Correlation of Thermal Fluid Cryogenic Model through Implementation with Optimization Software

Ellen Smith & Nathan Andrews
Southwest Research Institute

Presented By
Ellen Smith

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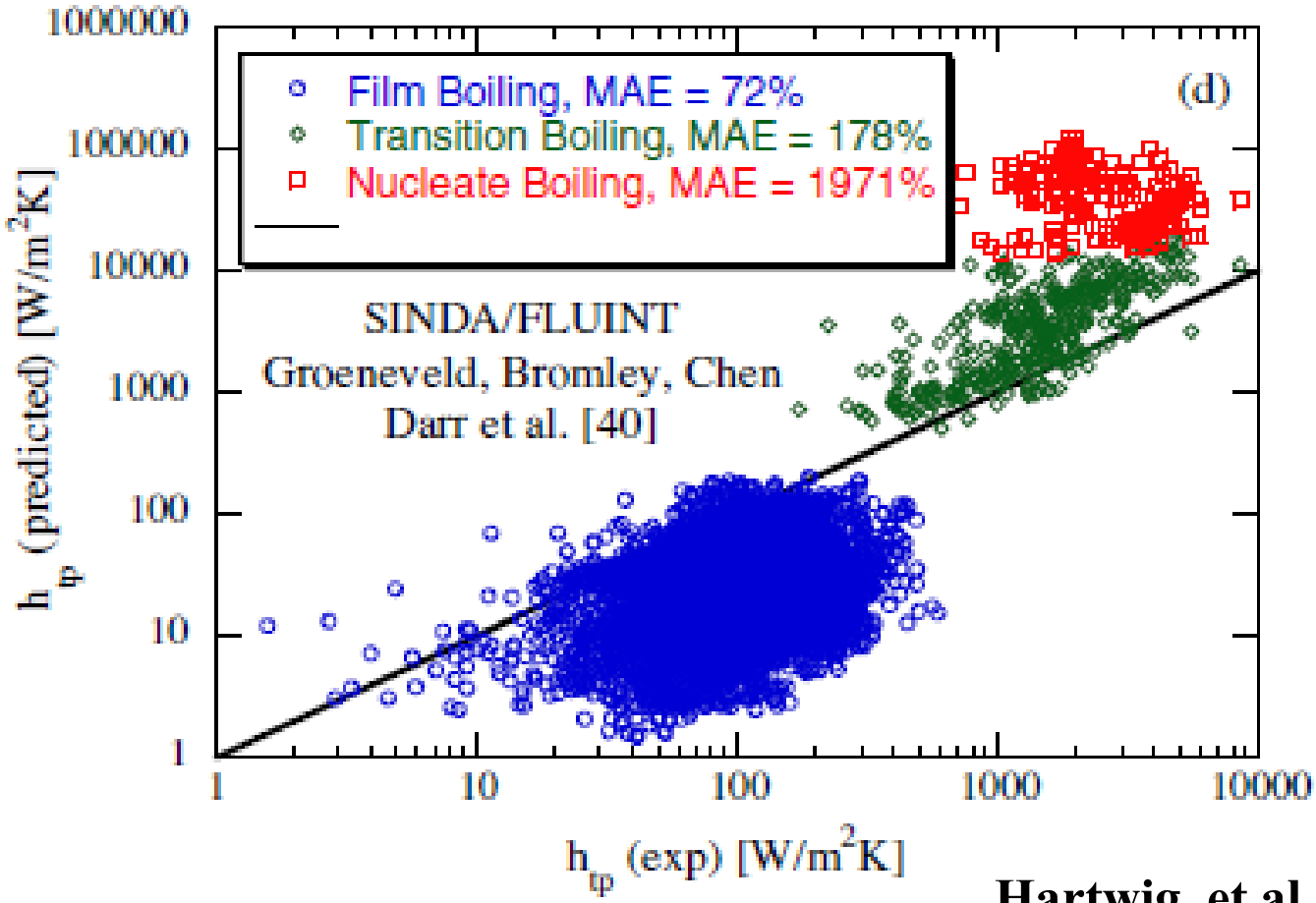
Southwest Research Institute

- Nonprofit
- Nearly 3,000 employees
- More than 1,300 patents

- 2.3 million ft^2 / 204,400 m^2 of laboratories & offices
- Over 1,500 acres / 6.07 km^2 facility in San Antonio, Texas
- 45+ *R&D 100* awards

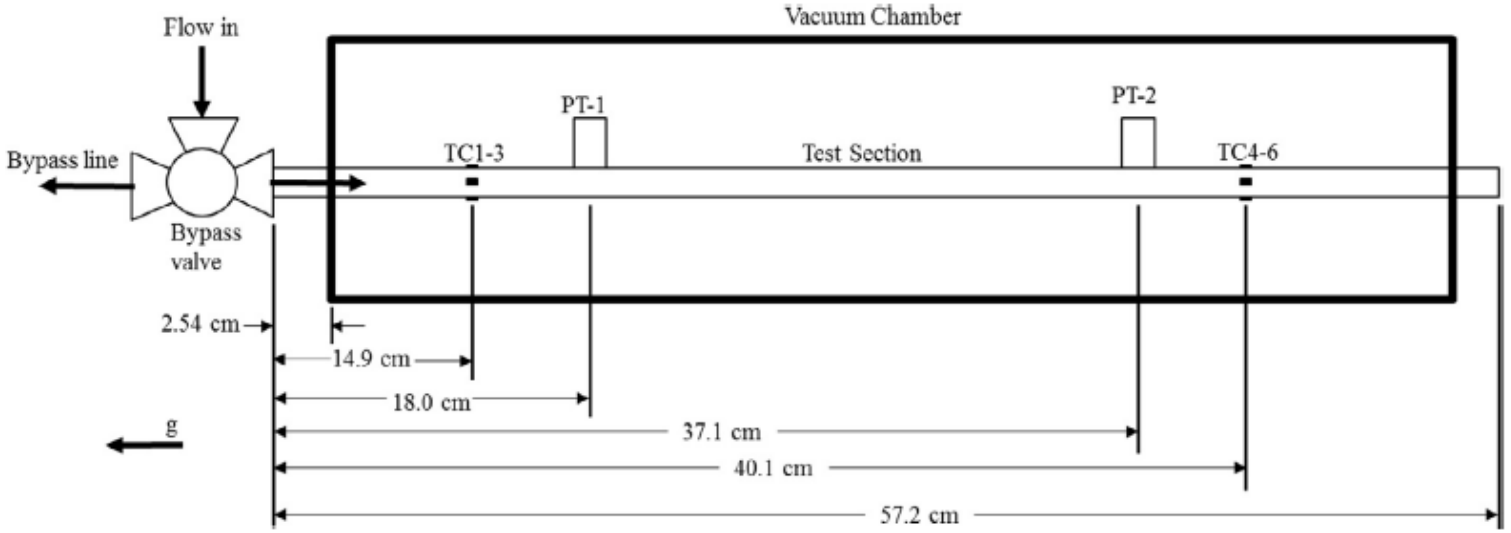
Large uncertainty in boiling predictions



Hartwig, et al

Experiment of Cryogenic Line Chilldown

- Liquid nitrogen
- Vertical stainless steel test section
- Mostly in vacuum chamber
- Flow Reynolds number of 5,992
- Upstream and Downstream thermocouple stations
- Upstream and Downstream pressure transducer locations



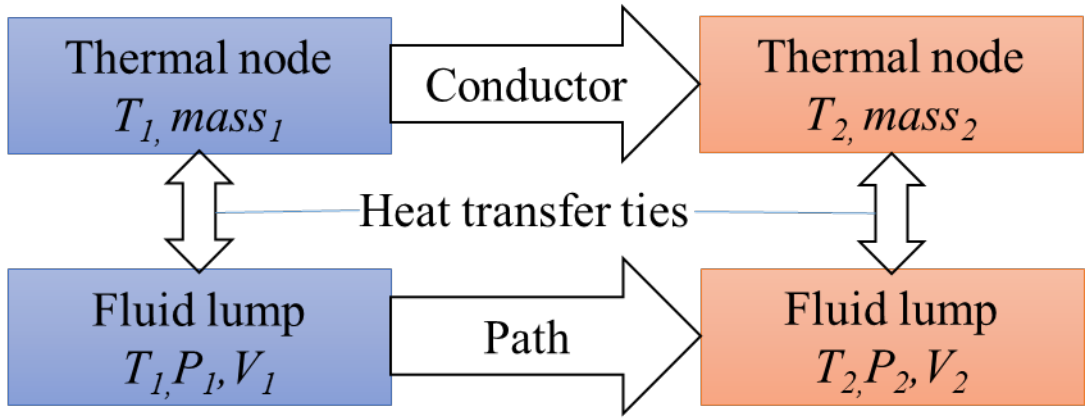
Darr, et al, 2016

The model is implemented in Thermal Desktop

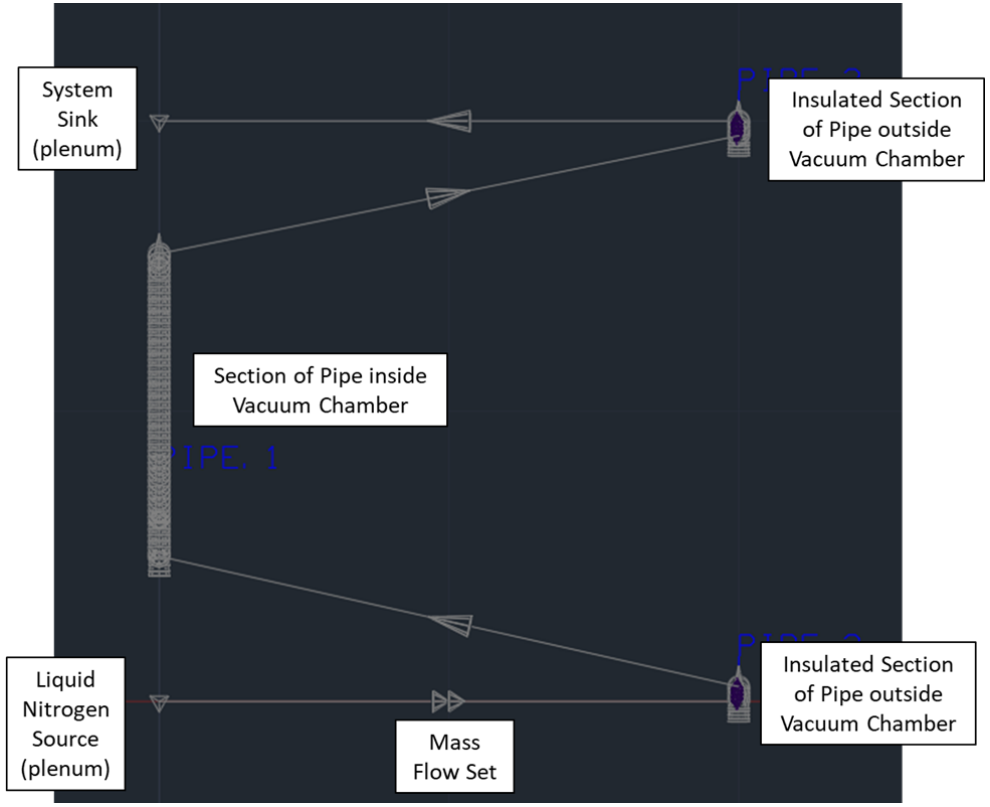
- **Thermal Desktop is a graphical user interface for the Sinda/Fluint solver implemented in an AutoCAD framework**
- **Thermal Desktop automates complicated geometry calculations and is used for advanced pre- and post-processing capabilities**
- **Sinda/Fluint is a lumped parameter and finite difference solver for 3D thermal and 1D fluid analysis**
- **Aerospace heritage dating back to 1960's**
- **Development originally for NASA, now commercialized by ANSYS**

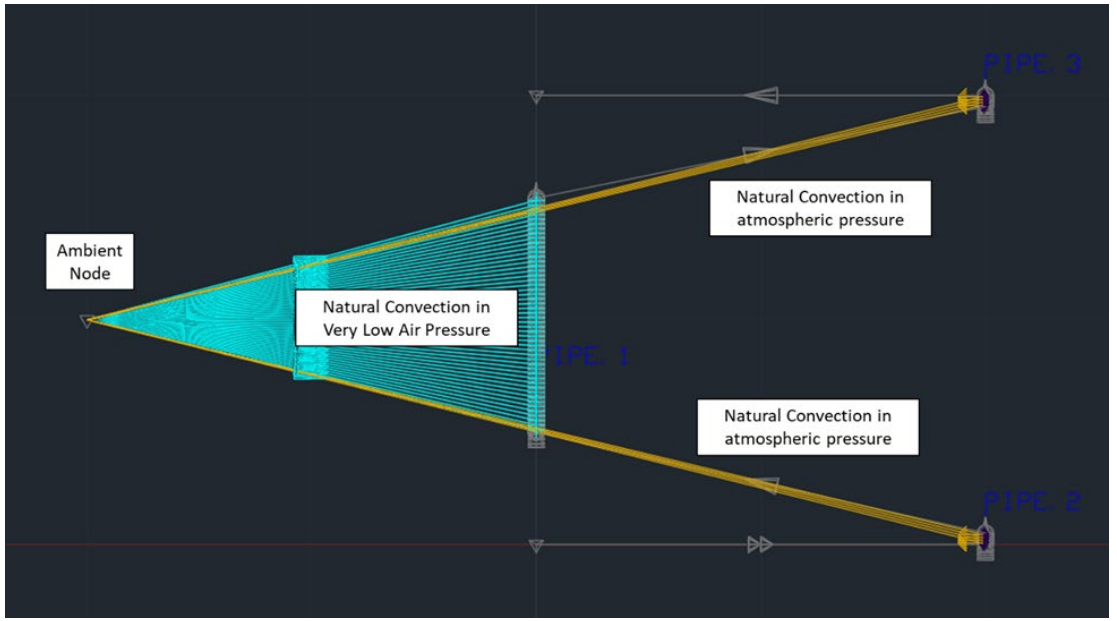
SINDA/FLUINT model network

The system is discretized into states (nodes, lumps) that exchange mass, momentum, and energy through connections (conductors, paths, ties)



Thermal Model of Experimental Setup





CENTAUR

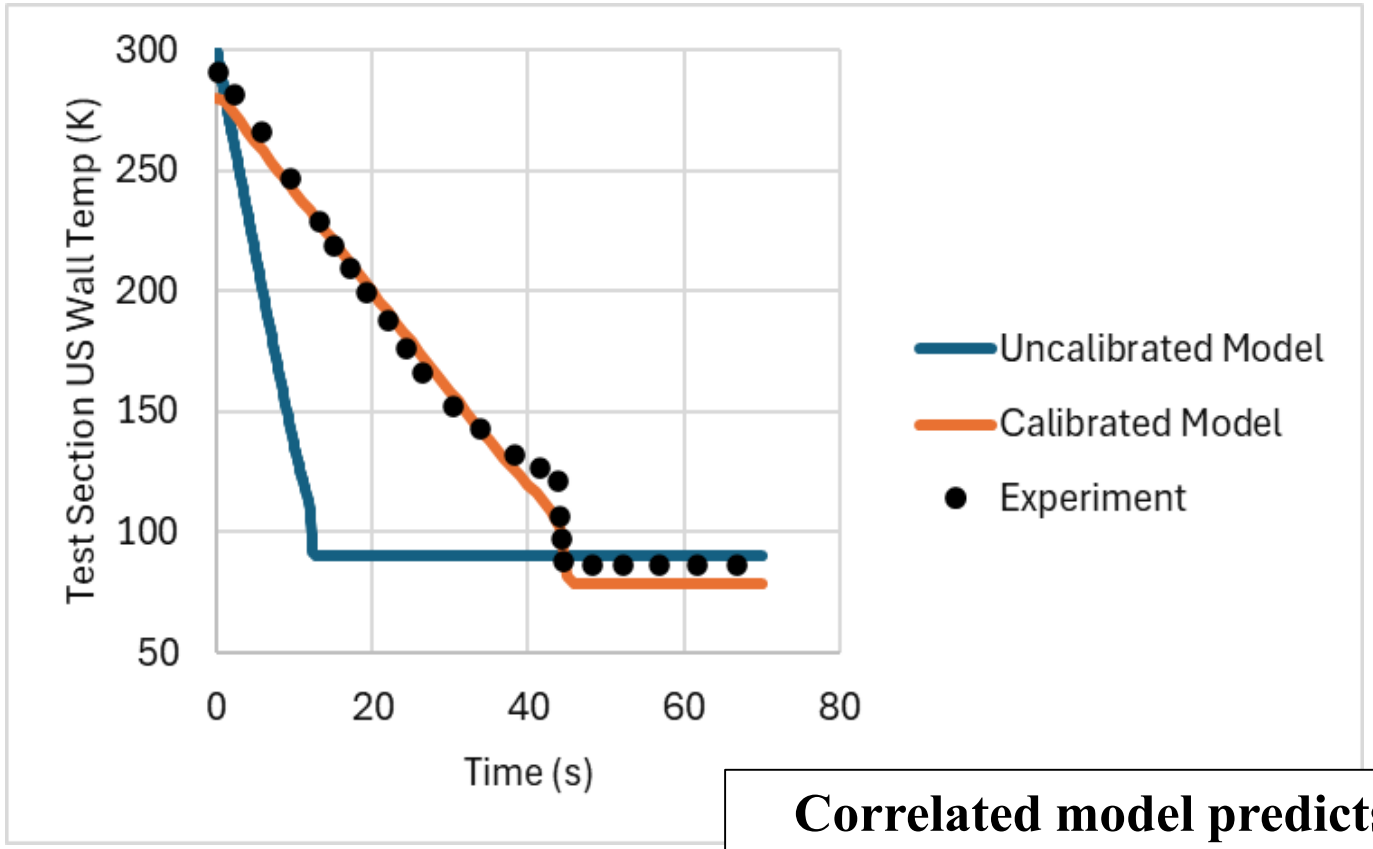
- **CENTAUR (Collection of Engineering Tools for Analyzing Uncertainty and Reliability)**

- **Engine behind SwRI's general purpose probabilistic analysis software, NESSUS**

- **Direct interfacing through Python allows for**
  - **Uncertainty quantification**
  - **Surrogate modeling**
  - **Model calibration**
  - **Optimization solution approaches**

Calibrated Model Comparison

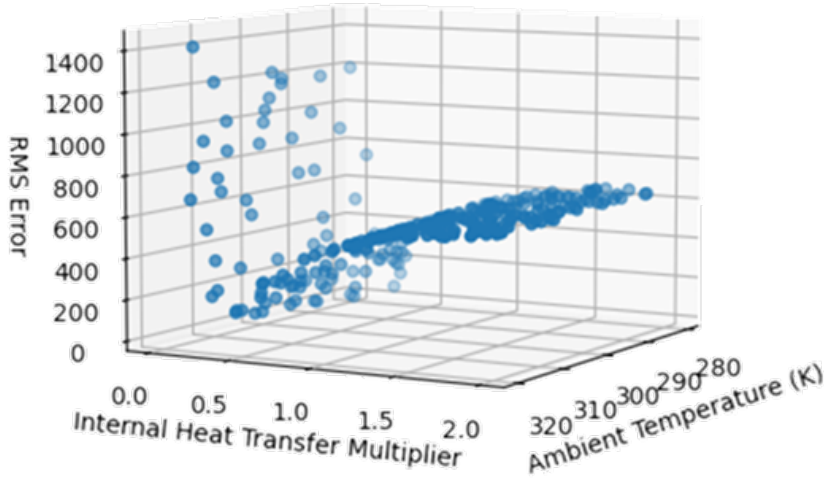
- **3 calibration parameters:**
- **Liquid Temperature**
  - Uncalibrated: 80 K
  - Calibrated: 78 K
- **Ambient Temperature**
  - Uncalibrated: 300 K
  - Calibrated: 280 K
- **Pipe Internal Heat Transfer Multiplier**
  - Uncalibrated: 1
  - Calibrated: 0.35

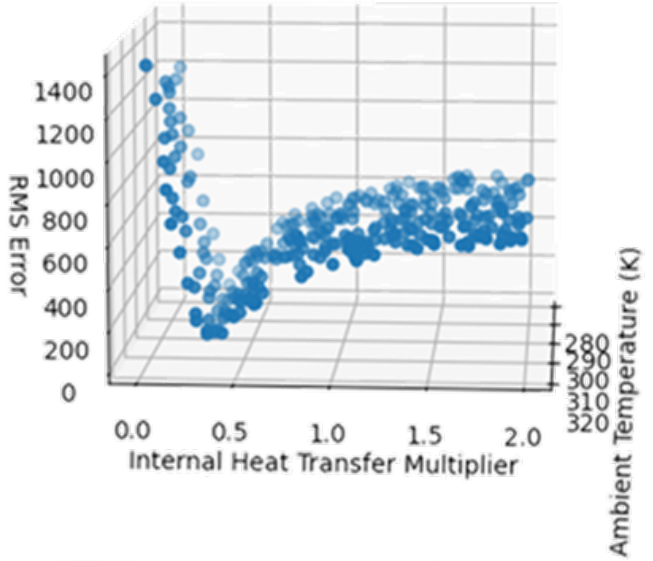


Correlated model predicts wall temp within 6%

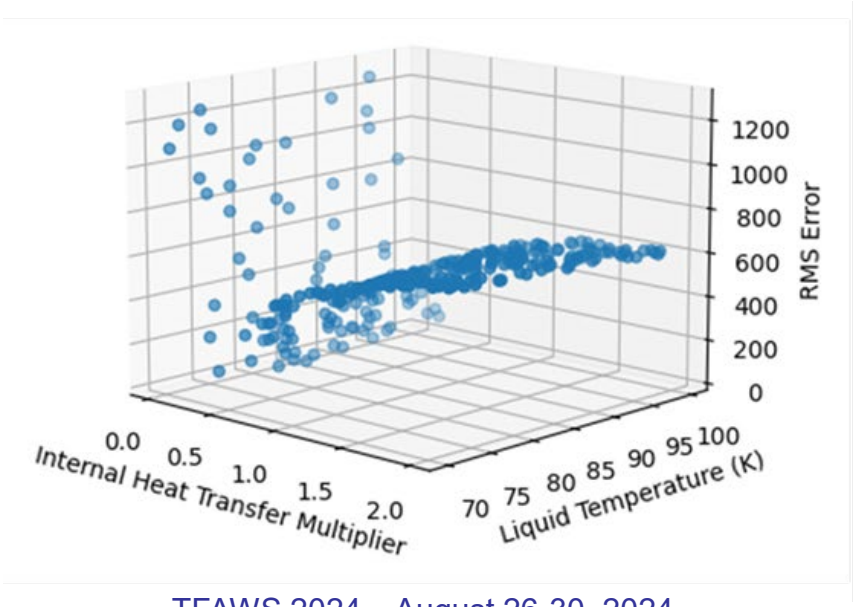
DOE RMS results for 2-parameters for visualization

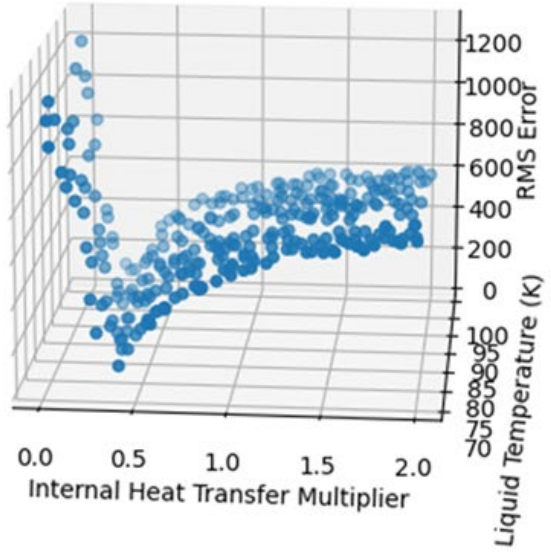
Holding liquid temperature constant at 86 K

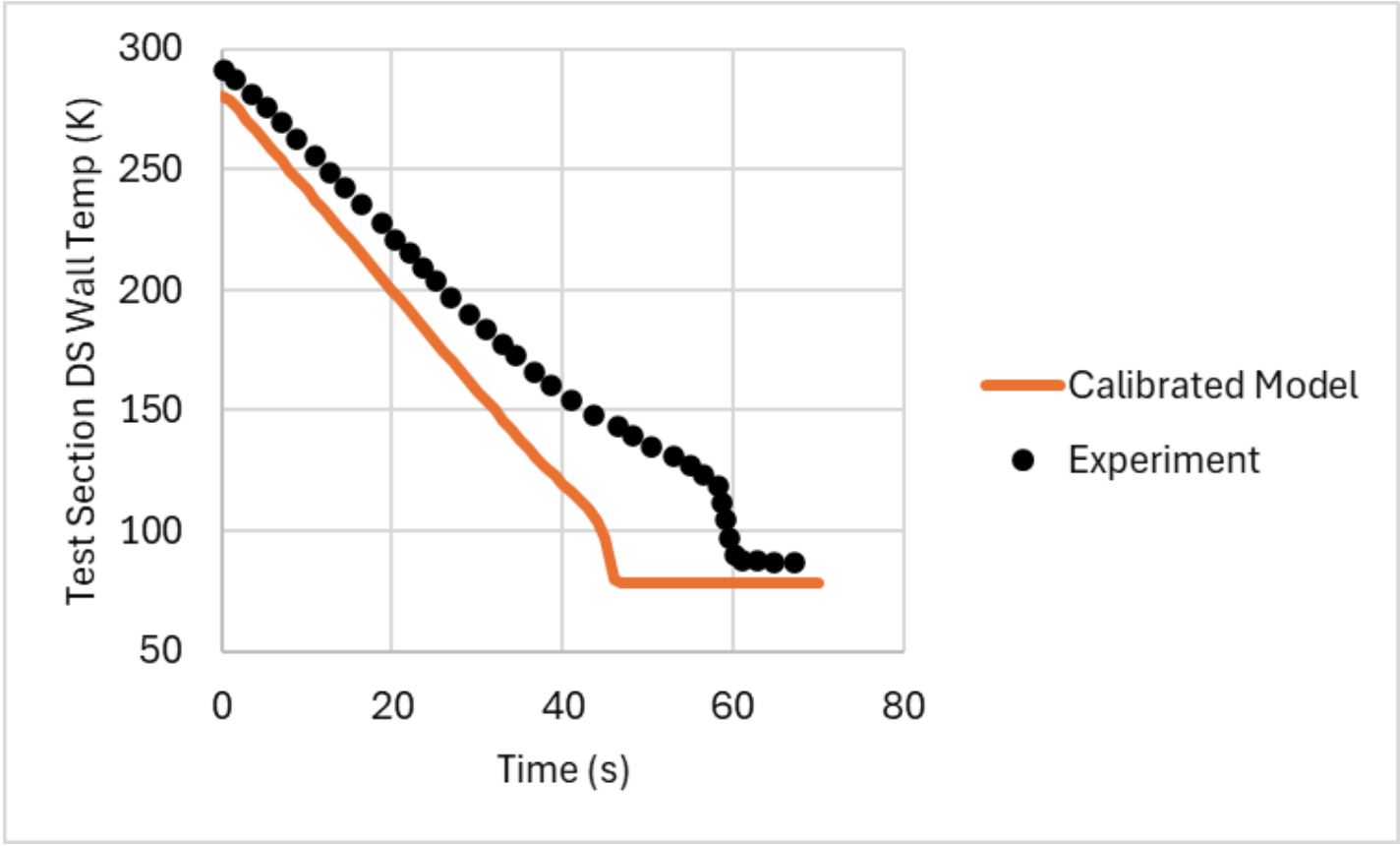




Holding ambient temperature constant at 291 K





Validation of correlated thermal model

- **Calibrated model prediction of downstream wall temperature is lacking**
- **Likely due to exclusion of ambient heat transfer coefficient in the calibration parameter set**
- **Emphasizes importance of understanding model sensitivity to parameters and confidence in parameter predictions**