Control and Monitoring of Beampipe Test Stand for the Electron Ion Collider

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To study the temperature of the Electron Ion Collider's (EIC) beryllium beamline and the inner surface of the silicon detector's superlayer 1 (SL1) as a function of ambient airflow, a mechanical test stand [1] has been assembled. The test stand's beampipe was wrapped in aerogel to maintain it at ~100°C. Test results are presented in this note.

Software to control and monitor temperature and airflow for the test stand, and log the data for evaluation, was written in LabVIEW and is run on a cRIO-9045 programmable automation controller.

There are six PT-100 resistive temperature devices (RTDs). The cRIO uses one, four-channel RTD module to read four RTDs—three on the inner surface of the outer aluminum tube (SL1 inner surface) and one on the outside surface of the inner pipe (beampipe), Fig. 1. Two channels of a universal analog input module read the RTDs H1 and H2 from two locations on the outer surface of a stainless steel tube, inside of which is the oil immersion heater. One of those channels reads the voltage signal from an Omega process controller, connected to RTD_H1, and converts the voltage to temperature for display and datalogging; the other channel reads RTD_H2.

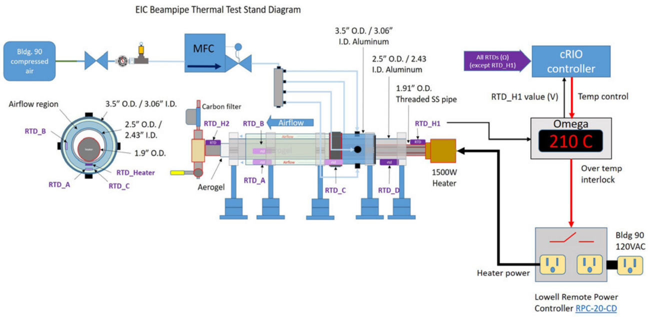
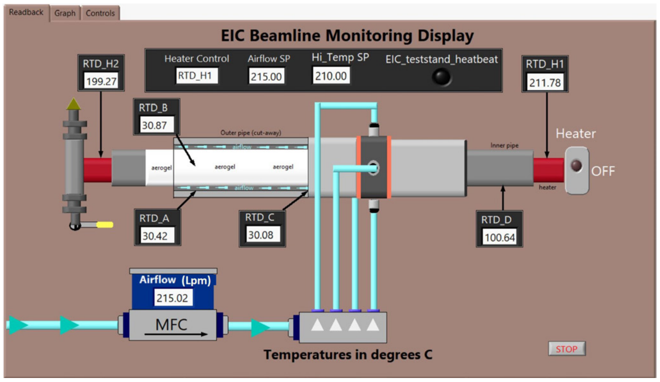


FIG. 1. Test stand controls diagram and pressure system elements.

Lastly, a digital output channel provides the control signal to actuate a Lowell RPC-20-CD AC relay, which controls 120 VAC to the oil immersion heater.

The test stand uses three independent LabVIEW programs—main controls logic, a user interface, and a data logger. The user interface is a 3-tabbed display, which provides the operator feedback on the test stand status. The first tab, Fig. 2, is a graphic representation of the test stand and displays temperatures, airflow, and setpoints; the second tab shows a 60-minute plot of these parameters, and the third tab allows the operator to change the heater's high-temperature setpoint, the airflow, and the temperature controls feedback sensor's value. The default feedback sensor is RTD_H1; it is the closest to the oil immersion heater element.

Heating mineral oil with a 1500-W heater presents a safety challenge, which is mitigated by using an independent interlock system (Omega process controller), which removes control power to the Lowell AC relay, thereby removing power from the immersion heater. The interlock is latched and stays tripped until it is reset manually.



EIC Beamline Monitoring Display

Heater Control: RTD_H1
Airflow SP: 215.00
Hi_Temp SP: 210.00
EIC_teststand_heatbeat

RTD_H2: 199.27
RTD_H1: 211.78
RTD_B: 30.87
RTD_A: 30.42
RTD_C: 30.08
RTD_D: 100.64
Airflow (Lpm): 215.02

Temperatures in degrees C

FIG. 2. Control and monitoring graphic user interface.

The control and monitoring software reads RTD_H1 and compares its value to the heater's high-temperature setpoint. If the temperature is 0.5% lower than the setpoint, the digital output channel turns on the heater until the setpoint is reached.

Ramp control is a sub-process of the main controls software that checks whether the user has set the heater's high-temperature setpoint value greater than 10% of the measured temperature at RTD_H1. When this is so, the ramp controls engage and limit the amount of time the heater is on during ramping, while monitoring the temperature and the entered heater's high-temperature setpoint, resulting in the heater being turned on for short, 10–15-second bursts, every three minutes.

Figure 3 displays a plot of the initial runs of the test stand. The heater was set so the beampipe temperature was 100ºC while the air flowed at 10 SLM for three hours, and then was reduced to zero for three hours to allow the test stand temperatures to recover to approximately the same values as before the flow. The temperatures of SL1 and the beampipe were observed and recorded for the flow values of 20, 50, 100, 150, 200, and 250 SLM. The overall result indicated that SLI's inside surface temperature could be reduced to ~30ºC. However, the airflow causes the beampipe temperature to fall below 100ºC.

Figure 4 shows the plot when the heater temperature and airflow were manually adjusted to find the combination of flow and temperature to maintain 100ºC on the beampipe and

30ºC on the inside surface of SL1. To achieve this, the heater temperature was set to ~210ºC, while the air flowed at 212 to 215 liters per minute.

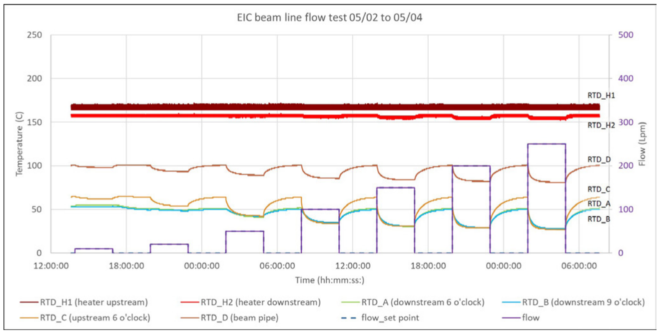


FIG. 3. Test stand initial flow test from 10 SLM to 250 SLM.

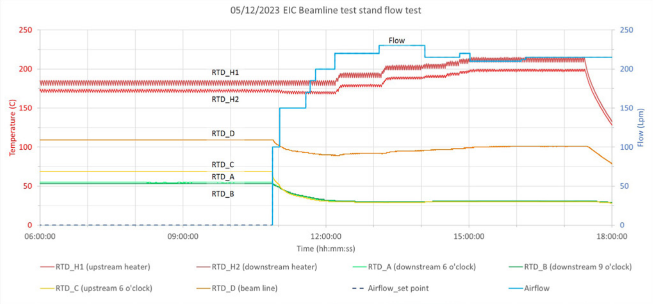


FIG. 4. Final flow test to maintain 100ºC on the beampipe while cooling SL1 to 30ºC.

In conclusion, a LabVIEW program was developed to control temperature and airflow of the simulated EIC beampipe test stand. Two tests were completed to show the relationship between beampipe temperature, airflow and SL1 temperature.

[1] M. McMullen, B. Eng, G. Jacobs, et al., *EIC –Beam Pipe Test Stand Functionality Test*, DSG Talk 2022-01, 2023.