Nuclear Thermocouples

Advanced Sensors and Instrumentation (ASI) Annual Program Webinar
October 24 – 27, 2022

PI: Richard Skifton, PhD

Idaho National Laboratory

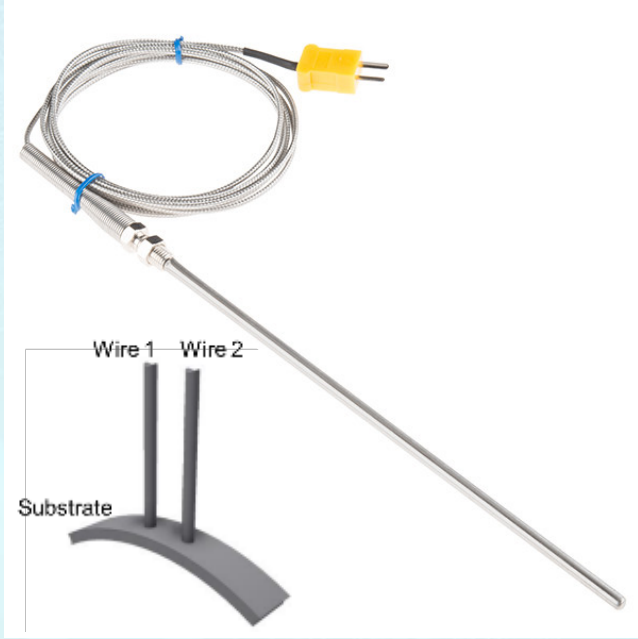
Project Overview

Nuclear Thermocouple Technology:

- The thermocouple element implements R&D activities to develop nuclear instrumentation that addresses critical technology gaps for monitoring and controlling existing and advanced reactors and supporting fuel cycle development. For temperature measurements, thermocouple instrumentation is typically composed of one or more sensing element, interrogation systems, data acquisition system as well as processes and procedures to collect, analyze and calibrate data. Temperature instrumentation is utilized to measure process parameters (i.e., such as temperature, fluid flow, and water level) independent of the experiment, component, or process in which it is deployed.
- In FY23 R&D activities are carried out in the following technical areas:
  - M3CT-23IN0702046 – HTIR heat treatment optimization method
  - M4CT-23IN0702048 – Uncertainty Quantification of Multi-point Measurement

Personnel:

- PI: Richard Skifton, PhD, Idaho National Laboratory
- CO-PI: Brian Jaques, PhD, Boise State University
- PhD Candidate: Scott Riley, Boise State University



Project Overview

Schedule:

Milestone / Activity	STI	2023 Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
ActivityCT-23IN0702041-Intrinsic junction thermocouples for surface temperature measurement													
M3CT-23IN0702043-Develop a calibration process for intrinsic junction thermocouples for surface temperature	Yes	M3											
ActivityCT-23IN0702042-Performance assessment of commercial thermocouples for nuclear applications													
M3CT-23IN0702044-Characterize performance of commercial thermocouples for nuclear applications	Yes	M3											
ActivityCT-23IN0702045-HTIR heat treatment optimization method													
M3CT-23IN0702046-Complete assessment of HTIR-TC testing results using the different heat treatment	Yes												
ActivityCT-23IN0702047-Uncertainty quantification of multi-point measurement													
M4CT-23IN0702048-Complete assessment of uncertainty quantification of multi-point measurement	Yes												M4

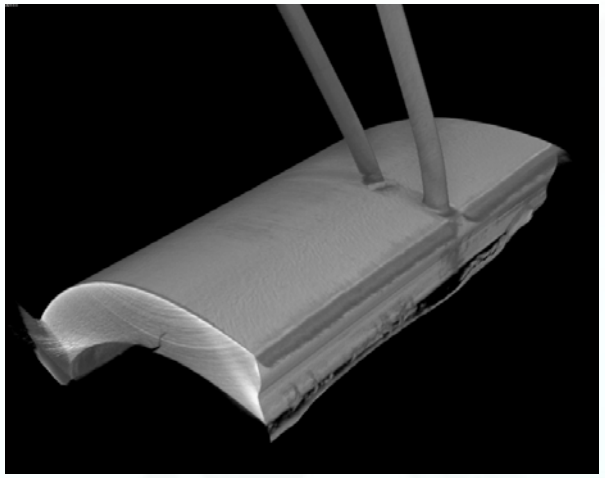
Technology Impact

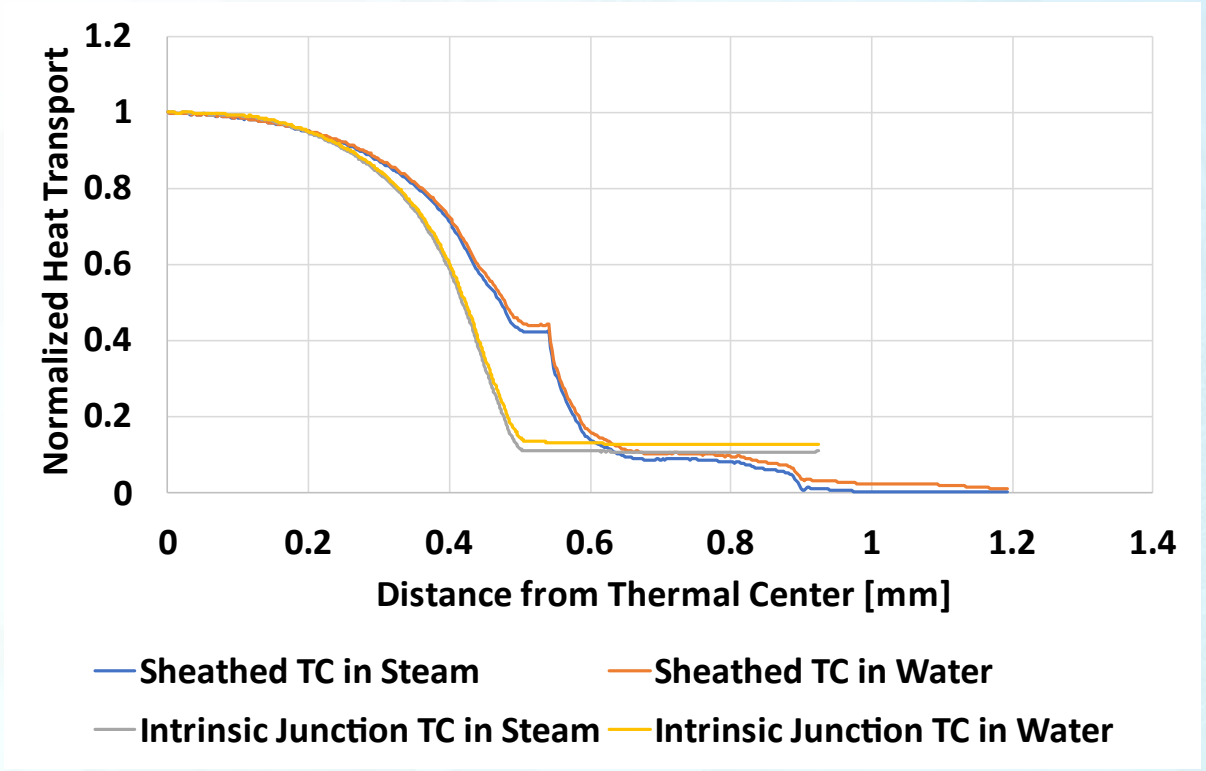
- Next generation reactors will make use of thermocouples for the temperature measurement of normal and abnormal operations–including fuel qualification tests.

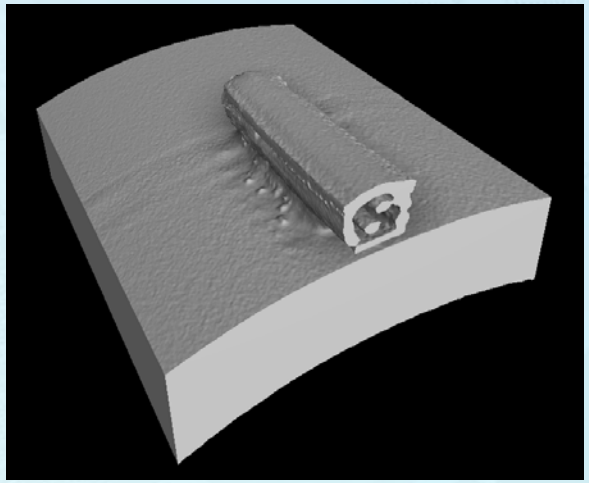
Thermocouple	Type K	Type B	Type N	HTIR-TC
Materials	Chromel vs Alumel	PtRh30% vs PtRh6%	Nicrosil vs. Nisil	Molybdenum vs. Niobium
Temperature Range	-270°C to 1260°C	250°C to 1700°C	-270°C to 1260°C	0°C to 1700°C
Cost	~$30/ft	~$250/ft	~$50/ft	~$250/ft
Radiation Tolerance as Compared to HTIR-TC	1/10th	~1/100th	1/4th	

Results and Accomplishments

Intrinsic Junction Thermocouple Heat Flux Study







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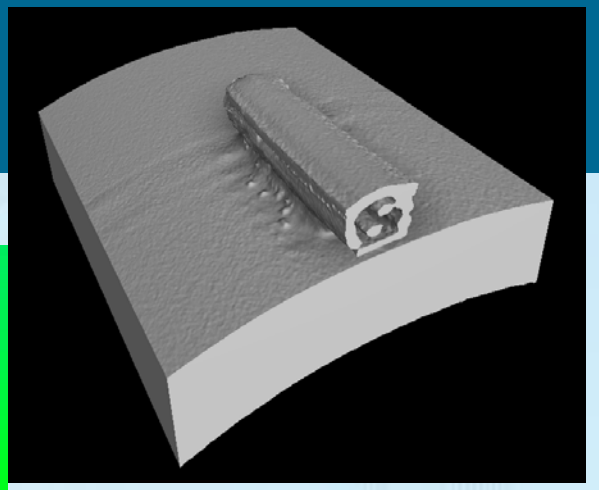

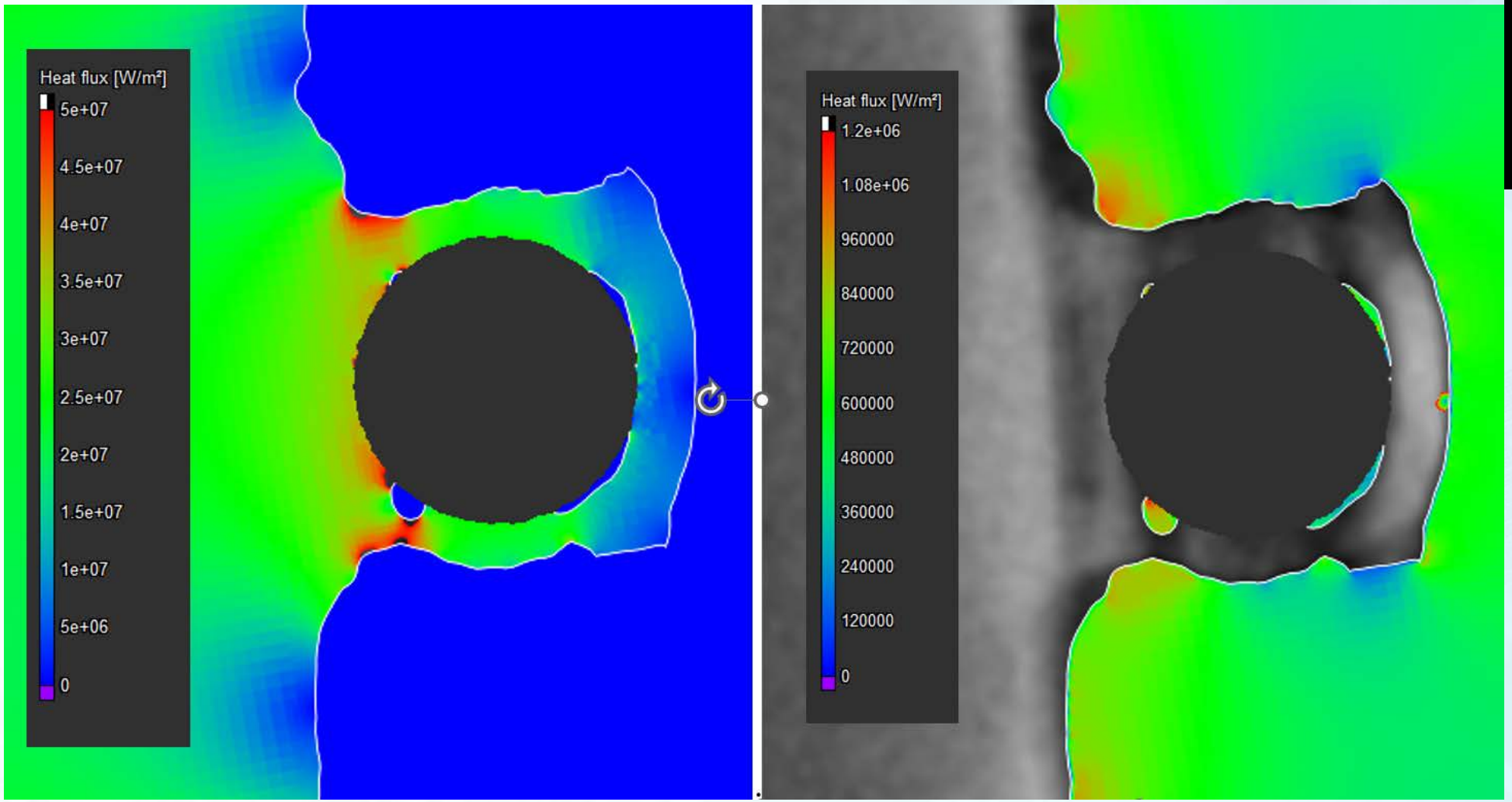

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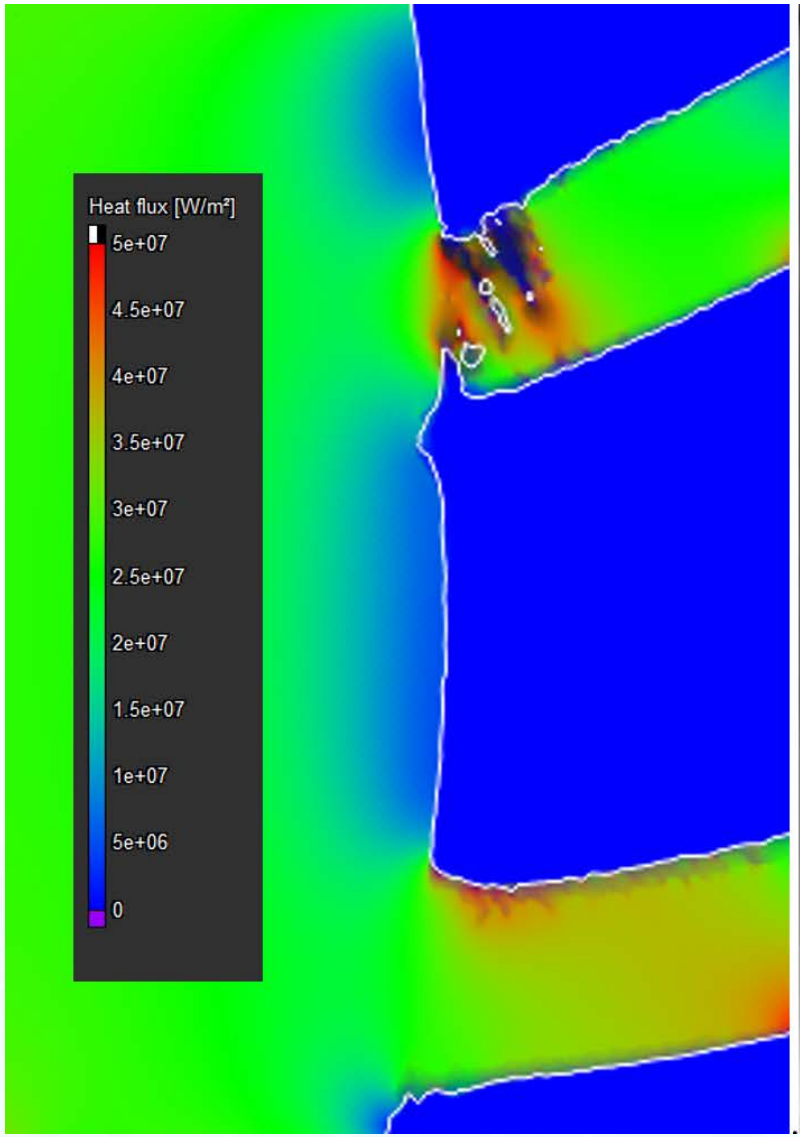
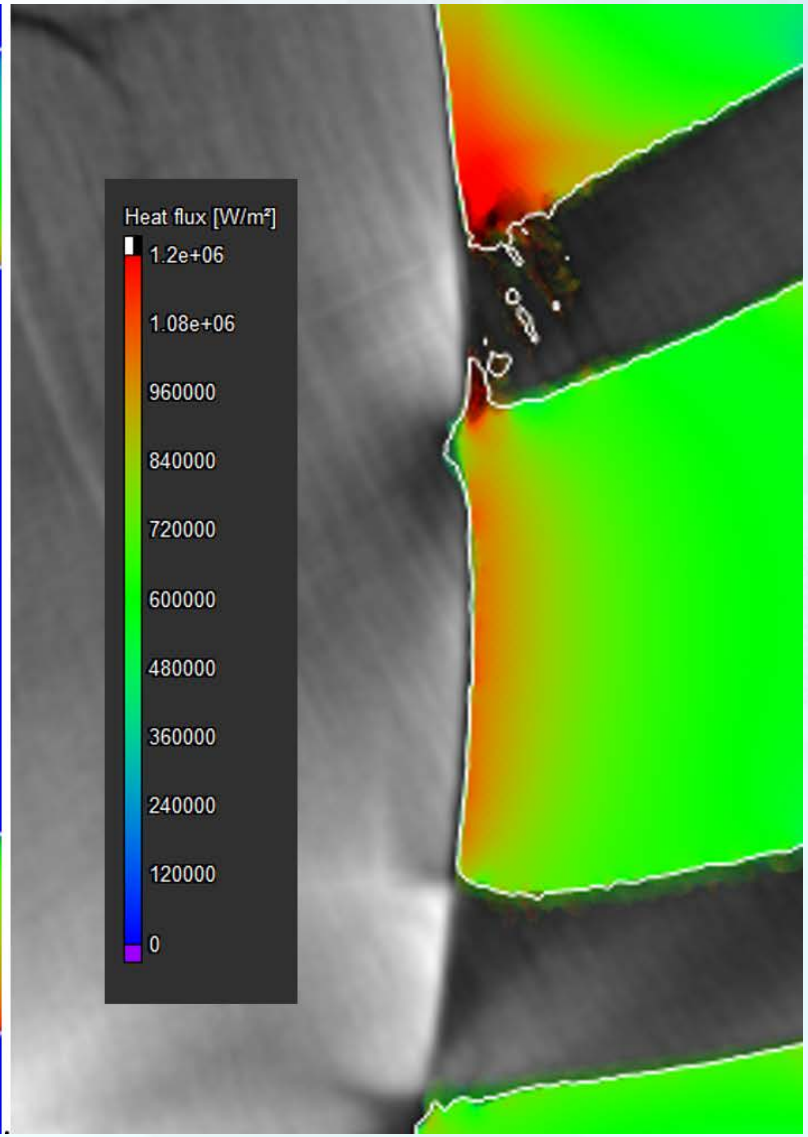
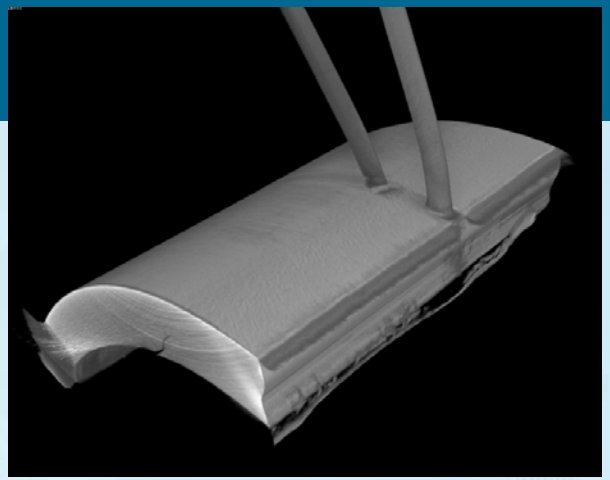






Results and Accomplishments

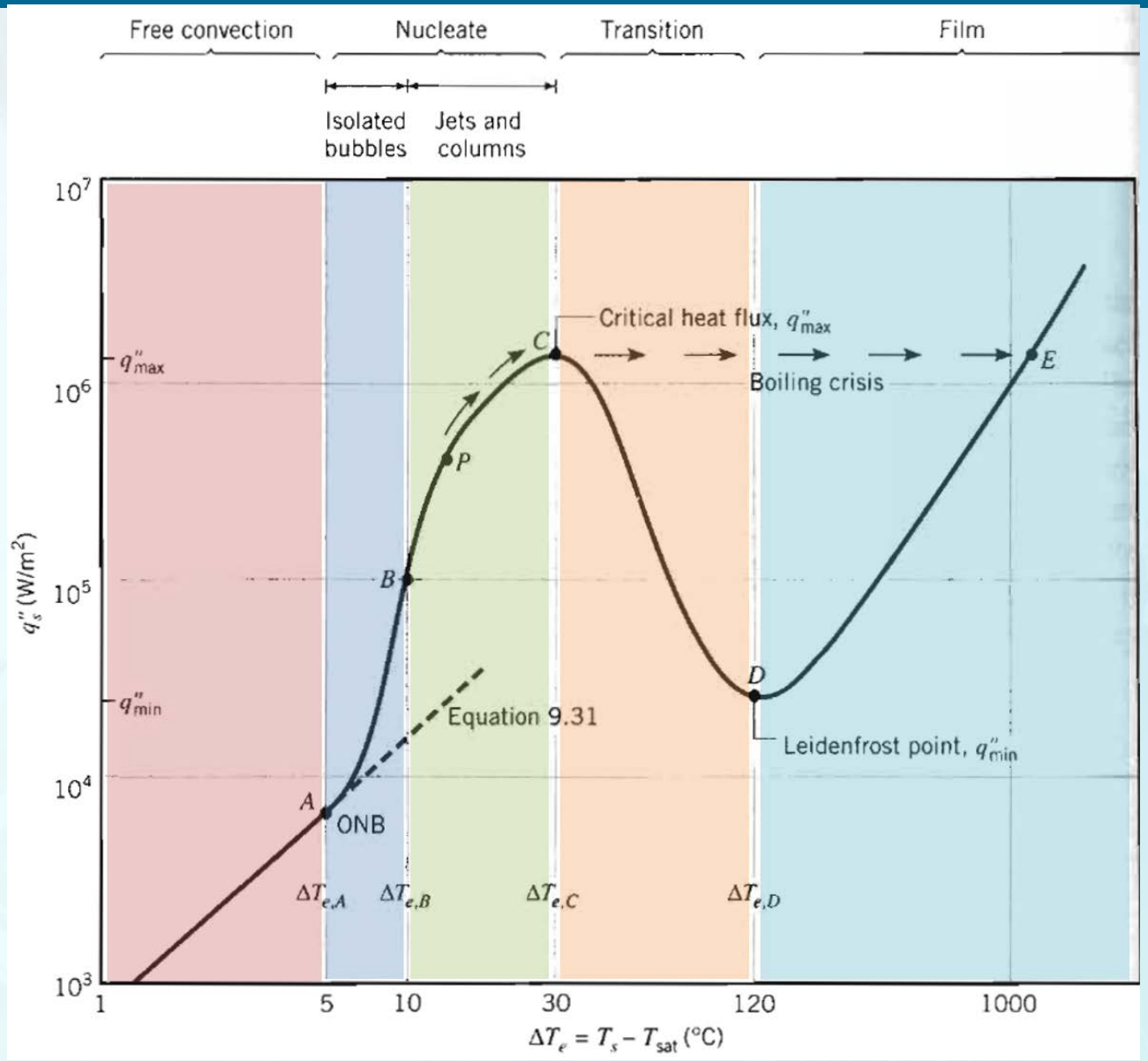
Intrinsic Junction Thermocouple Calibration

$$\Delta T_{fin} = (TC - T_{initial}) \cdot m$$

$$m = \frac{\Delta T_{fin}}{(TC - T_{initial})} = \frac{200°C}{(800°C - 20°C)} = 0.256$$

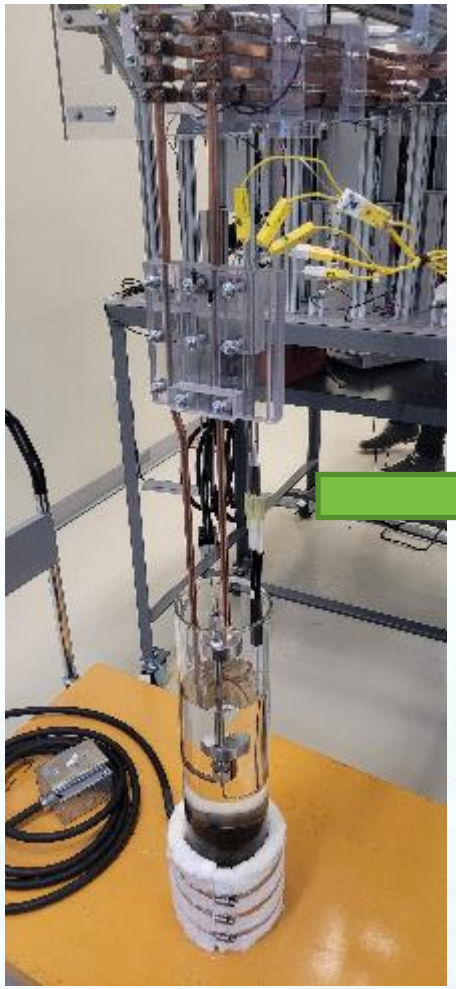
$$\Delta T_e = T_S - T_{sat}$$

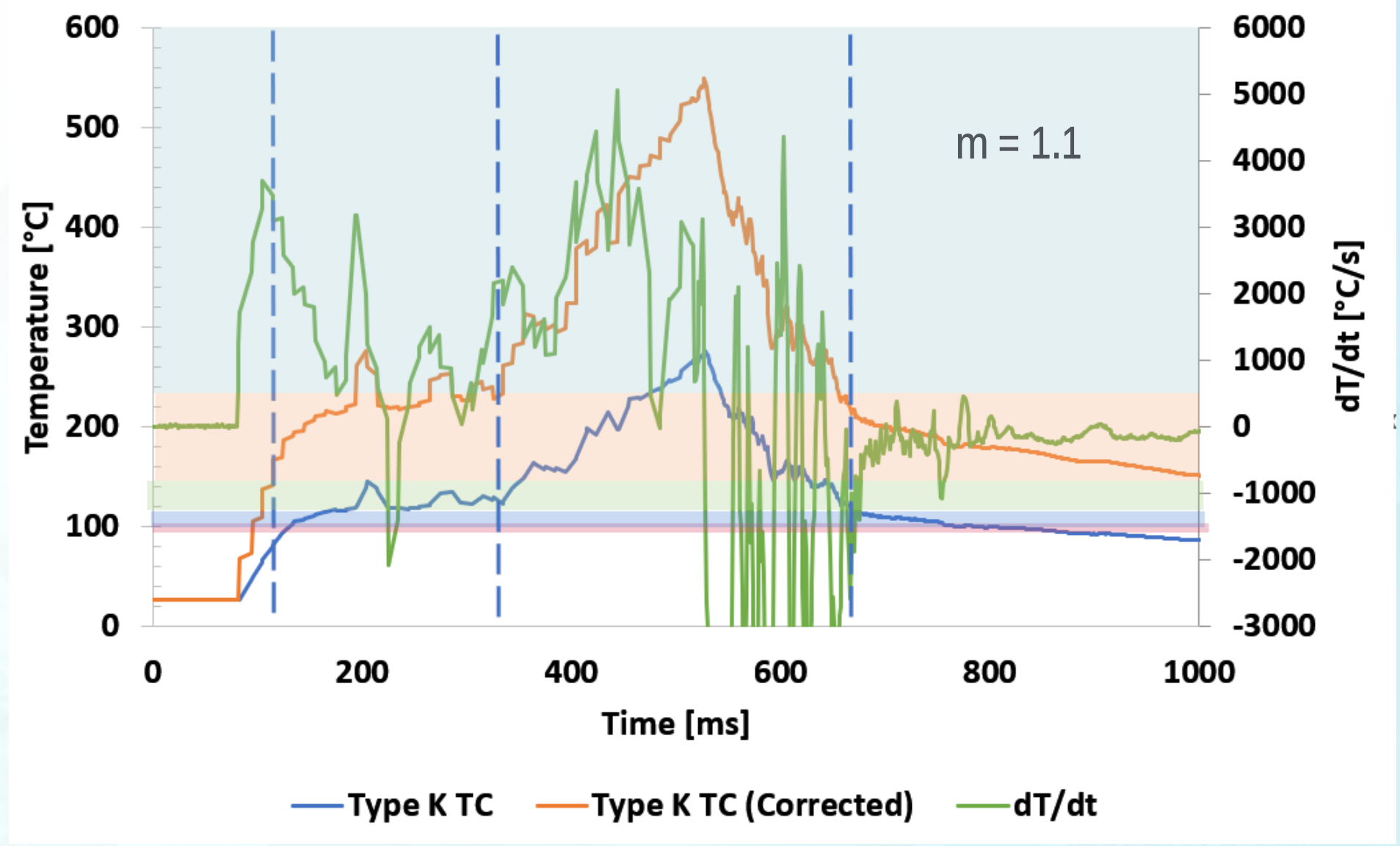
Idaho Falls 'STP'	Temperature [°C]
T_{sat}	96
$T_{e,A}$	101
$T_{e,B}$	106
$T_{e,C}$	126
$T_{e,D}$	216



Results and Accomplishments

$$T_{surface} = TC + \Delta T_{fin} \rightarrow TC + (TC - T_{initial}) \cdot \mathrm{m}$$





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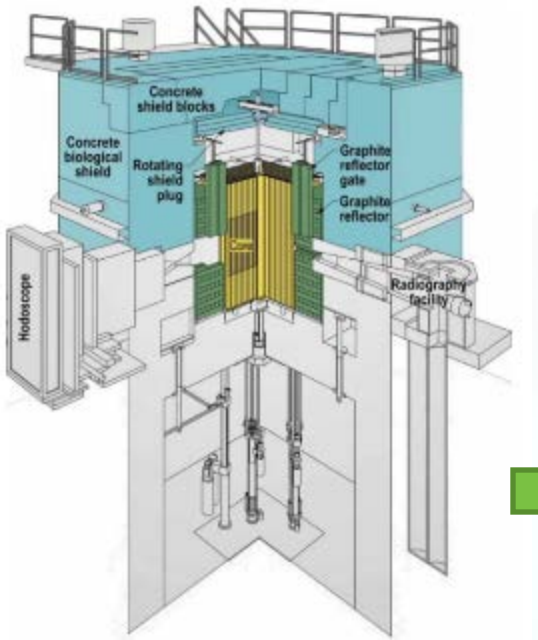
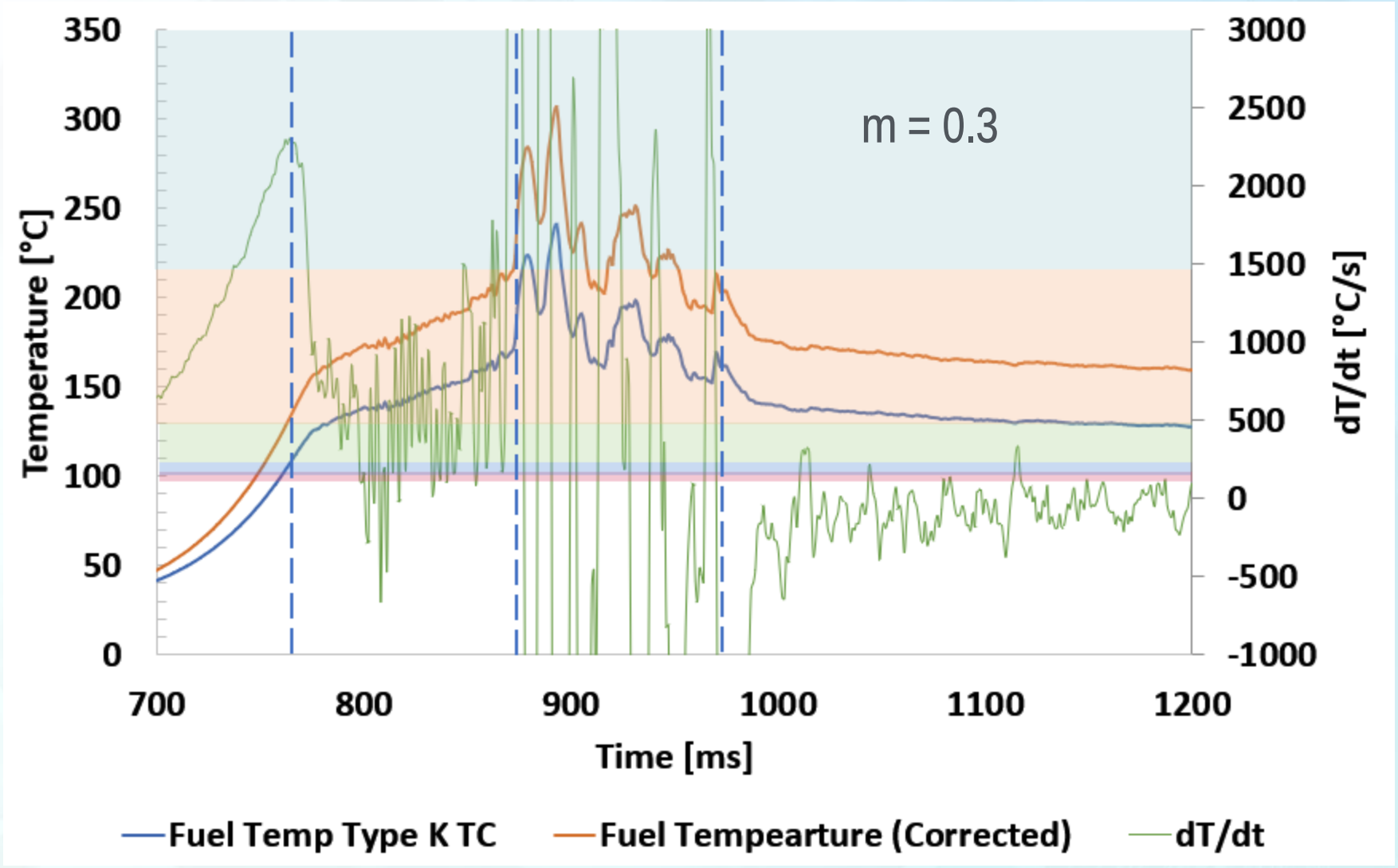


CHF-A



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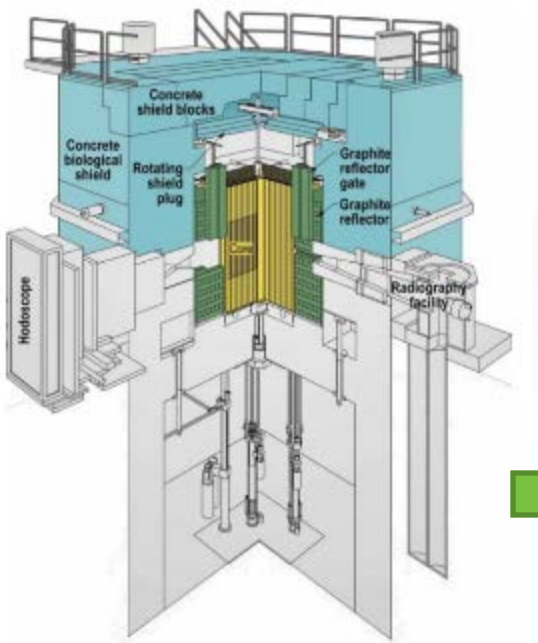
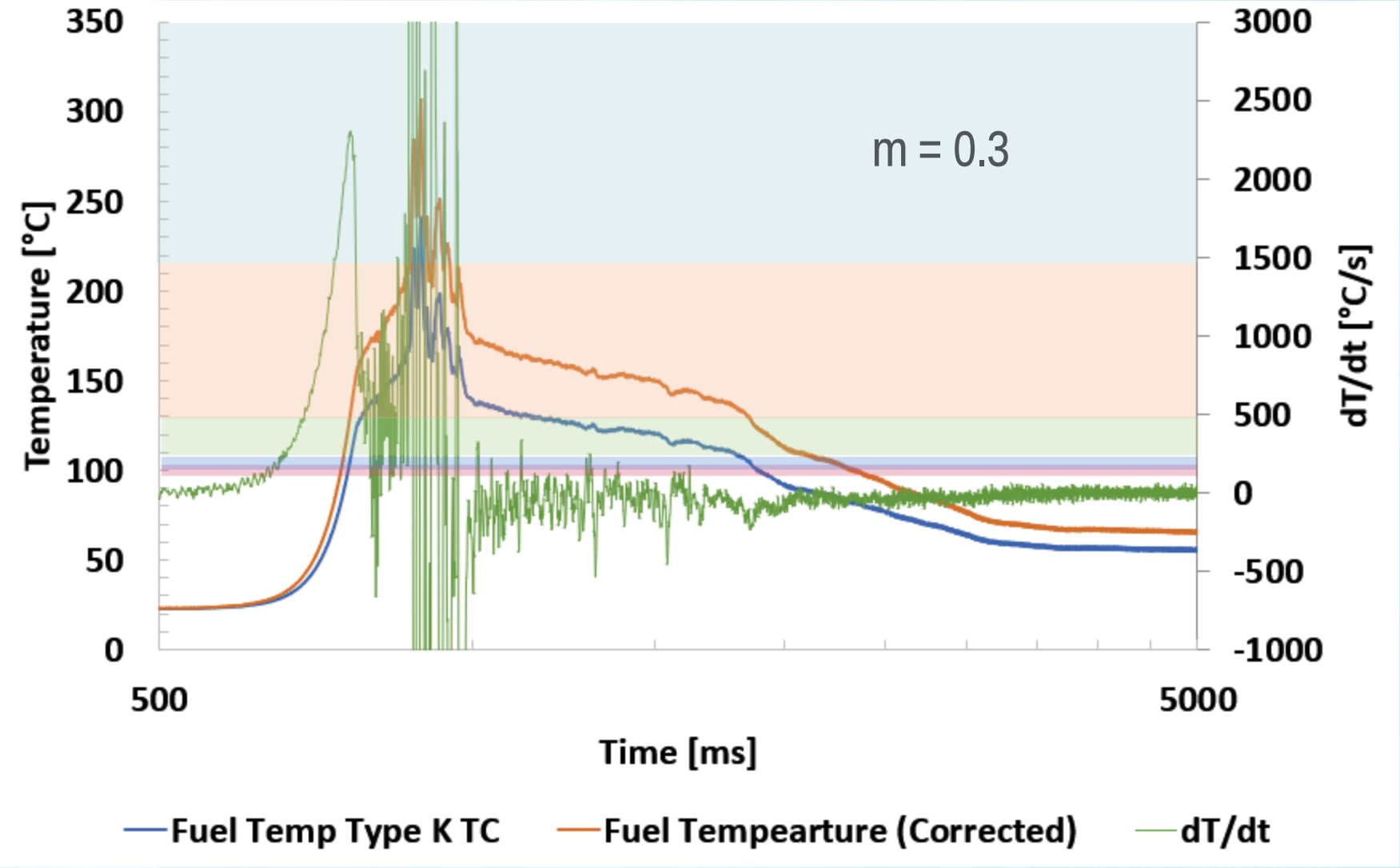


CHF-A



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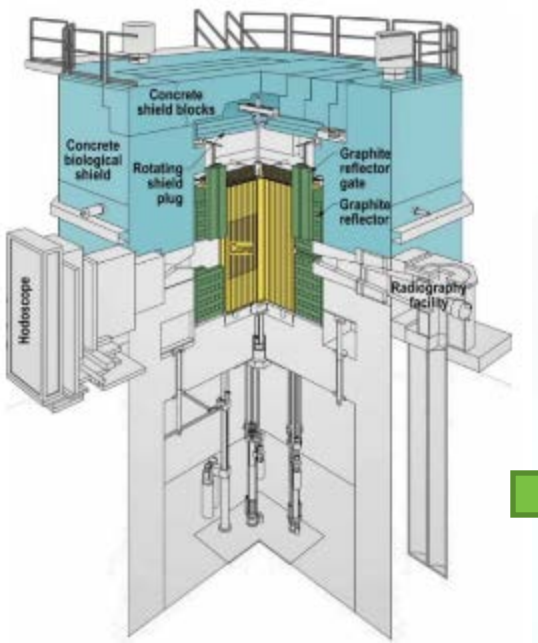
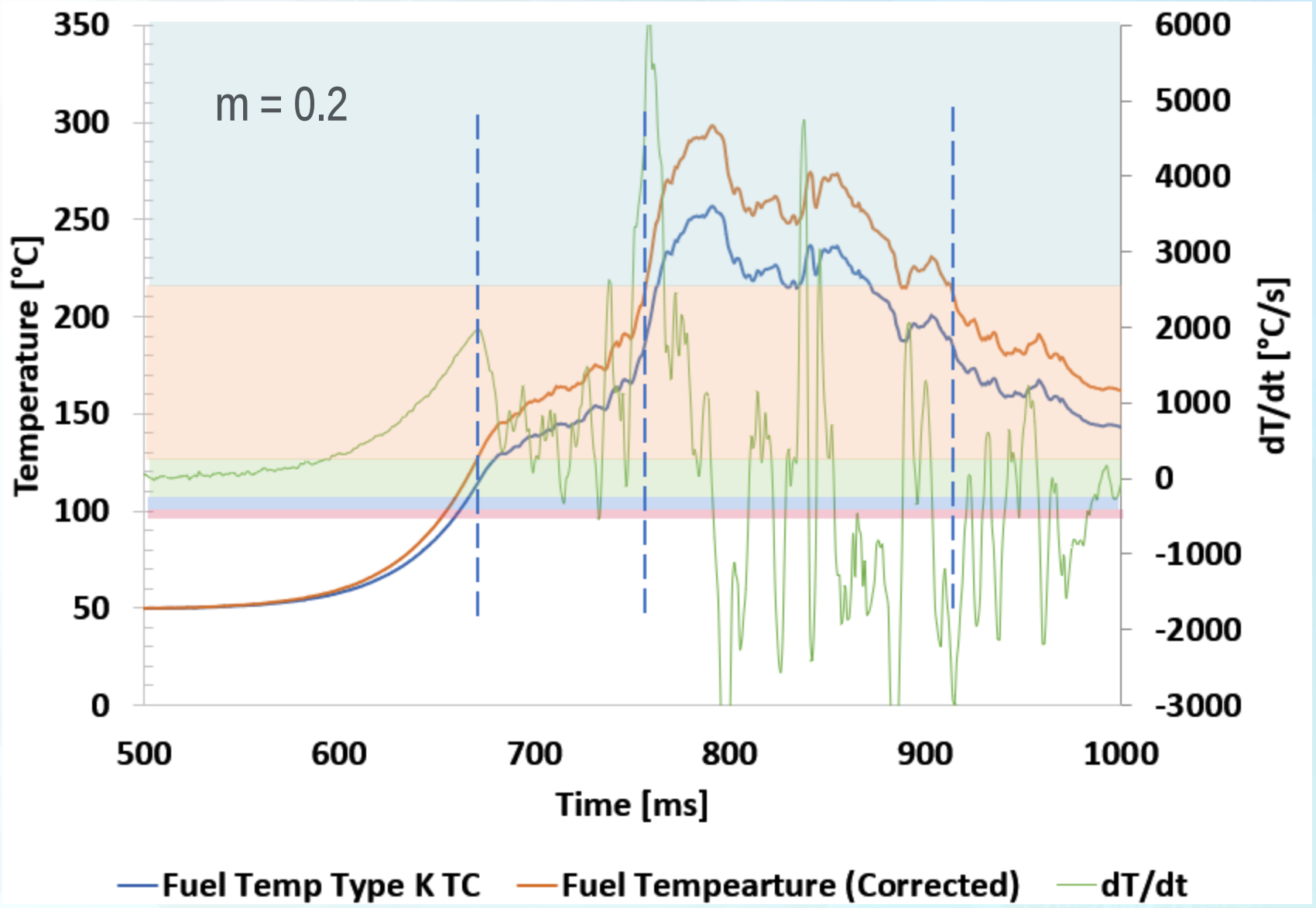
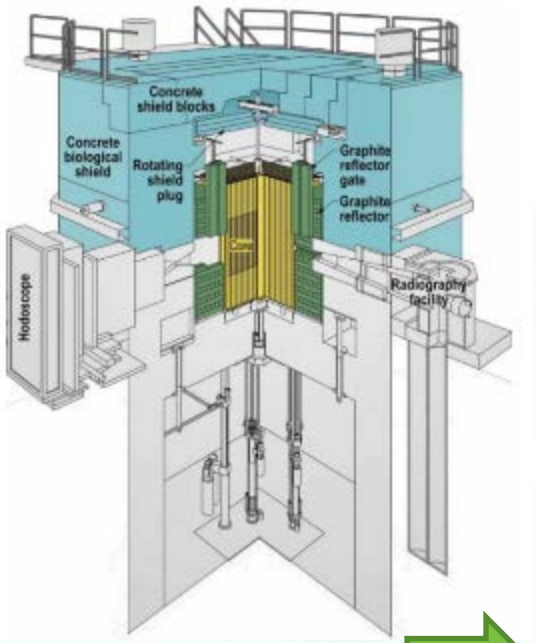


CHF-C

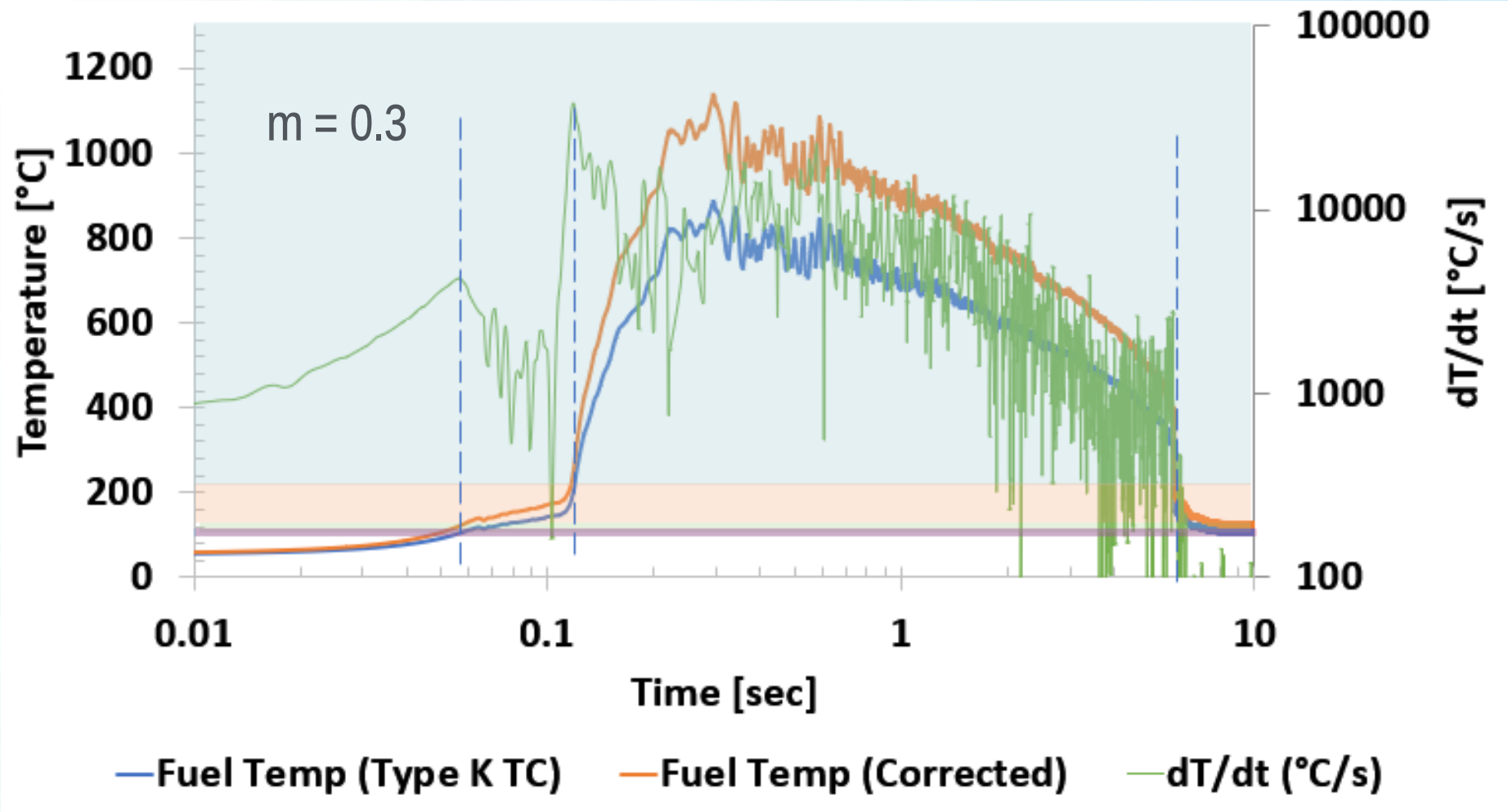


Results and Accomplishments

$$T_{surface} = TC + \Delta T_{fin} \rightarrow TC + (TC - T_{initial}) \cdot \mathrm{m}$$



CHF-B



Concluding Remarks

- HTIR-TC Accomplishments
  - Successfully commercialized with Idaho Laboratories Corporation, ILC (currently taking orders for HTIRs)!
  - 4 follow on US Patents:
    - Advancements in High Temperature Irradiation Resistant Procedures and Calibration Methods.
    - Fast response High Temperature Irradiation Resistant thermocouple (HTIR-TC) using a coaxial configuration.
    - Multicore High Temperature Irradiation Resistant Demicouple
    - Protected High Temperature Irradiation Resistant Thermocouple
  - Technology Commercialization Fund with ILC
  - Energy I-Corps study
  - 3 Related SBIR/STTRs for follow on Technology
    - Printed HTIRs with Mo/Nb Inks
    - Transient Time Flow Measurement using HTIR-TC Technology (Patent Pending)
  - 2019 R&D 100 Award Winner
- Featured article: *Small business funding benefits Idaho research* by Joelyn Hansen →

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Thank You