was set to 60ºC and it took ~30 minutes to reach the setpoint, after the 10ºC overshoot.

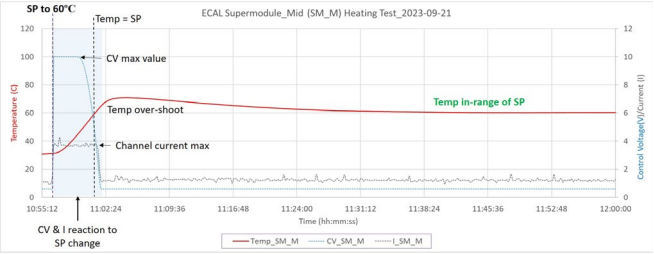

FIG. 4. Plot shows that the temperature of the SM_Mid zone stabilizes ~30 minutes after overshooting the setpoint of 60ºC.

To conclude, the PID software works as expected.

[1] D. Jones, *Hall A ECAL Heater Zones*, May 16, 2023.

[2] M. McMullen, et al., *ECal Heater Controls and Instrumentation*, DSG Talk 2023-12, 2023.

[3] M. McMullen, et al., *ECal Power Supply Tests*, DSG Talk 2023-11, 2023.