NPS Detector Volume – CFD Thermal Simulation

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The Neutral Particle Spectrometer (NPS) detector has as the main source heat the power applied to the PMTs for each crystal block and the power dissipated by the electronics, since the detector enclosure is suppose to be completely sealed and there is not inlet or outlet areas the only way to keep desired temperature inside the detector was by adding a cooling system which consist on cooling plates that surrounds the crystal blocks' array and two heat exchanger located at the top and bottom of the called electronic volume. Each heat exchanger has two fans which allows the air circulation through their fin area which is cooled at 10 °C.

I generated a simplified model with only the components that could have a significant thermal affect for the simulation. The model comprises of the detector enclosure walls, high voltage plate, LED plate, crystal blocks' array (represented by a single block volume), crystal block array heat exchanger plate, electronic volume, top heat exchanger with two fans, and bottom heat exchanger with two fans. See fig.1. Model was build on SpaceClaim, I used tools to combine inner parts with the detector volume to ensure thermal interaction in the simulation. Shared topology option used to ensure contact between touching or intersecting bodies and surfaces.

With the model completed, I proceeded with the mesh of the model using *Fluent Meshing* option, which allows adding local sizing, improve surface mesh, establish part fluid or solid domain, add boundary layers and improve volume mesh. During the process I had issues using the shared topology features in Space Claim and also meshing the model, I was able to solve all of them prior to run the simulation.

I calculated some parameters required for the setup of the thermal simulation in Fluent, some of them are shown in table 1.

- **Modeled NPS detector enclosure with necessary parts for the thermal interaction**
- **Meshed model and configured all required cell zones and boundary conditions**
- **Created definition and expression reports to monitor and compare results for set variables**
- **Generated contour plots and pathlines plots to show resultant velocity and temperature**

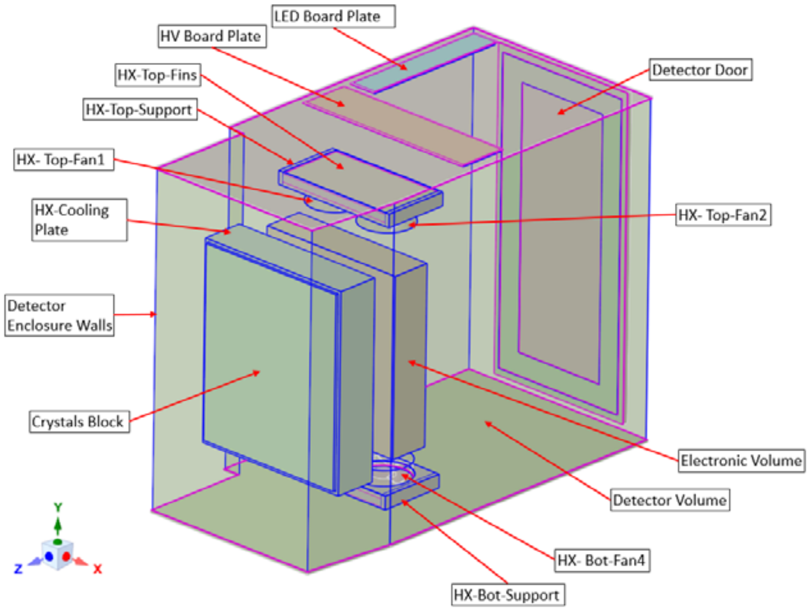

Fig. 1. NPS detector enclosure simplified model

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- Critical configuration prior to the simulation involved the setting up of the cell zone conditions and boundary conditions. The cell zone conditions setup included: The assignment of the heat exchanger fans angular velocity magnitude and direction, definition of the heat source for the system, which was assigned to the crystal block array, setting fixed temperatures for the heat exchanger plates and heat exchanger fin area, and setting the porous volumes to allow flow through fins and between individual crystal blocks. The boundary conditions included: the assignment of the ambient temperature and in the convection heat transfer applied to the detector enclosure walls.
- I ran 2500 iteration for the simulation and generated expression report definitions and report definitions to monitor variables of interest. I also generated contour and pathline plots to visualize the results accurately. See Fig 2-4. I observed temperature for crystal block array of 22.92 °C.
- I plan to improve the simulation by adding plastic and lead tungstate materials for detector enclosure walls and crystal blocks respectively, by correcting geometry to make contact between heat exchanger cooling plate and crystal block, and by adding cell conditions for electronics volume.
- I completed the CFD thermal simulation for the initial setup, results showed an expected velocity magnitude and direction for the air flow and temperature for the crystal block array.

Power per Crystal Block	0.326 W
Total Power Dissipated in Crystal Block Array	341.65 W
Heat Generation Rate	3426.76 W/m3
HX Liquid Inlet Temp	10 °C
HX Max Temp Air Inlet	25 °C
HX Liquid Flow	1 gal/min
HX Air Pressure Drop	24.9 Pascals
hx Fan Flow Rate	500 CFM
HX Fan Angular Vel	1650 RPM
HX Inertial Resistance	386 [m-1]
Inlet Temp Difference (ITD)	15 °C
Performace Capability (Q/IDT)	117 W/°C

Table 1. Calculated values used for thermal simulation cell zones and boundary conditions

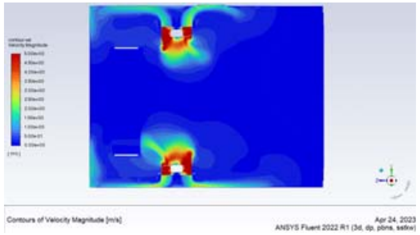

Fig.2. Velocity contour plot

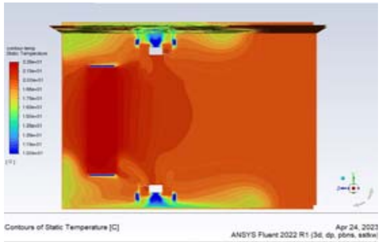

Fig.3. Temperature contour plot

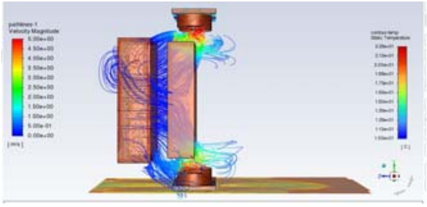

Fig.4. Velocity and temperature Pathline scene

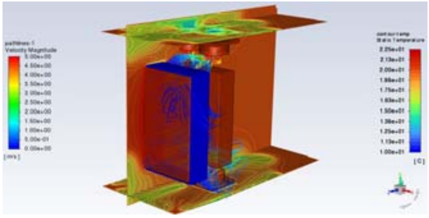

Fig.5. Velocity and temperature pathline scene iso view