INL/MIS-23-74161-Revision-0

June 2023 NS&T Highlights

August 2023

Addison Marie Arave

Changing the World's Energy Future

INL is a U.S. Department of Energy National Laboratory operated by Battelle Energy Alliance, LLC

INL/MIS-23-74161-Revision-0

June 2023 NS&T Highlights

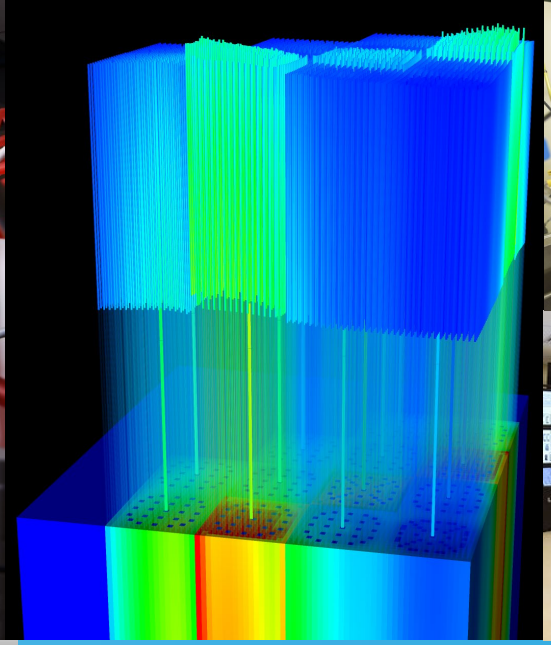
Addison Marie Arave

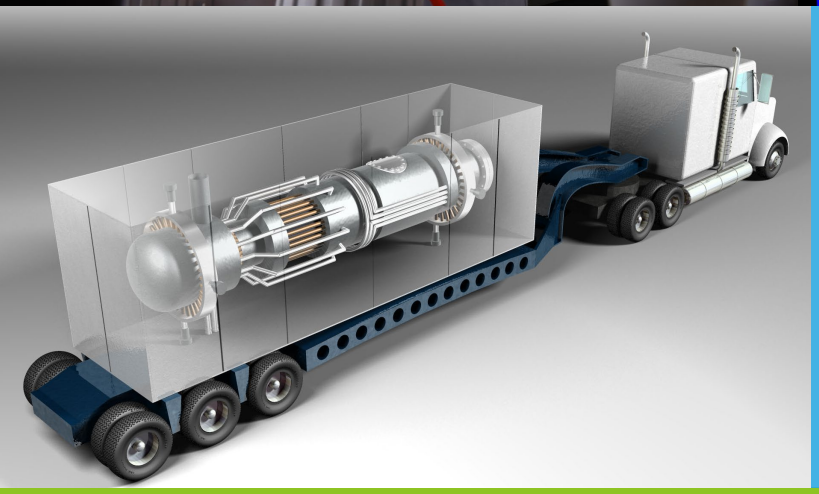
August 2023

Idaho National Laboratory
Idaho Falls, Idaho 83415

http://www.inl.gov

Prepared for the
U.S. Department of Energy
Under DOE Idaho Operations Office
Contract DE-AC07-05ID14517



Nuclear Science & Technology

June 2023 Highlights

Idaho National Laboratory

DOE-NE Systems Analysis & Integration Campaign - INL/RPT-23-72925

Researchers Perform Analysis of Federal Legislations and Their Effects on Nuclear Cost Data

- The Systems Analysis & Integration (SA&I) campaign assessed the impact of tax credits from the Inflation Reduction Act (IRA) and Bipartisan Infrastructure Law (BIL) on the energy cost to the power plant owners (impact on net revenue in $/MWh).
- INL/RPT-23-72925 answers three main questions:
  - What are the primary effects of IRA and BIL on nuclear technologies and the secondary effects on nuclear by way of provisions that affect non-nuclear energy technologies?
  - How can an analyst take base nuclear cost data available to them and adjust that data for the impacts of policy to obtain nuclear cost data adjusted by policy?
  - What is the tradeoff between the production tax credit (PTC) and investment tax credit (ITC), the amounts received by producing carbon free electricity and investing in renewable energies, respectively? Is there a preference between them in terms of revenue per megawatt hours?
- The results of this study allow modelers to adjust the capital expenditures (CAPEX) and operating and maintenance (O&M) costs including the benefits from IRA and BIL legislations.

The study estimated a CAPEX reduction between ~6% and ~54% depending on the ITC rate, and an O&M cost reduction between $7.6 and $45.8/MWh depending on the PTC rate

Supporting Mechanism	New Advanced Nuclear	Existing Nuclear Plants	Wind	Solar	Carbon Capture	Hydrogen	Energy Storage
IRA - Tax Credit - PTC (45 U)	No	Yes	No	No	No	No	No
IRA – Tax Credit – PTC (45 Y)	Yes	No	Yes	Yes	No	Yes	No
IRA – Tax Credit – ITC (48 E)	Yes	No	Yes	Yes	No	Yes	Yes
IRA – Tax Credit – PTC (45 Q)	No	No	No	No	Yes	No	No
IRA – Tax Credit – PTC (45 V)	Yes	Probably Yes	No	No	No	Yes	No
IRA – Advanced Energy Project Tax Credit (48 C)	Probably Yes	Probably Yes	Probably Yes	Probably Yes	Probably Yes	Probably Yes	Probably Yes
IRA – Advanced Manufacturing PTC (45 X)	Probably No	No	Yes	Yes	Yes	Probably No	Probably Yes
IRA LGP - Energy Infrastructure Reinvestment (Title 1706)	Yes	No	Probably Yes	Probably Yes	Probably Yes	Probably Yes	Probably Yes
IRA LGP – Innovative Energy and Supply Chain (Title 1703)	Yes	No	Yes	Yes	Yes	Yes	Yes
IRA - HALEU	Yes	No	No	No	No	No	No
IRA – Monetizing Tax Credits PTC/ITC direct payments	Yes	Yes	Yes	Yes	Yes	Yes	Yes
IRA + BIL – Industrial Sector Decarbonization	Probably Yes	No	Probably No	Probably No	Probably Yes	Probably Yes	Probably Yes
BIL – Civil Nuclear Credit Program	No	Yes	No	No	No	No	No
IRA – Tribal Energy Development Projects	Yes	No	Yes	Yes	Yes	Yes	Yes
IRA - Rural community	Probably Yes	No	Probably Yes	Yes	Yes	Probably Yes	Yes
Defense Production Act	No	No	No	Probably Yes	No	Probably Yes	Probably Yes
USDA	Probably Yes	No	Yes	Yes	Yes	Probably Yes	Yes

Yes Probably Yes Probably No No

Trade-off Between PTC and ITC

Technology	SMR1	SMR2	SMR3	SMR4	SMR5
Capacity Factor/Overnight CAPEX	$6,000/kWe	$7,500/kWe	$8,500/kWe	$10,500/kWe	$13,500/kWe
75%	ITC	ITC	ITC	ITC	ITC
80%	ITC	ITC	ITC	ITC	ITC
85%	PTC	ITC	ITC	ITC	ITC
90%	PTC	ITC	ITC	ITC	ITC
95%	PTC	ITC	ITC	ITC	ITC
100%	PTC	ITC	ITC	ITC	ITC

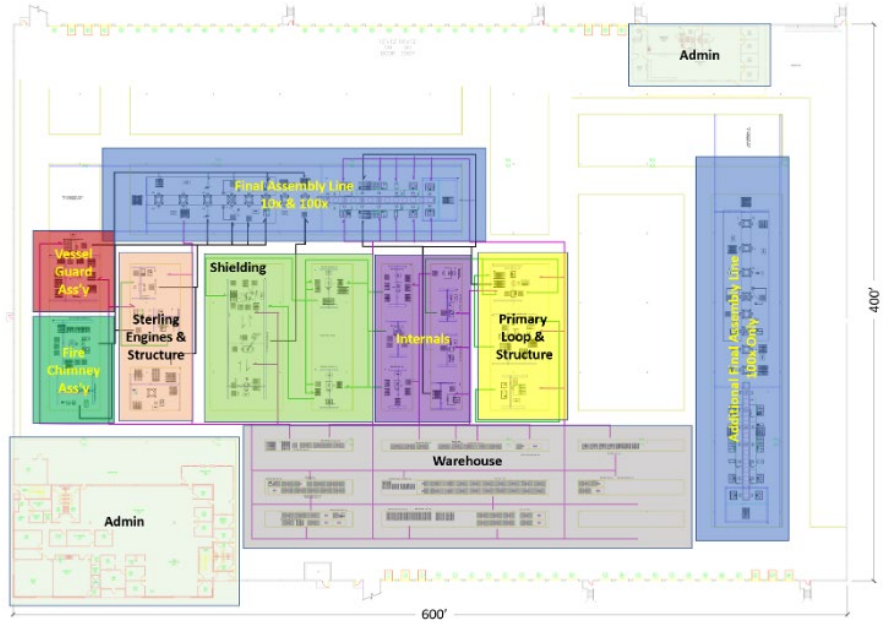
REACTOR SYSTEMS DESIGN & ANALYSIS | INTEGRATED ENERGY & MARKET ANALYSIS
Nahuel.Guaita@inl.gov

Research Highlight

DOE-NE Systems Analysis & Integration Campaign and DOE-NE Microreactor Program

New Study Quantifies Cost Reduction Potential from Microreactor Mass Production & Investment Scales Need

- Idaho National Laboratory in collaboration with Munro & Associates published a detailed evaluation of a microreactor factory with throughput ranging from 10 units/year to 100 units/year.
- Mass production will play a key role in driving the costs for microreactors down to commercially viable levels.
- The study estimated that shifting from a stick-built single unit to a factory producing 100 units/year could lead to over 70% cost reductions (excluding site activities).
- While previous studies have discussed the potential benefits from 'learning rates', this is the first study in the open literature to conduct a detailed assessment of costs and potential benefits.
- The conceived factory layout consisted of 22 workstations, 2 final assembly lines, and a 2-shift rotation each with 51 staff members per shift.
- The level of investment needed was projected to be:
  - ~$10M in equipment, $72M in building costs
  - ~$20M/year in staff, $1M/year in utilities



Detailed schematic of the microreactor factory plant.

Title: Assessment of Factory Fabrication Considerations for Nuclear Microreactors
Authors: Abdalla Abou-Jaoude,Yasir Arafat, Chandrakanth Bolisetti, Botros Hanna,J oshua Belvedere, James Blocker, Brandon Cooper, Shanda Harmon & Dan McCarthy
Journal: Nuclear Technology
Link: https://doi.org/10.1080/00295450.2023.2206779

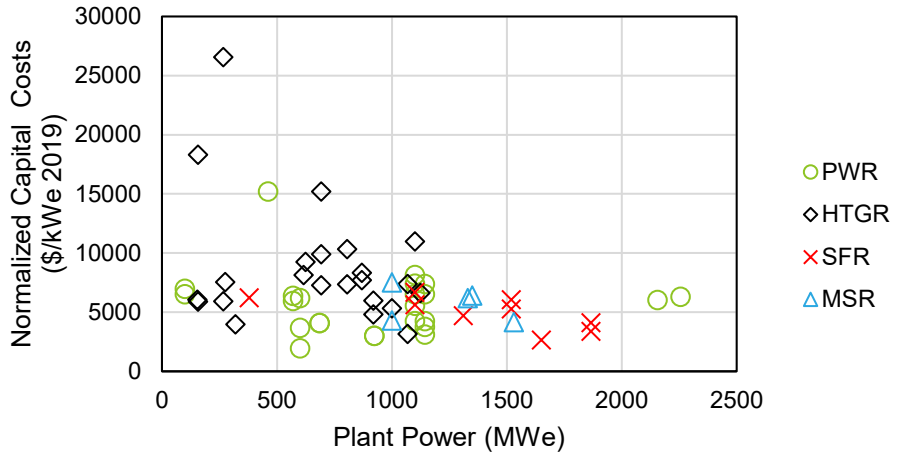
IREACTOR SYSTEMS DESIGN & ANALYSIS | ADVANCED REACTOR TECHNOLOGY & DESIGN
Abdalla.Aboujaoude@inl.gov

Research Highlight

DOE-NE Integrated Energy Systems Program

Integrated Energy Systems Program Publishes Comprehensive Literature Review of Projected Nuclear Reactor Deployment Costs

- Various stakeholders and modelers need to account for projected costs of nuclear energy and overly conservative cost estimates may lead to nuclear being dismissed by energy planners.
- Thirty literature references were evaluated to harvest a broad sample of advanced reactor cost estimates and cost recommendations were provided for a nuclear reactor between a first and Nth of a kind (BOAK).
- The resulting overnight capital cost for nuclear was $4,000–$7,000/kWe, and operating costs were $15–$35/MWh.
- These estimates are in line with several nuclear-centric studies and underscores the harm in models using higher target estimates.
- Other important findings of the study are:
  - It is not possible to distinguish, at this level, how reactor technology type (sodium, salt, gas, etc.) impacts costs.
  - It is challenging to delineate if small modular reactor (SMR) costs will differ substantially from costs of larger reactors.
  - Adjustment factors can be used to account for demonstration premiums, learning effects, and multi-plant synergies.



Compiled normalized cost estimates for various reactor types.

Title: Literature Review of Advanced Reactor Cost Estimates
Authors: Abdalla Abou-Jaoude, Linyu Lin, Chandrakanth Bolisetti, Elizabeth Worsham, Levi M Larsen, Aaron Epiney
Journal: INL Technical Report, INL/RPT-23-72972

IREACTOR SYSTEMS DESIGN & ANALYSIS | ADVANCED REACTOR TECHNOLOGY & DESIGN
Abdalla.Aboujaoude@inl.gov

IES Integrated Energy Systems

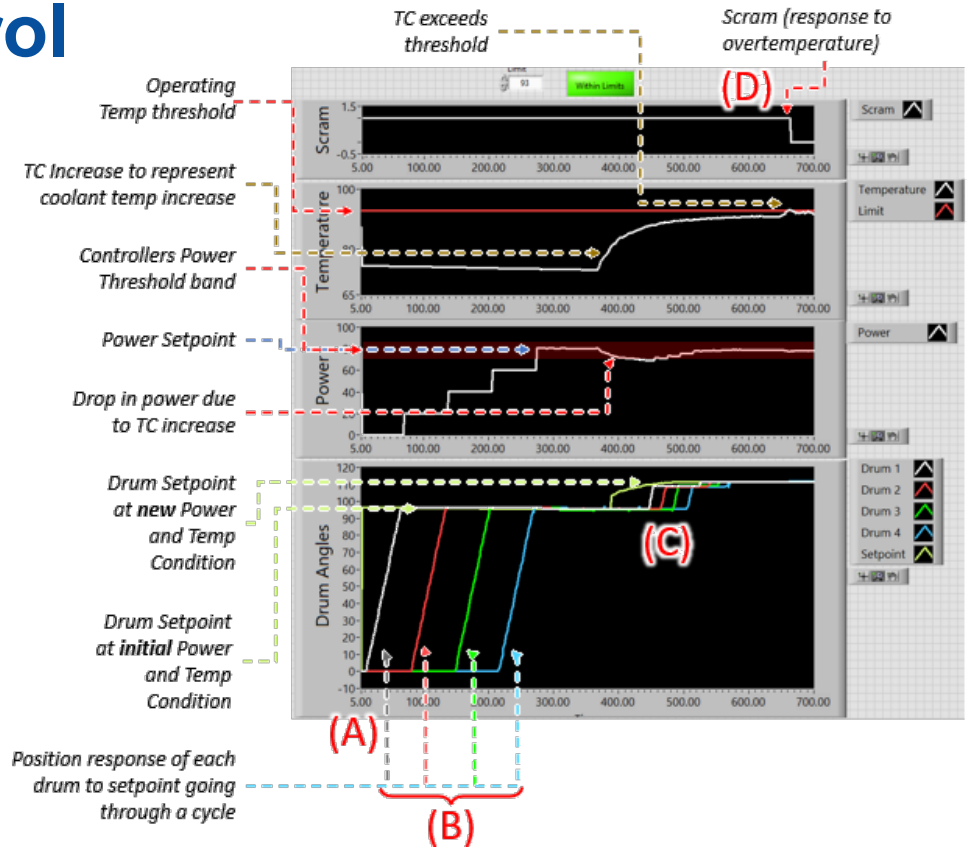
IDAHO NATIONAL LABORATORY

DOE-NE Microreactor Program

Microreactor Autonomous Control System Actuation Hardware Demonstrates Automated Power Control

- The Microreactor Autonomous Control System (MACS) hardware platform provides an accessible general microreactor hardware/digital testbed to test control strategies with an appreciation of hardware/software architectures.
- MACS achieved automated power control using its hardware/digital interface shown in the figure.
  - A. Individual Control Drum Position Control
  - B. 4 Control Drum Iteration Control
  - C. Power control with simple digital plant including a thermocouple input to simulate coolant
  - D. System scram given an over temperature condition
- The MACS helps pave the way toward autonomous operation of microreactors, which is key to making them cost competitive.

MACS Actuation System (left) controlled by Microreactor Applications Research Validation and Evaluation (MARVEL) prototype control cabinet (right).



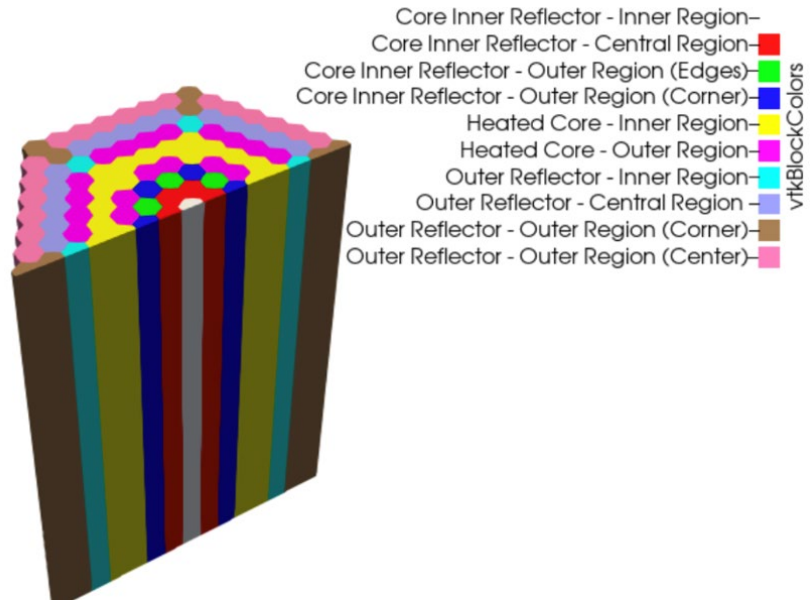
Result of experiment used to demonstrate 4 different automated functions.

Anthony.Crawford@inl.gov

DOE-NE Nuclear Energy Advanced Modeling and Simulation Program

Validation Completed for Pronghorn Modeling of Gas-Cooled Reactors

- High temperature gas-cooled reactors (GCR) have radial and azimuthal temperature gradients due to differential heating and cooling of the graphite core.
- Pronghorn is a MOOSE (Multiphysics Object-Oriented Simulation Environment) based code that provides information on the ability of coolants to remove heat from nuclear fuel.
- Novel approaches for solid conductivity homogenization, radiation heat transfer, and heat exchanges in developing flow were implemented in Pronghorn's 3D porous-media modeling.
- Validation of the Pronghorn modeling capability for both steady-state and transient conditions was completed.
- Experiment data from the Oregon State University High-Temperature Test Facility were used for the validation.
- This expansion of Pronghorn's capabilities provides an additional analysis tool for GCR designs and the Generation IV International Forum.



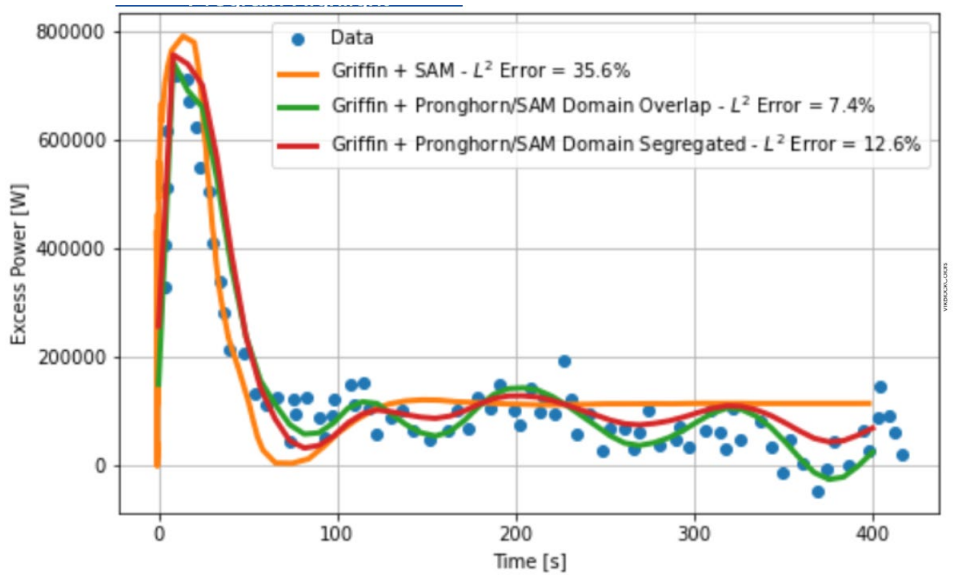
HTTF heated core regions in the Pronghorn model.

Reactor Systems Design & Analysis | Thermal Fluids Systems Methods & Analyses
Mauricio.TanoRetamales@inl.gov; Sebastian.Schunert@inl.gov
Computational Frameworks
Vasileios.Kyriakopoulos@inl.gov

DOE-NE Nuclear Energy Advanced Modeling and Simulation Program

New MOOSE Modeling Capability Uses Pronghorn and Systems Analysis Method for Molten Salt Reactor Analyses

- Liquid-fueled molten salt reactors (MSRs) require detailed multidimensional modeling of the flow, temperature, and delayed neutron precursors fields in the reactor core.
- Pronghorn is a MOOSE-based code that provides information on the ability of coolants to remove heat from nuclear fuel.
- The systems analysis method (SAM) is a whole-plant transient analysis code for design scoping of advanced non-light-water reactors.
- Pronghorn and SAM were coupled to provide complete plant analyses of MSRs with high-fidelity core models.
- The coupling was validated for reactivity insertion transients in the Molten Salt Reactor Experiment.
- This new MOOSE-based modeling capability provides an additional analysis tool for small modular reactors using molten salt as the coolant.



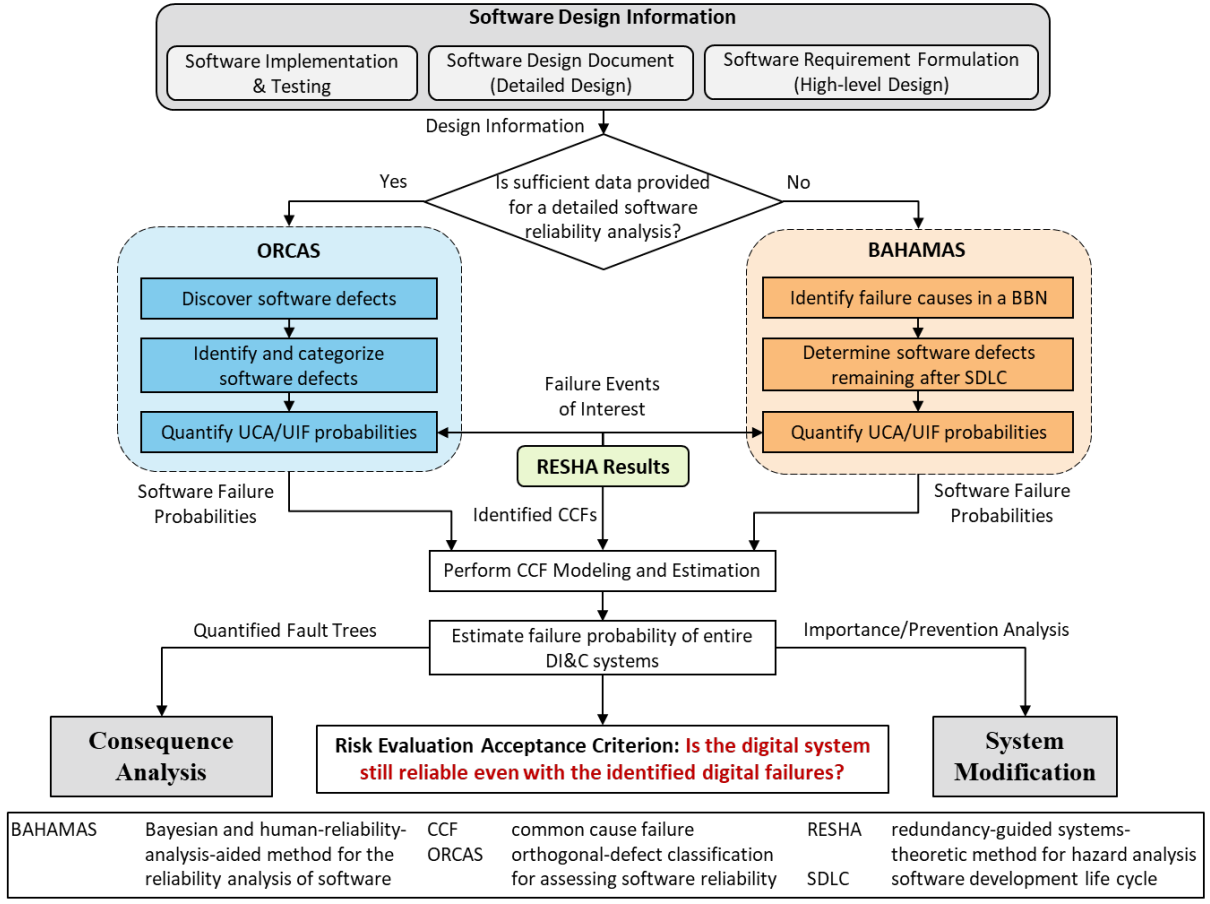
Excess Power for a Reactivity Insertion Transient in the Molten Salt Reactor Experiment.

Reactor Systems Design & Analysis | Thermal Fluids Systems Methods & Analyses
Mauricio.TanoRetamales@inl.gov; Sebastian.Schunert@inl.gov

DOE-NE Light Water Reactor Sustainability Program

Light Water Reactor Sustainability Program Develops New Methodology to Analyze Reliability of Digital Instrumentation & Control Systems

- Researchers from the Light Water Reactor Sustainability (LWRS) Program are developing a new framework and new methods to support a quantitative reliability analysis of safety-critical digital instrumentation and control (DI&C) systems for use at a nuclear utility.
- The LWRS-developed framework aims to fill the technical gaps in reliability analysis of safety-critical DI&C systems by:
  - Using a new method (i.e., **RESHA**) to identify crucial software failure modes and common cause failures (CCFs).
  - Employing independent methods (i.e., **BAHAMAS** and **ORCAS**) to address challenges of limited data and estimate software reliability.
  - Evolving a hybrid method to estimate CCF parameters for various DI&C system designs.
- This framework defines and quantifies metrics of DI&C system reliability to inform decision-makers for managing risk and reducing costs to aid with DI&C design and upgrades.
- This effort was a collaboration with Westinghouse and utilities.



The workflow of multiscale reliability analysis in the LWRS-developed framework for DI&C risk assessment.

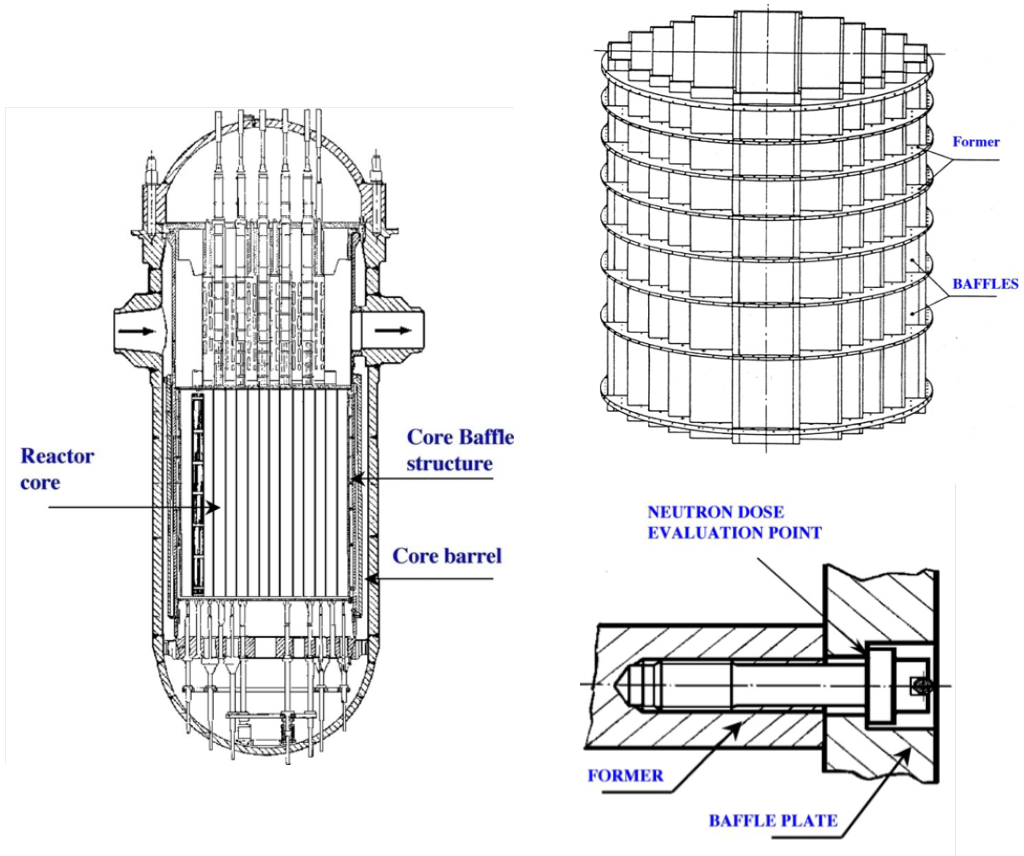
REACTOR SYSTEM DESIGN AND ANALYSIS | DIGITAL REACTOR TECHNOLOGY & DEVELOPMENT
Han.Bao@inl.gov

LWRS LIGHT WATER REACTOR SUSTAINABILITY

DOE-NE Nuclear Science User Facilities

Three Consolidated Innovative Nuclear Research Proposals Awarded

- The Department of Energy (DOE) has selected one national laboratory-led and two university-led projects that will take advantage of Nuclear Science User Facilities (NSUF) capabilities to investigate important nuclear fuel and material applications.
- The three projects will be supported by more than $6.3 million in facility access costs and expertise for experimental neutron and ion irradiation testing, post-irradiation examination, synchrotron beamline characterization and technical assistance for design and analysis of experiments through the NSUF.
- A complete list of NSUF projects with their associated abstracts is available here.



Highly-Irradiated stainless steel baffle plates to be investigated for intergranular cracking

DOE-NE Light Water Reactor Sustainability Program - Cooperative Research and Development Agreement with Constellation Energy Generation

Limerick Safety-Related Instrumentation and Control Upgrade Project Report Completed

- A partnership has been established between the Department of Energy and Constellation Energy to pilot the use of Nuclear Regulatory Commission (NRC) and industry developed processes. This partnership is meant to enable safety-related instrumentation and control (I&C) upgrades and to capture associated lessons learned.
- As part of this effort, INL worked with Constellation to produce a report that describes:
  - Conceptual design phase efforts.
  - Portions of the detailed design phase efforts (up to Constellation's submission of their license amendment request to the NRC for this upgrade).
- Information captured will promote further upgrades in the industry.

Limerick Generating Station.

Mutli-Organization Project Team.

Title: Safety-Related Instrumentation and Control Pilot Upgrade: Conceptual - Detailed Design Phase Report and Lessons Learned
Authors: INL - P. Hunton, R. England / Constellation: M. Samselski, G. Segner
Report: INL Technical Report INL/RPT-23-72105
Link: https://inldigitallibrary.inl.gov/sites/sti/sti/Sort_66259.pdf

International Students Learn About Nuclear Deployment at Idaho National Laboratory

- Idaho National Laboratory hosted students from Germany, France, Italy, Canada and the United States to learn from experts in nuclear about deploying nuclear microreactors .
- The "*2023 Small Modular Reactor Microreactor Pitch*" was organized by:
  - University of Michigan, Fastest Path to Zero Initiative
  - Organization for Economic Cooperation and Development
  - Nuclear Energy Agency, Nuclear Education, Skills and Technology (NEST) Small Modular Reactors Program
  - McMaster University, Small Modular Advanced Reactor Training (SMART) Collaborative Research and Training Experience (CREATE) program
  - INL, Emerging Energy Markets Analysis Initiative

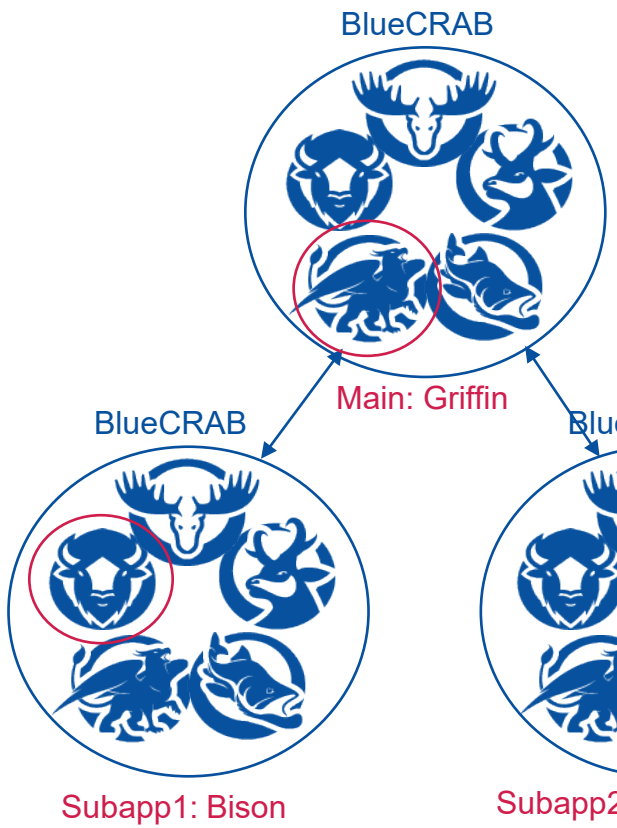
INL Director John Wagner (left) welcomes 38 international students who participated in the NEST program, a weeklong summer school, May 22-26. Students (below) presented their plans on deploying a microreactor, following lessons/ discussions with experts in the field.

Dawn.Scates@inl.gov

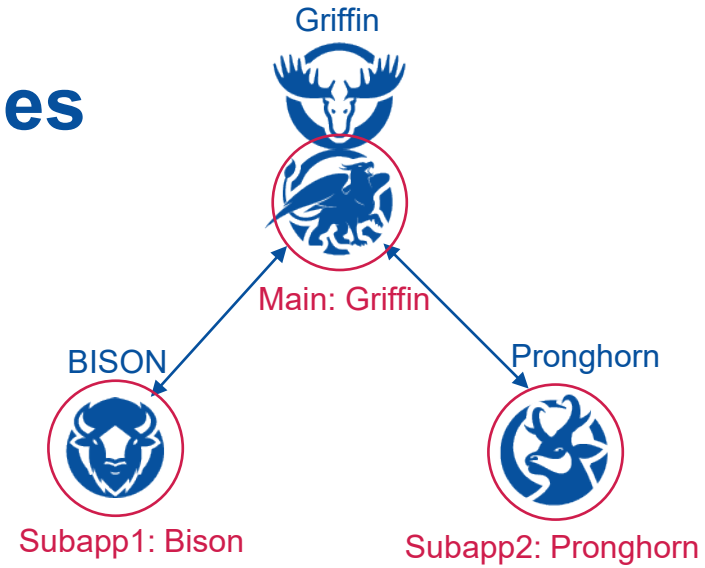
DOE-NE Nuclear Energy Advanced Modeling and Simulation Program

MOOSE Dynamic Application Loading Simplifies Configurations, Licensing and Accessibility

- MOOSE's dynamic application loading capability allows individually compiled applications to work with one another seamlessly.
- Only directly-used applications must be licensed and available during runtime.
- Users do not need to add an application to a combined app prior to use in a MultiApp simulation.
- Minimal input file changes may be needed to supply a library search path.



Previous monolithic MultiApp example.

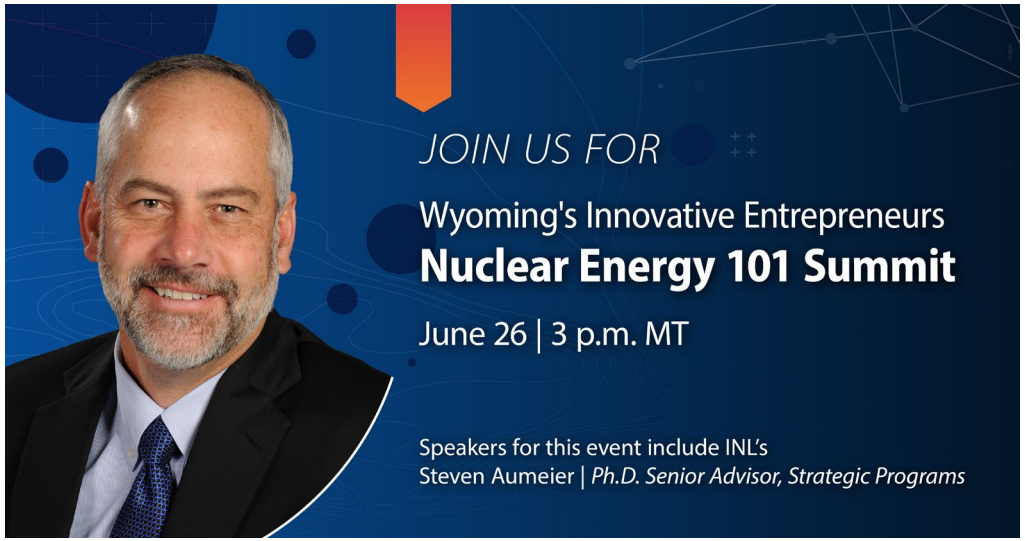


New dynamically loaded MultiApp example.

Cody.Permann@inl.gov

Steven Aumeier Presents at the 2023 Nuclear Energy 101 Summit

- On June 26, Steven Aumeier participated in the 2023 Nuclear Energy 101 Summit in Gillette, Wyoming.
- Aumeier spoke on advanced nuclear energy technologies and applications to explain how Wyoming can expand their energy future.
- The mayor of Gillette requested the presentation from INL to inform the public about the basic understanding of advanced nuclear energy technologies and economic opportunities and provide the public a chance to ask questions.



- The event was sponsored by Wyoming's Innovative Entrepreneurs, a group of business leaders who aim to diversify Wyoming's economy through advanced manufacturing collaborations and technologies.
- Other speakers included Todd Allen from the University of Michigan and Marcio Paes Barreto from the Wyoming Energy Authority.

Nuclear Energy Influencers Isabelle Boemeke and Madi Hilly Visit Idaho National Laboratory

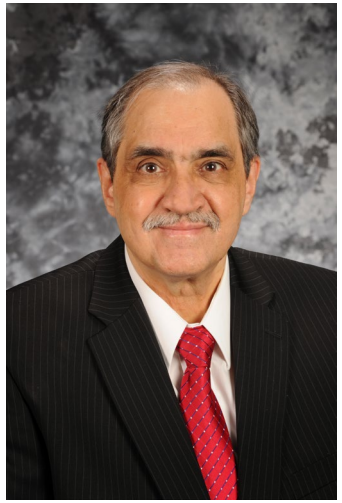
- As part of INL's efforts to elevate public perception of nuclear energy, Nuclear Science & Technology communications arranged for nuclear energy influencers to tour the lab and promote its clean energy work on social media.
- Isabelle Boemeke, model and influencer known as Isodope, presented a lecture to staff on using social media to impact the narrative around nuclear energy.
- Madi Hilly, founder of Green Nuclear Deal and author of a recent New York Times opinion piece on nuclear waste, also visited.
- Social posts from the influencers about the visit garnered more than 4 million views and resulted in coverage in Newsweek and other national outlets.

Madi Hilly and Isabelle Boemeke with INL Laboratory Director John Wagner.

External Engagement & Communications
Joel.Hiller@inl.gov

Curtis Smith, Abderrafi Ougouag, and Yasir Arafat Recognized for Exceptional Nuclear Science Achievements

- Curtis Smith, INL's director of Nuclear Safety and Regulatory Research, and Abderrafi Ougouag, INL senior researcher, were elevated to American Nuclear Society (ANS) Fellows, the organizations highest honor, recognizing individuals with outstanding accomplishments in any one of the areas of nuclear science and engineering.
- Yasir Arafat, lead engineer for the MARVEL microreactor project, was awarded the Walter H. Zinn Medal. The Zinn Medal is one of only three pinnacle awards and recognizes outstanding contributions to the advancement or implementation of nuclear technology.
- These INL employees were recognized during the opening plenary of this year's ANS Annual Meeting.



ANS Fellow Abderrafi Ougouag (left), ANS Fellow Curtis Smith (bottom) and Walter H. Zinn Medal winner Yasir Arafat (right).

NUCLEAR SCIENCE & TECHNOLOGY
Yasir.Arafat@inl.gov; Abderrafi.Ougouag@inl.gov; Curtis.Smith@inl.gov

Dr. Jacy Conrad Elected to the Miller Trust for Radiation Chemistry

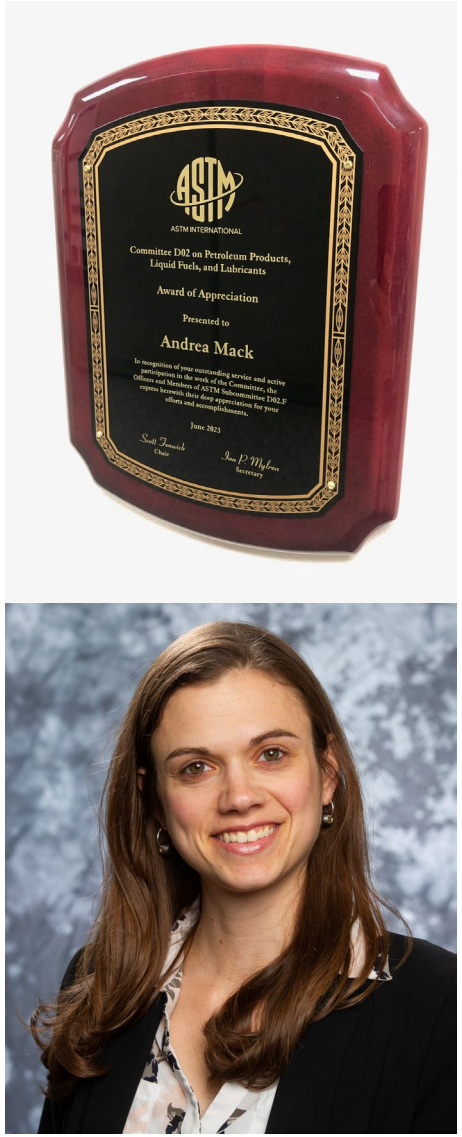
- At the 32nd Miller Conference on Radiation Chemistry, June 3–8, Jacy Conrad was elected as a committee member for the Miller Trust.
- The Miller Trust is an international society dedicated to public education on the chemical effects of radiation that hosts conferences on this subject every two years.
- Dr. Conrad is a staff scientist at the INL Center for Radiation Chemistry Research, a group of INL researchers whose mission is to:
  - Address radiation chemistry challenges throughout the nuclear fuel cycle and beyond.
  - Advance our fundamental and applied knowledge of ionizing radiation phenomena.
  - Train the next generation of radiation chemists, to preserve the world's expertise for future generations.

Jacy Conrad of the INL Center For Radiation Chemistry Research

jacy.conrad@inl.gov

INL Statistician Andrea Mack Receives an Appreciation Award from the American Society for Testing and Materials

- Andrea Mack received an Award of Appreciation from the American Society for Testing and Materials (ATSM) for her work developing probabilistic analysis methodologies for nuclear graphite.
- This award is in recognition of Mack's outstanding service and active participation in the ASTM Subcommittee D02.F, Manufactured Carbon and Graphite Products.
- Graphite is a quasi-brittle material requiring complex probabilistic analysis to determine failure probability within the core components. Development of these probabilistic failure criteria for nuclear graphite is critical in qualifying and eventually licensing graphite core components within Gen IV High Temperature Reactor (HTR) designs.
- The new standards quantify the probability of developing a flaw (crack/pore) within the graphite. Additionally, these methodologies are currently being incorporated within the new ASME Section III, Division 5 design code rules for graphite and ceramic composite components.
- Andrea Mack works with the DOE Advanced Reactor Technologies Graphite research and development program.



American Society for Testing and Materials Award of Appreciation winner Andrea Mack.

NUCLEAR SCIENCE & TECHNOLOGY
andrea.mack@inl.gov

Laboratory Fellow Sam Sham Recognized with ASME Award

- Ting-Leung (Sam) Sham received the Certificate of Acclamation Award from the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Committee on Construction of Nuclear Facility Components (III).
- The award recognizes Sam's technical contributions and leadership for the development activities at Idaho National Laboratory, Oak Ridge National Laboratory and Argonne National Laboratory, establishing three new ASME Section III, Division 5 Code Cases for the evaluation of elevated temperature components.
  - N-924 for primary load
  - N-861-1 for strain limits
  - N-862-1 for creep-fatigue
- These three new code cases take advantage of modern computing technology and pseudo-yield stresses to significantly simplify the structural design evaluations for advanced reactors.
- This development was part of the multi-year Alloy 617 Code Case effort, supported by the DOE Office of Nuclear Energy, Advanced Reactor Technologies (ART) Program.

ASME
SETTING THE STANDARD

THE
BPV COMMITTEE ON CONSTRUCTION OF NUCLEAR FACILITY COMPONENTS (III)
AWARDS
THIS CERTIFICATE OF ACCLAMATION TO

Ting-Leung Sham

For outstanding service and technical excellence in the development of three new code cases for the evaluation of elevated temperature components: N-924 for primary load, N-861-1 for strain limits, and N-862-1 for creep-fatigue. These three new code cases take advantage of modern computing technology and pseudo-yield stresses to significantly simplify the evaluations.

Thomas P. Pastor
Sr. Vice President and Chair,
Standards and Certification

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

Thomas Vogan
Board Chair,
Standards and Certification

REACTOR SYSTEMS DESIGN & ANALYSIS
TingLeung.Sham@inl.gov

Publications

- A. Abou-Jaoude, Y. Arafat, C. Bolisetti, B. Hanna, J. Belvedere, J. Blocker, B. Cooper, S. Harmon, D. McCarthy. 2023. "Assessment of Factory Fabrication Considerations for Nuclear Microreactors." NUCLEAR TECHNOLOGY. https://doi.org/10.1080/00295450.2023.2206779.
- A. Earthperson, C. Otani, D. Nevius, S. Prescott, M. Diaconeasa. 2023. "A combined strategy for dynamic probabilistic risk assessment of fission battery designs using EMRALD and DEPM." PROGRESS IN NUCLEAR ENERGY. Vol. 160. https://doi.org/10.1016/j.pnucene.2023.104673.
- A. Khanolkar, M. Cinbiz, J. Yu, X. Hu. 2023. "High temperature elastic properties of sub-stoichiometric yttrium dihydrides." MATERIALS TODAY COMMUNICATIONS. Vol. 35. https://doi.org/10.1016/j.mtcomm.2023.105879.
- A. Shah, J. Kim, R. Christian, H. Kang. 2023. "Sensitivity Analysis of Effectiveness of FLEX Strategies Using a CDF-Based Importance Measure Under Accident Conditions." NUCLEAR SCIENCE AND ENGINEERING. https://doi.org/10.1080/00295639.2023.2194460.
- B. Miller, F. Di Lemma, C. Smith, J. Cole, D. Keiser, J. Giglio, J. Jue, T. Trowbridge. 2023. "Annealing influence on the microstructure of irradiated U-Mo monolithic fuel foils." NUCLEAR MATERIALS AND ENERGY. Vol. 35. https://doi.org/10.1016/j.nme.2023.101436.

Publications

- C. Estrada-Perez, P. Sabharwall, P. Bhowmik, J. O'Brien, S. Balderrama Prieto, J. Johnson, J. Fishler, I. Reichow. 2023. "Integral and Separate Effects Test Facilities To Support Water Cooled Small Modular Reactors: A Review." PROGRESS IN NUCLEAR ENERGY. Vol. 160. https://doi.org/10.1016/j.pnucene.2023.104697.
- G. Horne, C. Celis-Barros, J. Conrad, T. Grimes, J. McLachlan, B. Rotermund, A. Cook, S. Mezyk. 2023. "Impact of lanthanide ion complexation and temperature on the chemical reactivity of N,N,N',N'-tetraoctyl diglycolamide (TODGA) with the dodecane radical cation." PHYSICAL CHEMISTRY CHEMICAL PHYSICS. Vol. 25. https://doi.org/10.1039/d3cp01119d.
- J. Conrad, K. Iwamatsu, M. Woods, R. Gakhar, B. Layne, A. Cook, G. Horne. 2023. "Impact of iodide ions on the speciation of radiolytic transients in molten LiCl-KCl eutectic salt mixtures." PHYSICAL CHEMISTRY CHEMICAL PHYSICS. Vol. 25. https://doi.org/10.1039/d3cp01477k.
- J. Conrad, M. Woods, G. Horne. 2023. “Radiolytic Evaluation of Select Sulfur Chlorides (S2Cl2 and SOCl2) for Advanced Low Temperature Chlorination of Zirconium-based Used Nuclear Fuel Cladding.” RADIATION PHYSICS AND CHEMISTRY. Vol. 206. https://doi.org/10.1016/j.radphyschem.2022.110732.

Publications

- J. Ke, A. Jokisaari. 2023. "Effects of Aluminum and Molybdenum on the Phase Stability of Iron-Chromium Alloys: A First-Principles Study." JOM. https://doi.org/10.1007/s11837-023-05909-0.
- J. Kim, S. Yoon, T. Yoo, E. Kim. 2023. "Modelling and analysis of salt-convection effect on oxide reduction process for uranium oxides using smoothed particle hydrodynamics." INTERNATIONAL JOURNAL OF HEAT AND MASS TRANSFER. Vol. 206. https://doi.org/10.1016/j.ijheatmasstransfer.2023.123965.
- J. Smith, C. Jesse, W. Hanson, C. Scott, D. Cottle. 2023. "Channel Gap Measurements of Irradiated Plate Fuel and Comparison with Post-Irradiation Plate Thickness." NUCLEAR ENGINEERING AND TECHNOLOGY. Vol. 55. https://doi.org/10.1016/j.net.2023.02.034.
- J. Stempien, Y. Wu, J. Jiang. 2023. "Catalyzed oxidation of IG-110 nuclear graphite by simulated fission products Ag and Pd nanoparticles." NUCLEAR MATERIALS AND ENERGY. Vol. 35. https://doi.org/10.1016/j.nme.2023.101438.
- S. Riley, K. Holloway, A. Bateman, R. Skifton, B. Jaques. 2023. "Influence of microstructure and phase morphology on the stability of high temperature irradiation resistant thermocouples." MATERIALS TODAY COMMUNICATIONS. Vol. 35. https://doi.org/10.1016/j.mtcomm.2023.105972.

Publications

- W. Williams, S. Vogel, M. Okuniewski. 2023. "Phase transformations and thermal expansion coefficients of unirradiated U-X wt.% Zr (X=6, 10, 20, 30) measured via neutron diffraction." JOURNAL OF NUCLEAR MATERIALS. Vol. 579. https://doi.org/10.1016/j.jnucmat.2023.154380.
- S. Terlizzi, V. Laboure. 2023. "Asymptotic hydrogen redistribution analysis in yttrium-hydride-moderated heat-pipe-cooled microreactors using DireWolf." ANNALS OF NUCLEAR ENERGY. Vol.186. https://doi.org/10.1016/j.anucene.2023.109735.