Thermal Analysis of the Electron Ion Collider's Beryllium Beampipe Section

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This note presents the results of the computational fluid dynamics thermal analysis of the interaction between the beryllium beampipe section, with its inner face at 100°C and surrounded by a layer of aerogel as insulator, with silicon layer 1 (SL1). The results show the temperature of SL1 as a function of the air velocity flowing through the annulus and enclosure spaces. A comparison of the data with the model without aerogel insulator shows the aerogel insulator does have a significant influence even at a small air flow rate.

The models generated with *Ansys—Design Modeler* software for the EIC beampipe simulations consists of the beampipe, aerogel insulator, silicon layer, and enclosure, Fig. 1. Table I shows the dimensions of the models.

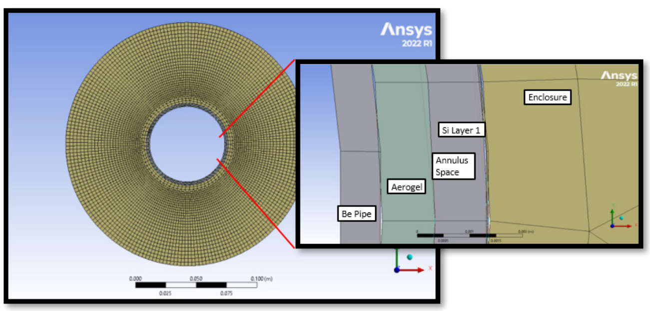

FIG. 1. Front (left side) and zoom view (right) for model with 2 mm of separation between outer face of beampipe and inner face of SL1 with 1 mm aerogel insulator.

Model	Part	ID [mm]	OD [mm]	Thickness [mm]	Length [mm]
2 mm	beampipe	62	63.52	0.76	
	SL1	67.52	67.6	0.04	
	aerogel	63.52	64.52	0.5	
	aerogel		65.52	1.0	
5 mm	beampipe	62	63.52	0.76	320.5
	SL1	73.52	73.6	0.04	
	aerogel	63.52	64.52	0.5	
	aerogel		65.52	1.0	

TABLE I. Dimensions of parts for the two models 2-mm and 5-mm.

After completing the geometry adjustments to implement the aerogel insulator, the setup of the contact regions and mesh was done. Four contact regions—beryllium beampipe to aerogel, aerogel to annulus space, annulus space to SL1, and SL1 to enclosure—define the connection between the model components. The generated mesh had ~60 K elements with an element size of 3 mm.

Each model was implemented in the *Ansys Fluid Flow Fluent* software; material properties such as density and thermal conductivity were set for each part of the model. The solid materials were beryllium, silicon [1], and aerogel; the fluid material was air. For the selected solver model, boundary conditions and simulation configurations are detailed in Table II.

Model	k-omega, Shear Stress Transport
Precision	double
Simulation iterations	100
Beampipe inner face T	100°C
Air T	20°C
Air flow velocity	0 to 5 m/s

TABLE II. Simulation parameters.

Figure 2 compares the results between beampipe without aerogel and beampipe with 1-mm thick aerogel, for the model with 5 mm separation between beampipe and SL1. When air flow velocity is $1*10^{-7}$ m/s (~0 m/s) through the annulus space and enclosure, the results show no change in the temperature of SL1. With air flow, the model in which the beampipe is wrapped with aerogel has a lower temperature than the model in which the beampipe is not wrapped with aerogel.

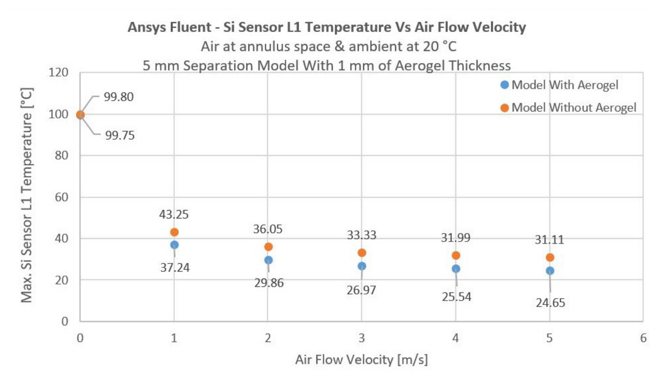

FIG. 2. SL1 temperature vs air flow velocity for the model with a separation of 5 mm between the beampipe and SL1 and with 1-mm thick aerogel (blue dots) and without aerogel (red dots).

The results for the model with 2 mm of separation between the beampipe and SL1, and with an airflow of 1 m/s, showed that with 0.5 mm aerogel around the beampipe, SL1's temperature decreased to 65°C from 76.8°C, which was the result of the model without aerogel [2].

Simulations with different densities and thermal conductivities, Table III, show that these changes do not significantly change SL1's temperature when there is no air flow.

Density [Kg/m^3]	Thermal conductivity [W/m*K]	Mass [Kg]	Max. SL1 T [°C]	Min. SL1 T [°C]
50	0.016	0.002	99.774	69.781
100		0.003		
150		0.005		
250		0.008		
50	0.014	0.002	99.765	69.537
100		0.003		
150		0.005		
250		0.008		

TABLE III. Simulation results with different aerogel properties for thickness of 0.5 mm, air velocity in annulus and enclosure of 1 $*10^{-7}$ m/s, and temperature in annulus and enclosure of 20°C.

The thermal analysis for the model with the added aerogel, and comparisons with model without aerogel, showed a decrease in SL1 temperature with air flowing through the annulus space and enclosure at a velocity greater than 1 m/s is required to keep the temperature lower than 30°C.

[1] P. Campero, et al., *EIC –Thermal Analysis of Beryllium section of Beampipe,* DSG Talk 2022-13, June 2022.

[2] P. Campero, et al. *Thermal Analysis of the Beryllium Beampipe at Interaction Point 6 of the Electron Ion Collider,* DSG Note 2022-09, 2022.