INL/MIS-24-77538-Revision-0

Publicly Available Molten Salt Data/Benchmarks

April 2024

Mark D DeHart

Changing the World's Energy Future

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Battelle Energy Alliance manages INL for the
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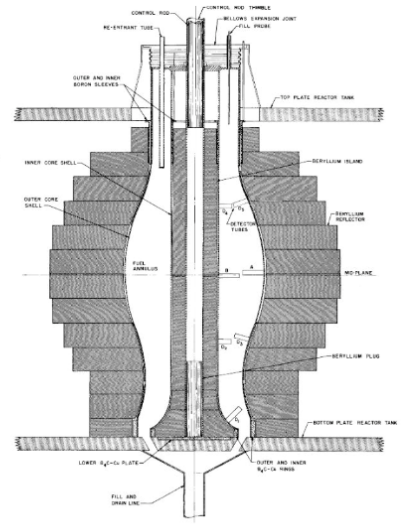
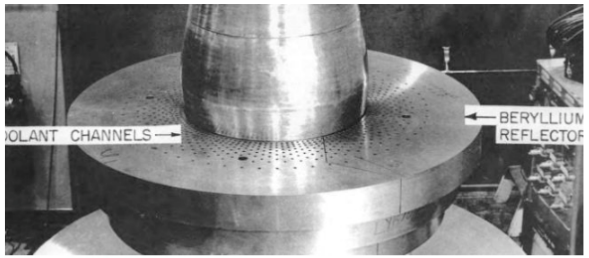
Three Molten Salt Experiments Were Operated at ORNL

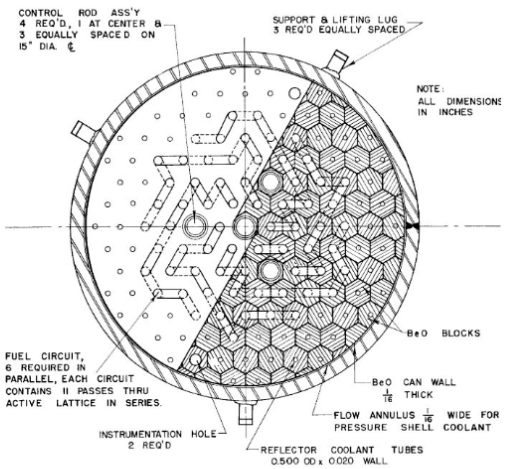
Zero Power Reactor Experiment (ZPRE)

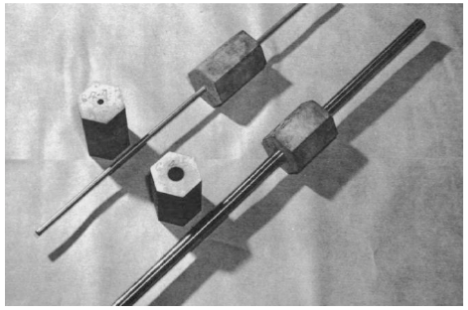




NaF-ZrF4-UF4 fuel, Be moderator, Inconel vessel.

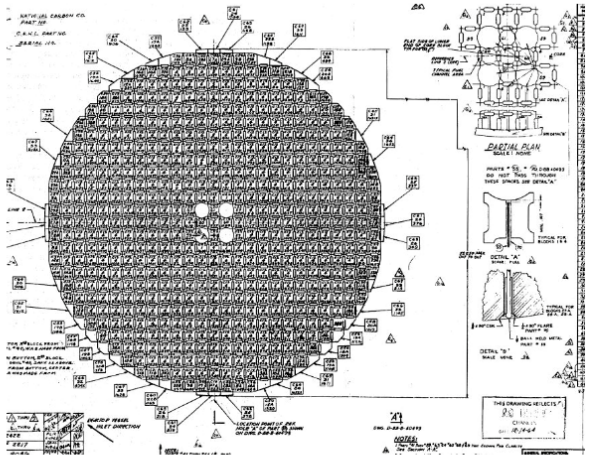
Aircraft Reactor Experiment (ARE)

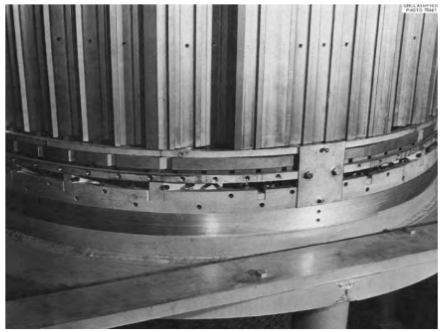




NaF-ZrF4-UF4 fuel, BeO moderator (+Na), Inconel vessel.

Molten Salt Reactor Experiment (MSRE)





7LF-BeF2-ZrF4-UF4 fuel, C moderator, hastelloy vessel.

Copenhagen Atomics Has Created Open-Source Models

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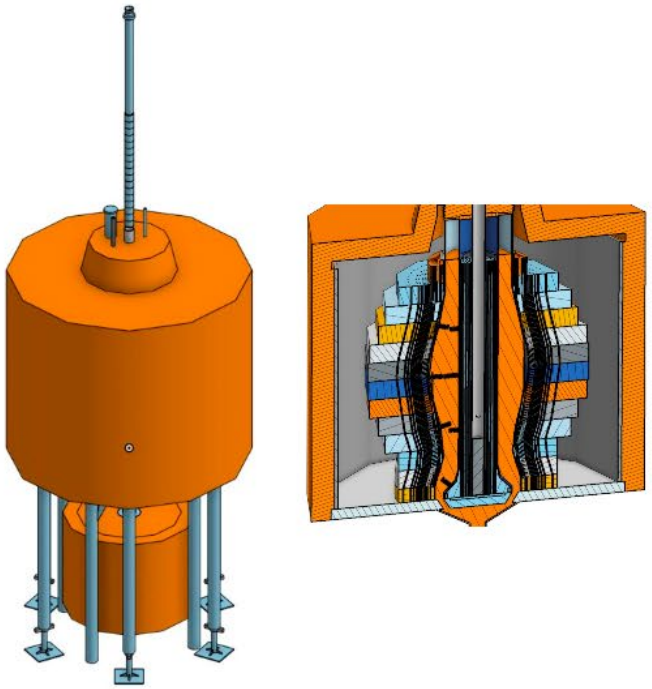
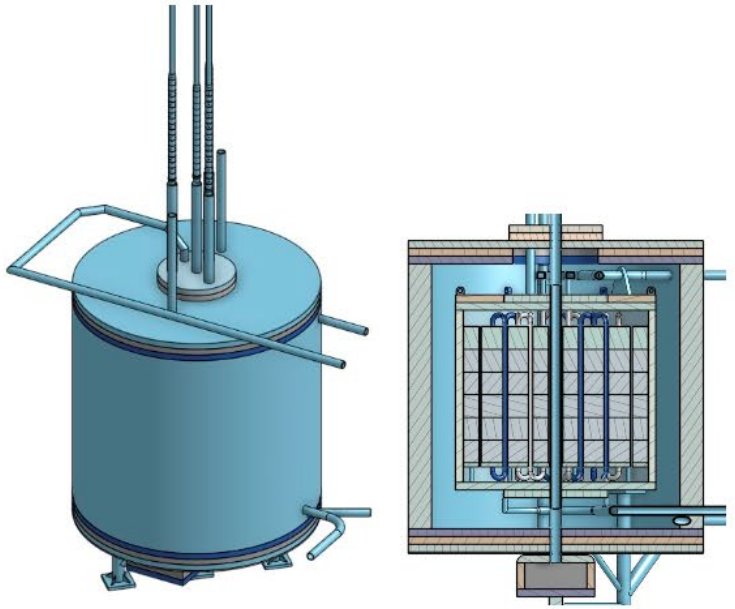
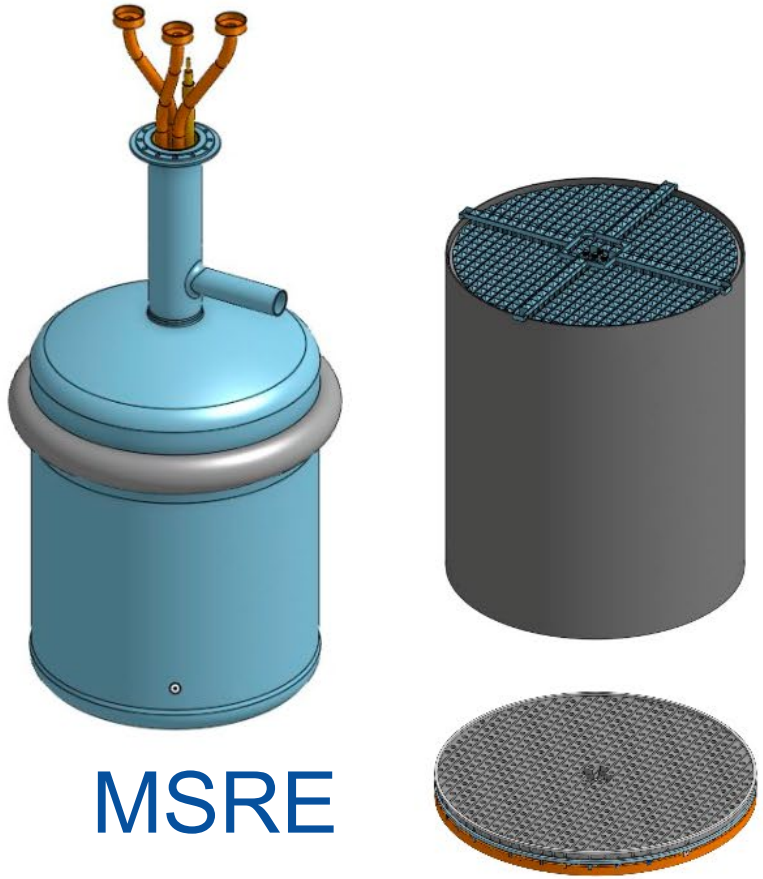


ZPRE



ARE



MSRE

Copenhagen Atomics Open-Source MSR Modeling
from CAD to burnup or dose calculations

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- Open-source Monte Carlo neutron and photon transport

OpenMC & DAGMC
Direct Accelerated Geometry Monte Carlo Toolkit

- CAD meshing tool

openmsr / **CAD_to_OpenMC** Public

- Installation scripts (OpenMC + GAGMC + MOAM + Embree + CAD_to_OpenMC + nuclear data)

Package Details: openmc-git v0.13.2.r497.g6218becb1-1

Git Clone URL: https://aur.archlinux.org/openmc-git.git (read-only, click to copy)
Package Base: openmc-git

- MSR modeling capabilities being build into OpenMC

msr continuous capabilities #2358

Open church89 wants to merge 132 commits into openmc-dev:develop from openmsr:msr_13.2_cont

Copenhagen Atomics Assessment of Data Quality

- ZPRE:
  - Core design accuracy is decent
  - Zero power data only, but only reactor with a Be metal reflector and unique design
  - Experimental data are sparse
- ARE:
  - Core design accuracy is decent
  - External design accuracy is poor
  - Moderate data
  - Experimental data is sparse
- MSRE
  - Core design accuracy is good
  - External design accuracy is decent
  - Experimental data is decent but sparse
  - In general, access to many drawings, data logs, and internal reports, not just high level ORNL & ORNL-TM reports

Copenhagen Atomics Assessment of Benchmark Potential

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- ZPRE: criticality benchmark decent
- ARE:
  - Criticality benchmark decent (includes some β_{eff} data)
  - Transient benchmark possible (only one case)
  - Missing data for burnup/redox benchmark
- MSRE
  - Criticality benchmark decent (includes β_{eff} data)
  - Transient benchmark decent (limited cases)
  - Burnup/redox benchmark decent (missing power history for ^{233}U & Pu run)
- General comment: nuclear data files are optimized for solid fuel, so deviations are expected.

Other Copenhagen Atomics Activities

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- Ongoing
  - Actively reaching out and helping other teams (university, national lab, and MSR developers) to learn OpenMC and develop open-source capabilities.
- Upcoming
  - Planning to run a subcritical test reactor in 2025, we plan to turn this into a open-source benchmark.
  - Planning to run a 1MW_{th} test reactor for 30 days by 2025/2026, and plan to turn this into an open-source benchmark.
  - Will dedicate more resources to developing the ORNL benchmarks in 2024.
  - Repositories updated as needed

Github Repositories

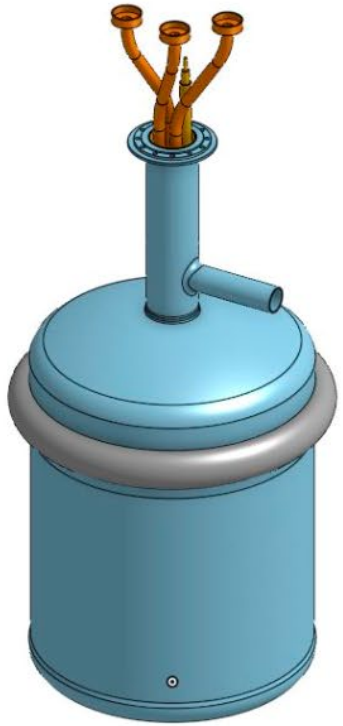
- ZPRE: https://github.com/openmsr/zpre
- ARE: https://github.com/openmsr/are
- MSRE: https://github.com/openmsr/msre
- These links, tools mentioned and archived data are available at https://github.com/openmsr

Idaho National Laboratory

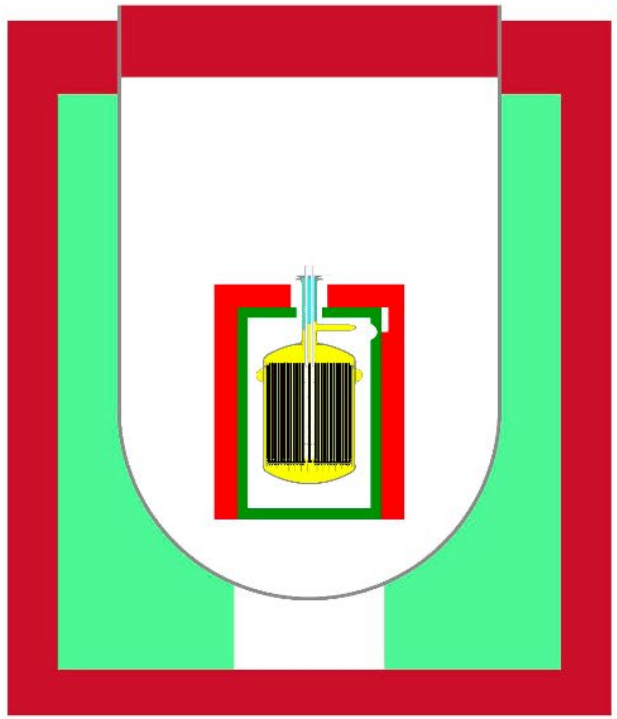
Battelle Energy Alliance manages INL for the U.S. Department of Energy's Office of Nuclear Energy. INL is the nation's center for nuclear energy research and development, and also performs research in each of DOE's strategic goal areas: energy, national security, science and the environment.

Extra Material from Copenhagen Atomics Simulations

MSRE Model

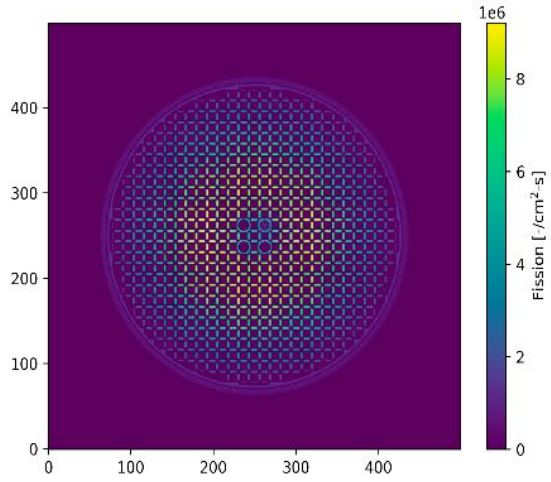


CAD geometry

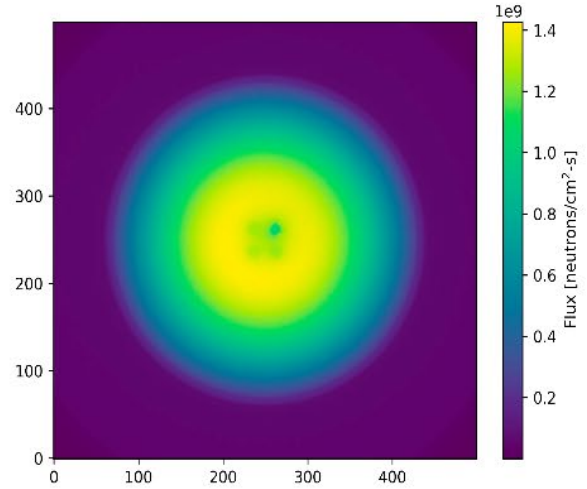


Mesh geometry

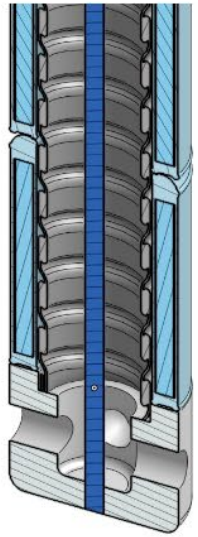
Fission rate distribution

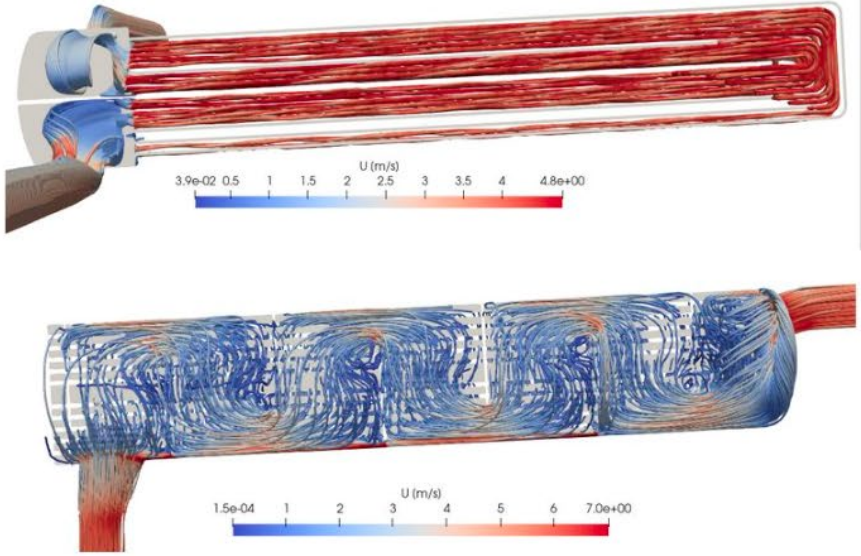


Neutron flux distribution



Neutrons flux spectrum





primary heat exchanger CFD

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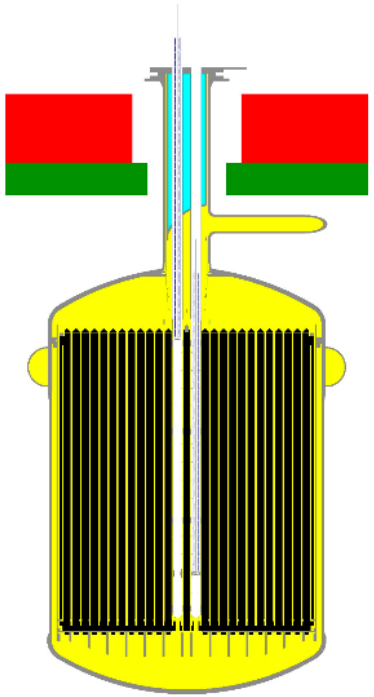
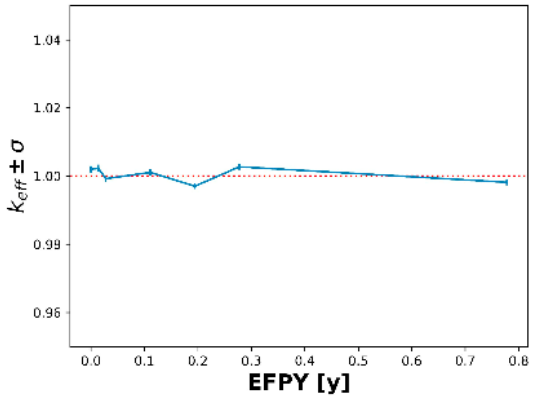
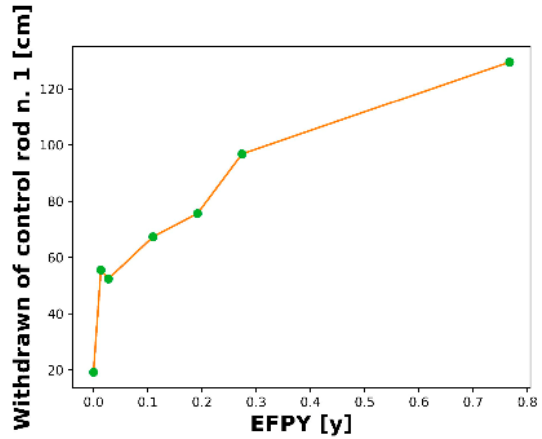
MSRE Burnup

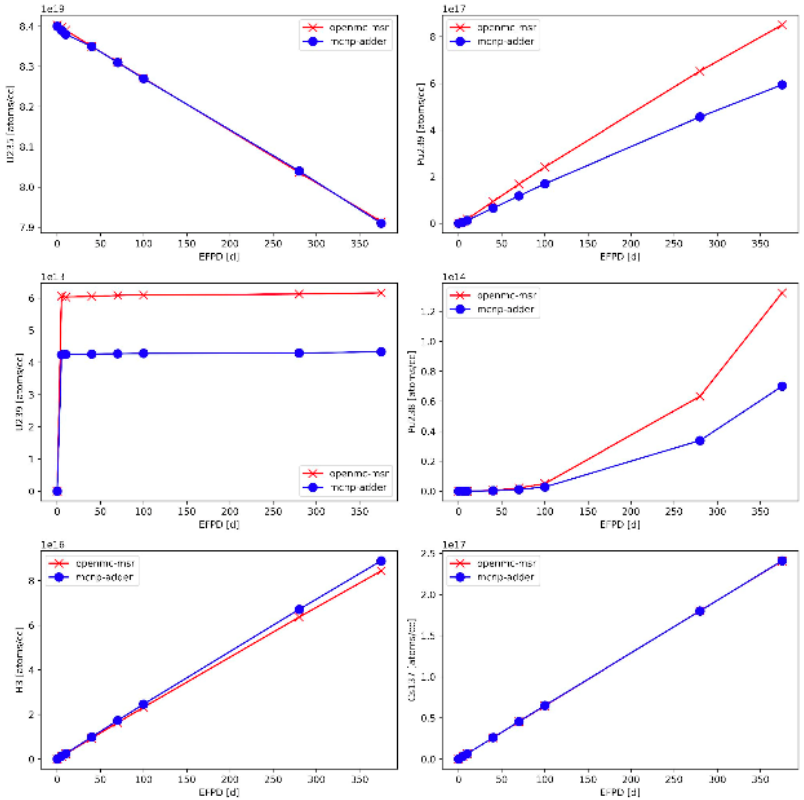
- Depletion power: 8 MWth
- Total fuel salt mass: 4590 kg
- U235 initial load: 65.25 kg
- Removal rates:
  - Noble gas (Xe, Kr) 4.067e-5 1/s
  - Metals (Se, Nb, Mo, Tc, Ru, Rh, Pd, Ag, Sb, Te) 8.777e-3 1/s

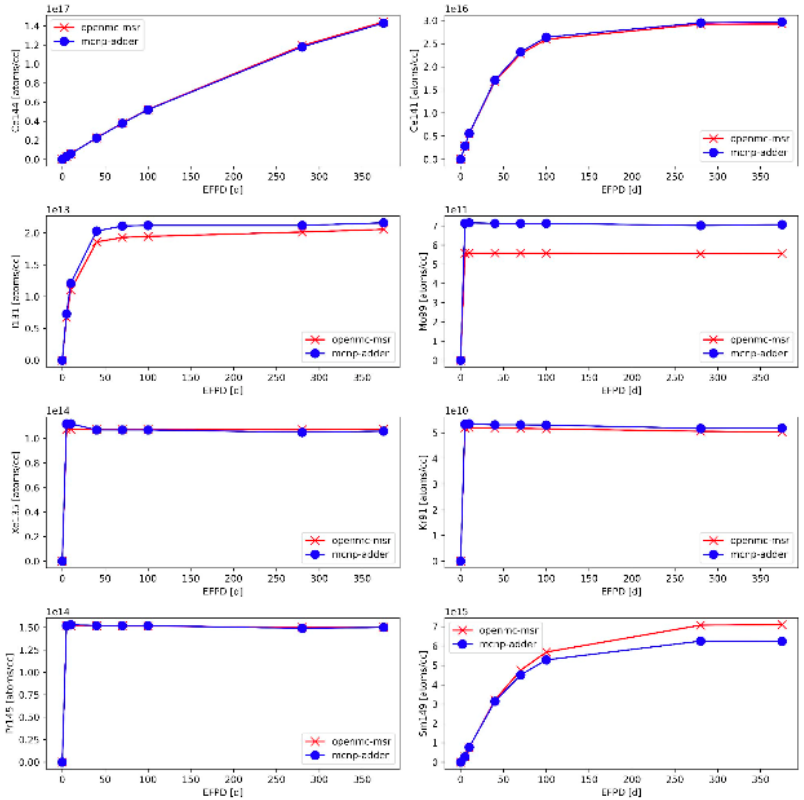






Code-to-code benchmark





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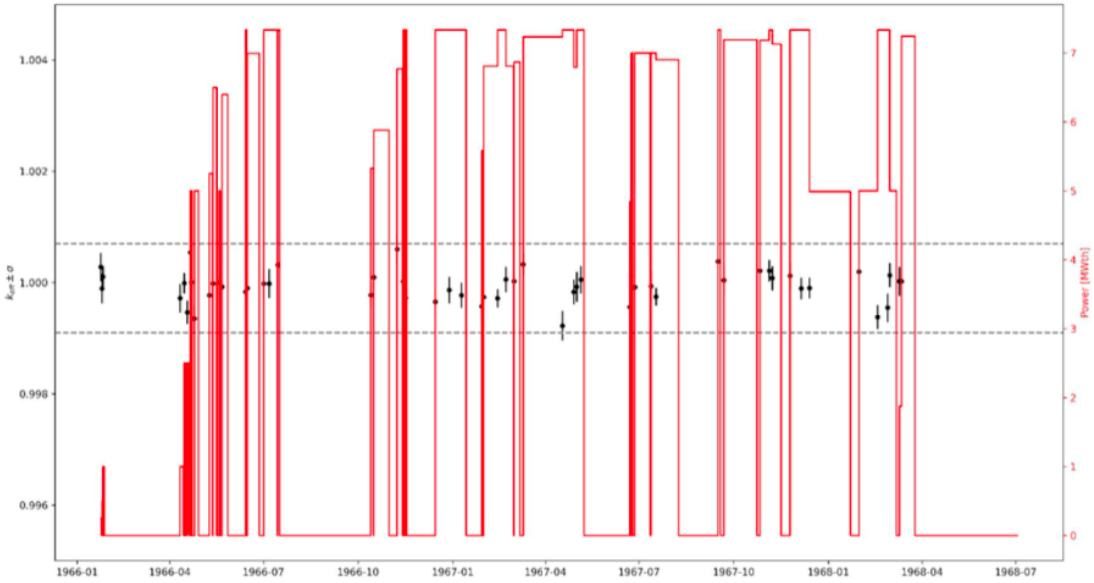
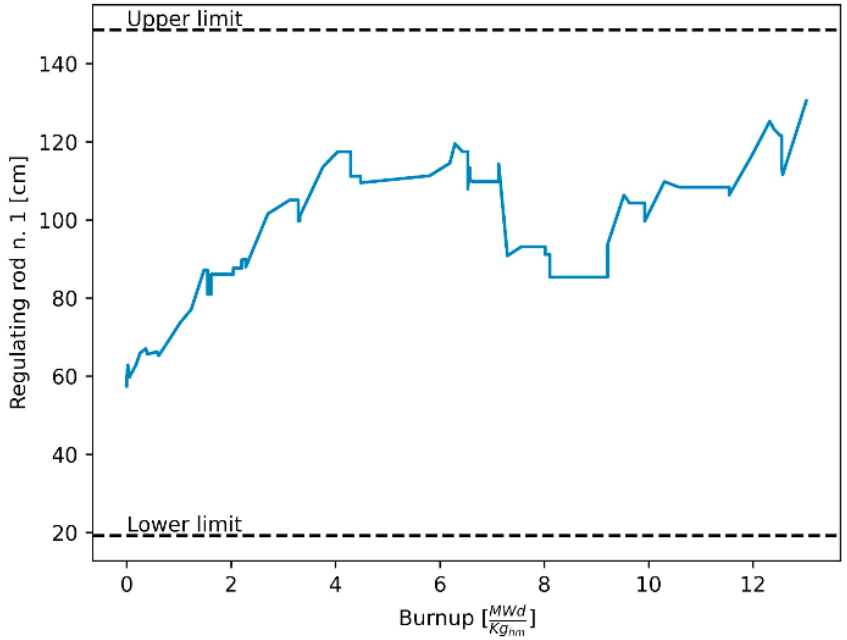
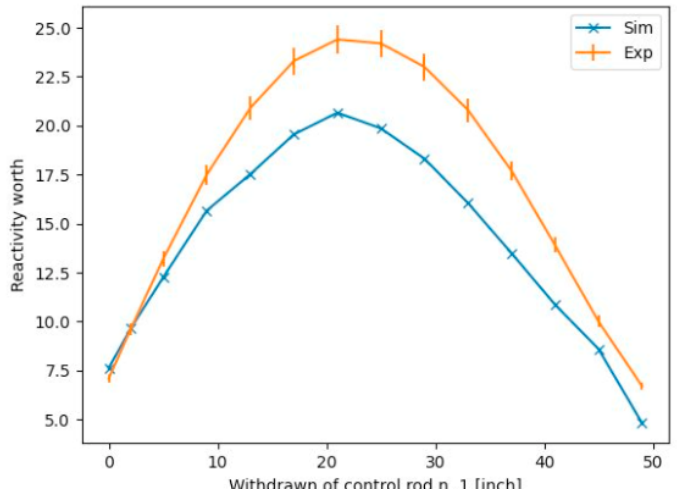
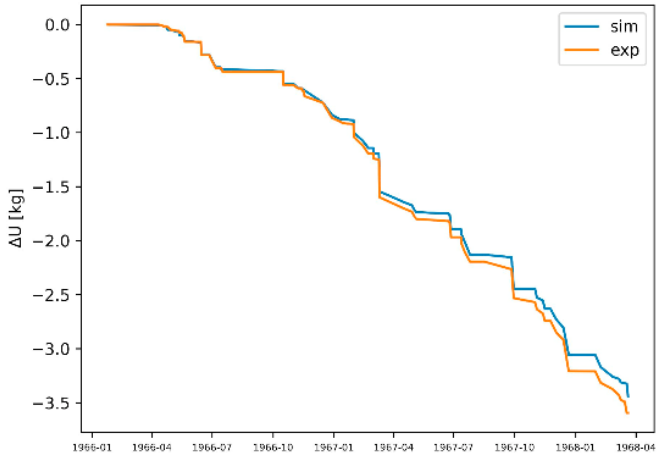
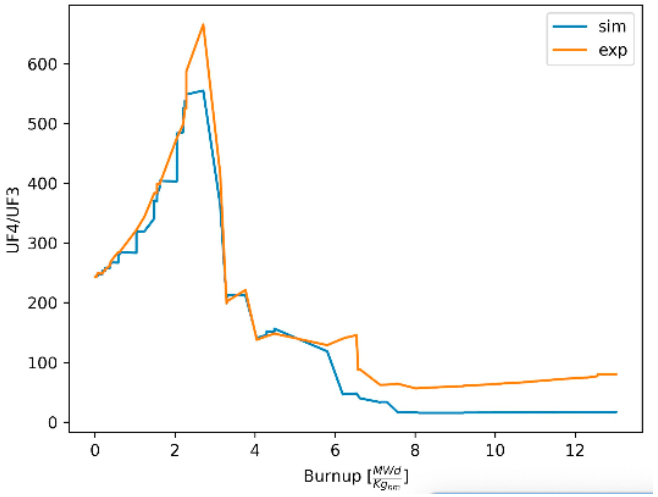
MSRE Burnup




Upper limit
Lower limit
Regulating rod n. 1 [cm]
Burnup [$\frac{MWd}{Kg_{hm}}$]


Sim
Exp
Reactivity worth
Withdrawn of control rod n. 1 [inch]


sim
exp
ΔU [kg]


sim
exp
UF4/UF3
Burnup [$\frac{MWd}{Kg_{hm}}$]