

## LA-UR-20-26782

Approved for public release; distribution is unlimited.

Title: GPHS Module Pre-Impact test Temperature Prediction with ANSYS

Author(s): Teague, Jonathan Gayle

Intended for: Report

Issued: 2020-09-01

---

**Disclaimer:**

Los Alamos National Laboratory, an affirmative action/equal opportunity employer, is operated by Triad National Security, LLC for the National Nuclear Security Administration of U.S. Department of Energy under contract 89233218CNA000001. By approving this article, the publisher recognizes that the U.S. Government retains nonexclusive, royalty-free license to publish or reproduce the published form of this contribution, or to allow others to do so, for U.S. Government purposes. Los Alamos National Laboratory requests that the publisher identify this article as work performed under the auspices of the U.S. Department of Energy. Los Alamos National Laboratory strongly supports academic freedom and a researcher's right to publish; as an institution, however, the Laboratory does not endorse the viewpoint of a publication or guarantee its technical correctness.

# GPHS Module Pre-Impact Test Temperature Prediction

with ANSYS



Jon Teague, PE

AET-1

8/20/2020

# Purpose

- **Develop a finite element thermal model of the General Purpose Heat Source (GPHS) Module loaded with four fueled clads**
- **Perform steady state analysis to validate the thermal model via energy balance**
- **Perform transient thermal analysis to predict clad temperatures at various times**
- **Transient model results will be used to inform module soak time needed to reach a desired clad temperature prior to impact**

# ANSYS Thermal Model

- **3D CAD models of the module assembly imported into ANSYS from Creo Parametric**
- **Conduction heat transfer**
  - Between all surfaces in mechanical contact
- **Bonded contact idealization (perfect contact)**
- **Radiation heat transfer from the exterior of the Module to the environment**
- **Quiescent convection on the exterior of the Module**
- **Heat rate of 59.2 W average applied to each pellet geometry as energy generation (  $3.836 \times 10^{-3}$  W/mm<sup>3</sup>)**
- **Prescribed temperature IPC corresponding to 58°F (14.4°C)**
  - Prescribed IPC temperature determined using separate analysis of the OPC/IPC assembly with chilled water running through the OPC and a thermal contact resistance between the OPC and IPC consistent with bare aluminum contact.
- **Steady state thermal model to demonstrate energy balance**
- **Transient (time-dependent)**
  - Convection applied from t=0 to t=1200s
  - Convection removed (module under vacuum) at t=1200s (20 min) until run end time t=3600 s (60 min)

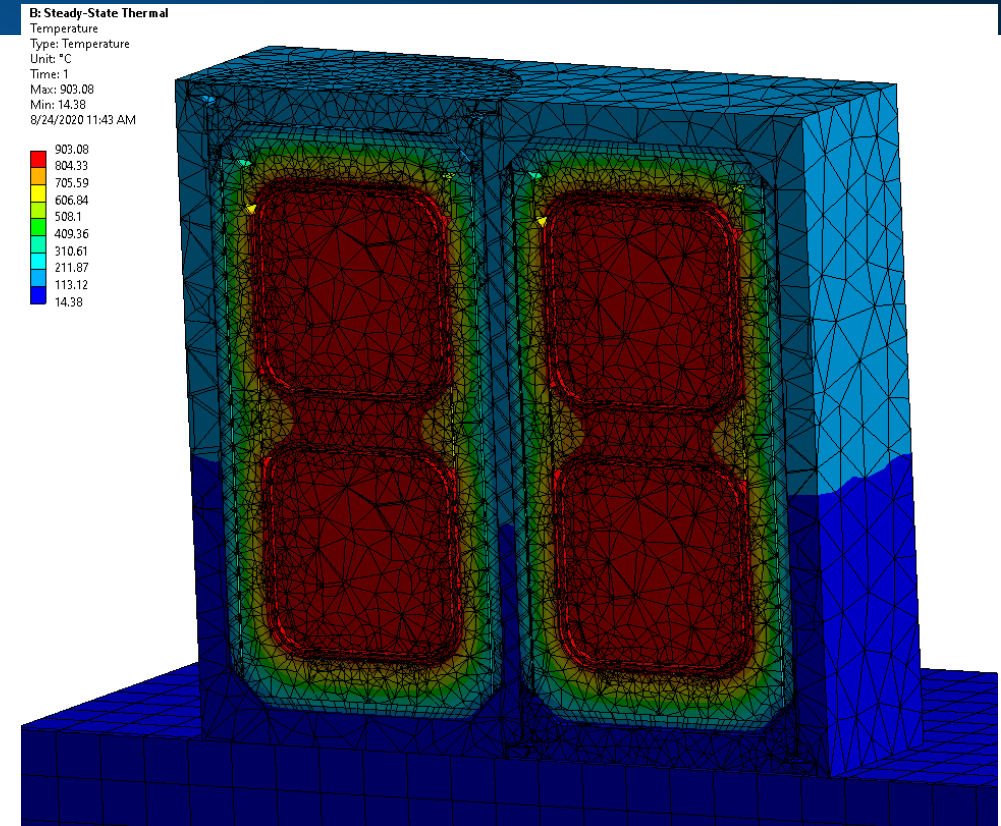
UNCLASSIFIED

# Material Models

- **Temperature dependent thermal properties**
  - Thermal conductivity
  - Specific heat
- **DOP-26 IR**
  - ORNL-TM-8949 R1, *Isotopic Space Power Materials Handbook*
- ***Pu-238 Oxide***
  - ORNL-TM-8949 R1, *Isotopic Space Power Materials Handbook*
- ***Carbon Bonded Carbon Fiber (CBCF)***
  - ORNL-TM-8949 R1, *Isotopic Space Power Materials Handbook*
- **Fine Weave Pierced Fabric**
  - ORNL-TM-8949 R1, *Isotopic Space Power Materials Handbook*

# ANSYS Steady State Result

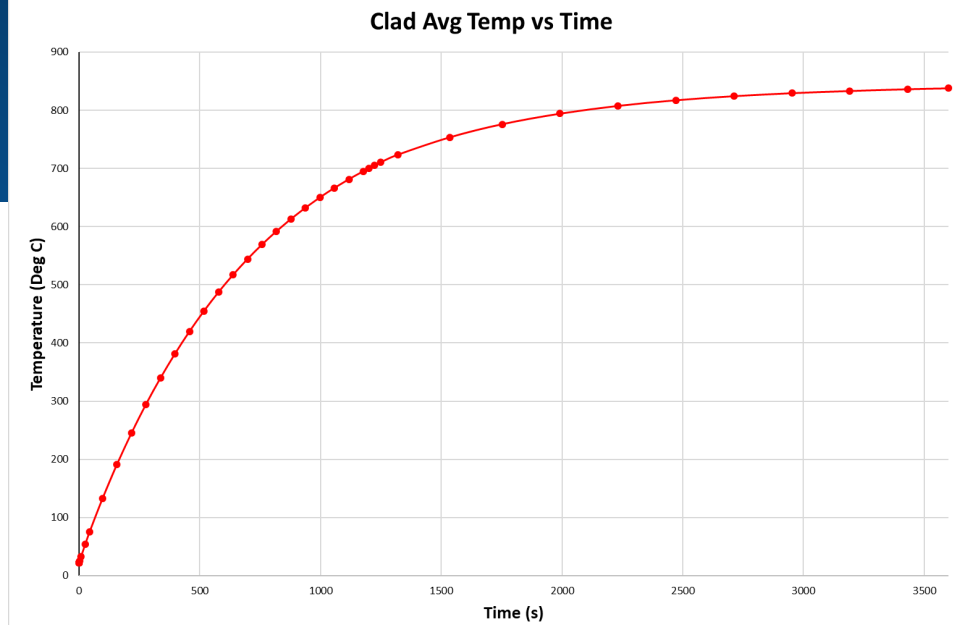
- Initial temperature of 22°C
- Maximum model temperature - 903°C (Pellet)
- Maximum clad temperature 861°C
- Steady state model validity can be checked by summing the energy in and energy out ( $E_{in} - E_{out} = 0$ )
- Energy balance checked using ANSYS results probes
- $236.8W - 231.01W - 5.402W - 1.58W = -1.18W$
- Solution error = 0.5%



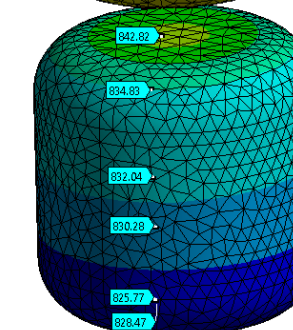
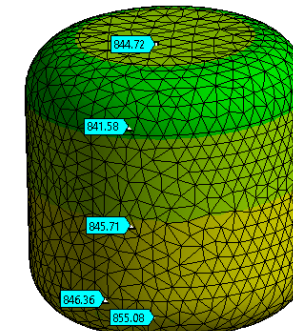
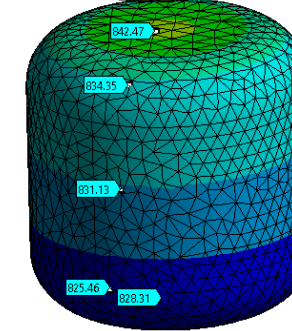
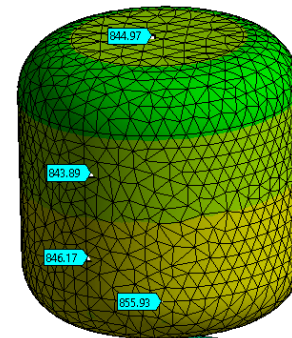
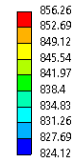
Steady State Temperature Results  
Cross-Section View

# ANSYS Transient Result

- At  $t = 20$  min clad temperatures reached an average of  $700^{\circ}\text{C}$
- Clad average temperature of  $760^{\circ}\text{C}$  reached at  $t = 1602$  s (26.7 min)
- Average clad temperatures at  $t = 30$  min was  $810^{\circ}\text{C}$
- Results show thermal gradient in clads.
- Average clad temperature at  $t = 60$  min was  $837.8^{\circ}\text{C}$
- Top clads (further away from the IPC) are about  $25^{\circ}\text{C}$  warmer than the bottom two



C: Transient Thermal  
Temperature 2  
Type: Temperature  
Unit: °C  
Time: 3600  
Max: 856.26  
Min: 824.12  
8/24/2020 11:38 AM



UNCLASSIFIED