# Ansys Mechanical Transient Thermal Simulation and Analysis of a Crystal of the Neutral Particle Spectrometer

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This note presents the results of the simulations conducted on crystal #522 of the Neutral Particle Spectrometer (NPS) to determine whether the internal heat generation and surface heat application options available in Ansys Mechanical Transient are equivalent.

The maximum crystal temperature difference $\Delta T$ between the Ansys Fluent steady-state thermal simulation and either of the initial simulations—Ansys Mechanical steady-state or transient [1]—was determined to be ~36°C.

To understand the disparity in the result, input parameters and boundary conditions were checked and the cause of the discrepancy was suspected to be the different heat generation options selected in the simulations.

In Ansys Fluent (steady-state or transient), heat generation can be only *internal*—power density inside a volume of the model—so it was the option used. Whereas the *external* option was used for both Ansys Mechanical steady-state and Ansys Mechanical transient simulations, in which heat generation can be *either internal or external*—heat application on a surface of the model.

To determine whether the discrepancy between the simulation results was due to the heat generation options, crystal #522 was studied in Ansys Mechanical transient simulations with external and internal options.

For the external option, 0.3 W—total power dissipated by the low and high voltage power supplies connected to the PMT [2]—was applied to the rear surface of the back region of the crystal, Fig. 1 .

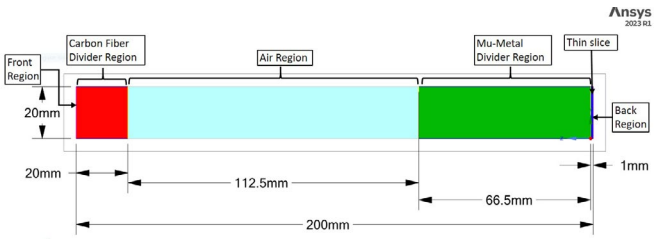


FIG. 1. Crystal with five regions with pill box at electronics side'

For the internal option, the power density in the pill box—thin slice of the crystal with dimensions 1 mm × 20 mm × 20 mm, back region of Fig. 1—was calculated to be $7.5\times10^5$ W/m$^3$, assuming total surface power absorption.

Three-dimensional models X, Y, and Z were generated using Ansys SpaceClaim. Model X of crystal block #522 has only the 1-mm thick pill box. In model Y, the crystal block is partitioned into five regions—back, front, air, mu-metal and carbon fiber, Fig. 1. Model Z has five regions as model Y and mu-metal and carbon fiber dividers.

Models X and Y were meshed with 688 cells each, model Z with 1980 cells. Crystal and divider materials were assigned the thermal property values used in the initial Ansys Mechanical steady-state and transient simulations [2].

The results, Table I, show $T_{max}$ of simulations with the following parameters: internal or external heat generation, air convection film coefficient $h$ = 5 W/m$^2$°C, and ambient temperature of 20°C as a function of number of convection walls.

| Model | Heat generation | # of convection walls | Dividers | $T_{max}$ [°C] |
|---|---|---|---|---|
| X | internal | 10 (5 pill box walls, 5 crystal walls) | no | 36.63 |
| | external | 10 (5 pill box walls, 5 crystal walls) | no | 37.23 |
| Y | internal | 6 (1 front, 1 back, 4 air walls) | no | 52.87 |
| | external | 6 (1 front, 1 back, 4 air walls) | no | 53.01 |
| Z | internal | 6 (1 front, 1 back, 4 air walls) | yes | 48.09 |
| | external | 6 (1 front, 1 back, 4 air walls) | yes | 48.21 |

TABLE I. $T_{max}$ [°C] for models X, Y, and Z.

When more walls convect, $T_{max}$ decreases—lowest $T_{max}$ is for 10 convection walls; $\Delta T$ of the simulations with internal or external heat generation for same number of convection walls and same parameters is ≤1°C. The effect of the dividers is that $T_{max}$ with dividers (~48°C) is less than $T_{max}$ without dividers (~52°C).

Figure 2 shows the right-side view of crystal #522's temperature profile for the simulations listed in Table I.

- $T_{max}$ at the pill box end (red) has different values for different models, but is the same within the same model for the same parameters.
- $T_{min}$ = 22°C at the front region of the crystal (blue), is close to the ambient temperature for all models.

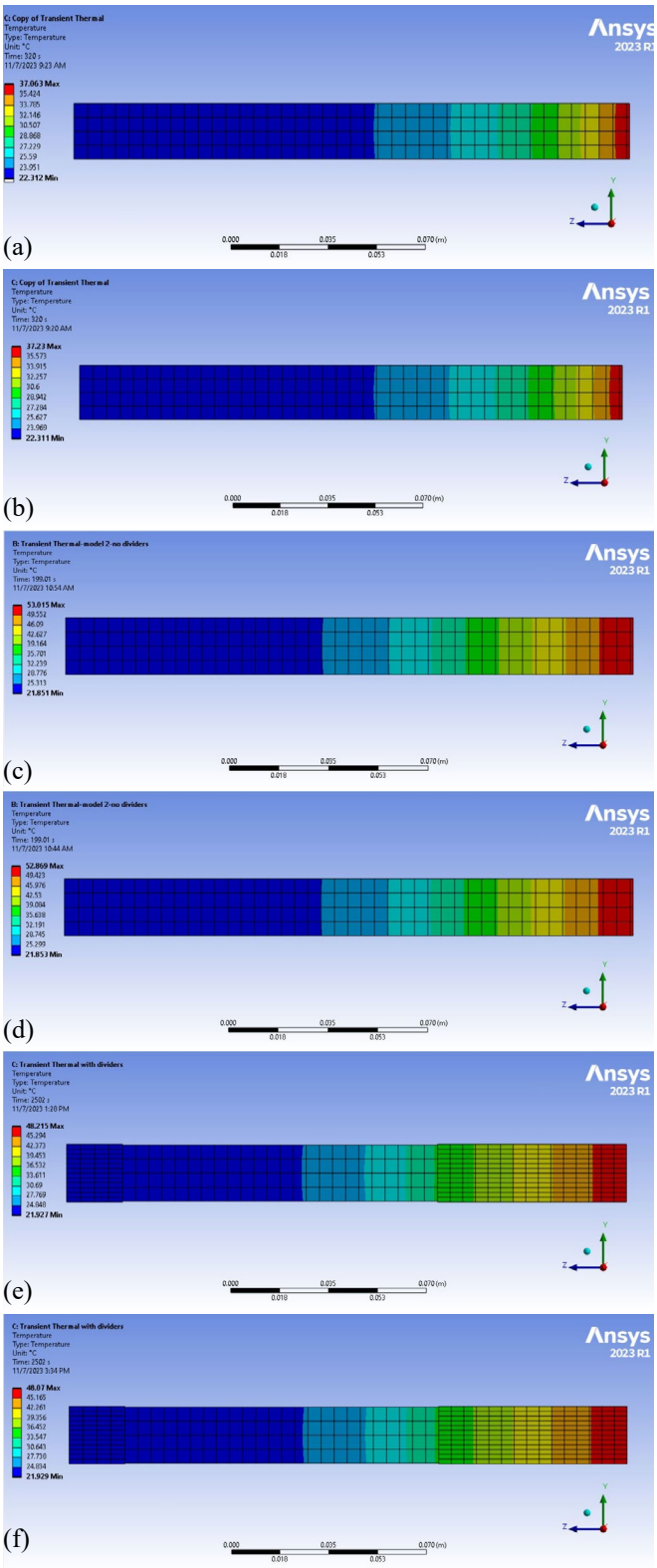


FIG. 2. (a) Model X. Temperature profile for 10 convection walls (five crystal sides and five pill box sides). Comparison of (a) $T_{int\,max}$ = 36.63°C to (b) $T_{ext\,max}$ = 37.23°C. (c) Model Y. Comparison of (c) $T_{int\,max}$ = 52.87°C to (d) $T_{ext\,max}$ = 53.01°C. (e) Model Z. Comparison of (e) $T_{int\,max}$ = 48.07°C to (f) $T_{ext\,max}$ = 48.21°C.

Temperature profiles look similar. Crystal temperatures reach close to ambient temperature of 20°C about half-way along the length of the crystal (dark blue)

To conclude, Ansys Mechanical transient simulation of crystal 522 shows that the internal option is equivalent to the external option; hence, the type of option is not the source of the 36°C difference between the initial Ansys Mechanical (steady-state or transient) simulations and the Ansys Fluent transient simulation. The disparity is being investigated.

[1] A. Brown, et al. *Ansys Steady-State Analysis of the Hall C Lead Tungstate Crystals of the Neutral Particle Spectrometer,* DSG-Note 2022-11, 2022.

[2] A. Brown, et all. *Ansys Steady-State Thermal Analysis of the Engineered Cooling Design for the Hall C Lead Tungstate Crystals of the Neutral Particle Spectrometer*, DSG-Note 2022-02, 2022.