Molten Salt Reactor Dynamics
Approach to Material Accountancy
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OUTLINE
• MSR design
• Safeguards for MSRs
• Dynamic parameters dependence on Materials
• Assembling of a generic MSR model
• Frequency response in diversion cases
• Future work
Acknowledgments

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Motivation and Background

• MSRs: GenIV concept with renewed interest
• Several start-up companies in North America*
• Broad spectrum of design concepts
• Limited R&D in the recent past
• Outside of nuclear engineering experience base

Specifics of MSR Design

• Homogeneous fuel mixture with changing composition
• Fuel circulating in and out of core
• Fission products (FPs) in transit, some remain dissolved, others do not
• Off-gassing of Xe-135 and other gaseous FPs
• Migration of delayed-neutron precursors
• Online fueling and FP reprocessing
Difficulties in Safeguarding/MC&A MSRs

• International Safeguards are **required** for global deployment of any reactor design
  • IAEA significant quantity of Plutonium: 8kg
• MSRs have no agreed upon method for safeguarding
• Traditional item counting does not apply here
• In a loss of the continuum of knowledge, there needs to be a means of material accountancy in the fuel salt
Material data retrieved from MSR library

Quarter core with Li-F-Be and LEU

Burned at 20 MW/MTHM in SCALE/ORIGEN 6.2 for 3 years

20 MW reactor power
Dynamic Modeling Approach

- Methodology inspired based off of published MSRE model*
- Lumped-parameter model
- Two liquid lumps for every solid lump

Modular Dynamic Modeling

- Model developed in MATLAB™-Simulink
- Nominal Power Scaling
- Modular organization
  - Plug and play components
Frequency Characteristics over Burnup

[Graphs showing gain and phase shift over frequency with different burnup conditions: Clean, 1 Full Power Year, 3 Full Power Year]
Frequency Characteristics in Removal

![Graphs showing frequency characteristics with and without Pu removal.](image-url)
Change in Frequency Characteristics

![Graph 1: Gain Difference vs Frequency](image1)

![Graph 2: Phase Shift vs Frequency](image2)
Removal Compared to Clean Fuel Salt
Conclusions

• Dynamic behavior of MSRs are relevant to safeguards
• Pu removal leads to characteristic patterns in frequency response
• Frequency characteristics can be established continuously and while operating
• Novel approach to MSR safeguards - avoids core liquid sampling
Further Discussion

• Determine sensitivities to model parameters
  • Core size
  • External loop length
• Evaluation of delayed neutron population in external loop
• Other forms of diversion (e.g. slow trickle)
• Explore other dynamic effects of Pu removal
Backup slides
Addition of OTSG
Frequency characteristics

U-235

U-233
Response to 50 pcm Step Insertion

% Pu removed
~100%
~15%
Frequency Characteristics
Change in Frequency Characteristics

ΔGain (%) vs Frequency (rad/s)

ΔPhase Shift (deg) vs Frequency (rad/s)