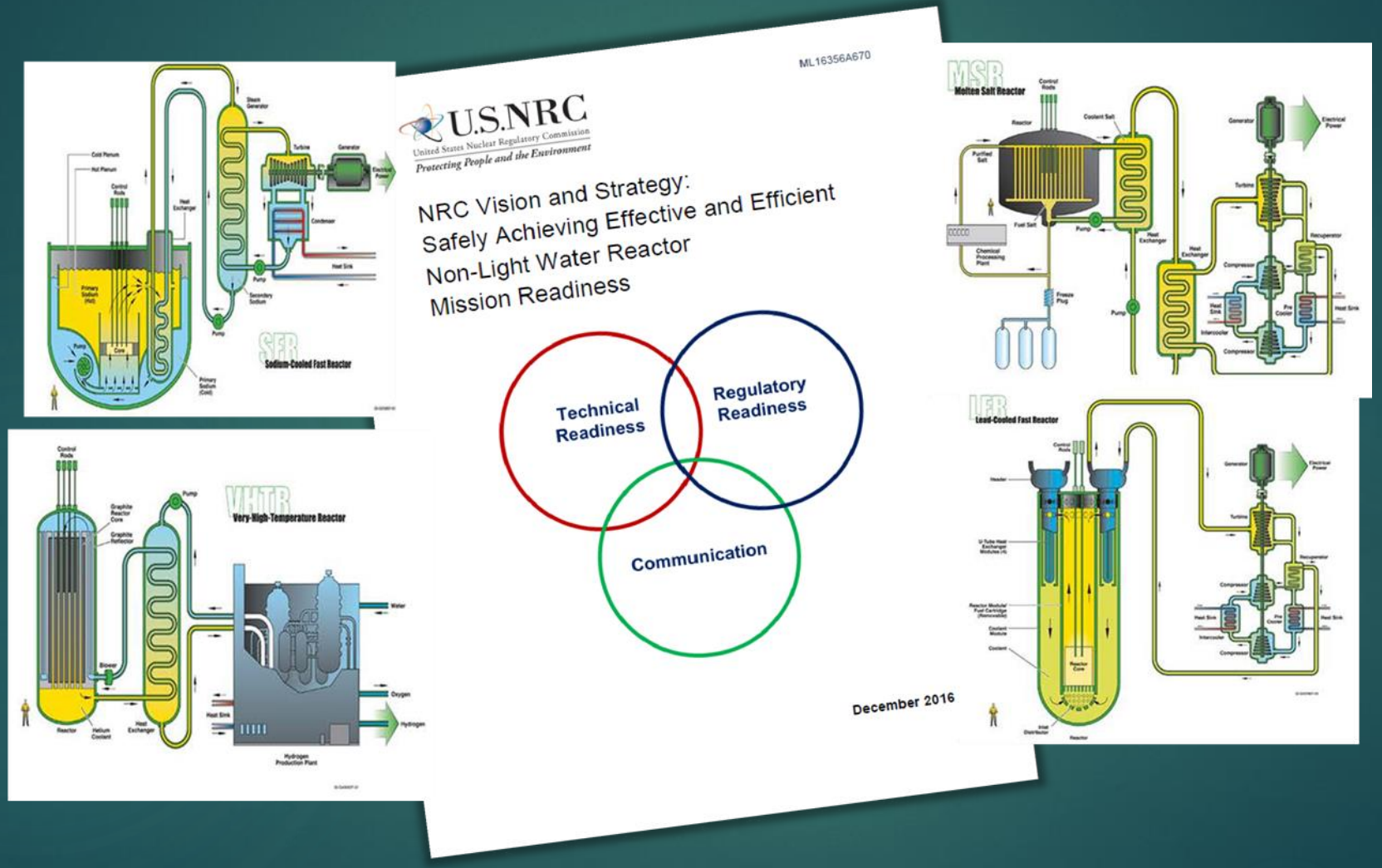
Technical Considerations for the Molten Salt Reactor Fuel Cycle

W. REED, J. CARLSON, R. IYENGAR
REACTOR ENGINEERING BRANCH
DIVISION OF ENGINEERING
OFFICE OF NUCLEAR REGULATORY RESEARCH

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

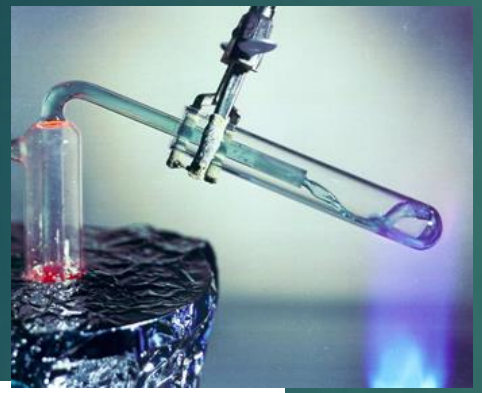
NRC's Advanced Reactor Program

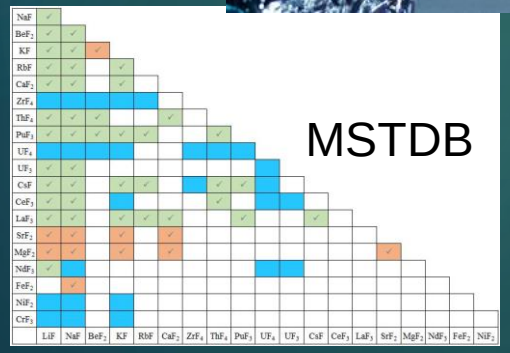


https://www.nrc.gov/reactors/new-reactors/advanced.html

Reactor Engineering Branch
Advanced Reactor Technical Support

Molten Salt Chemistry





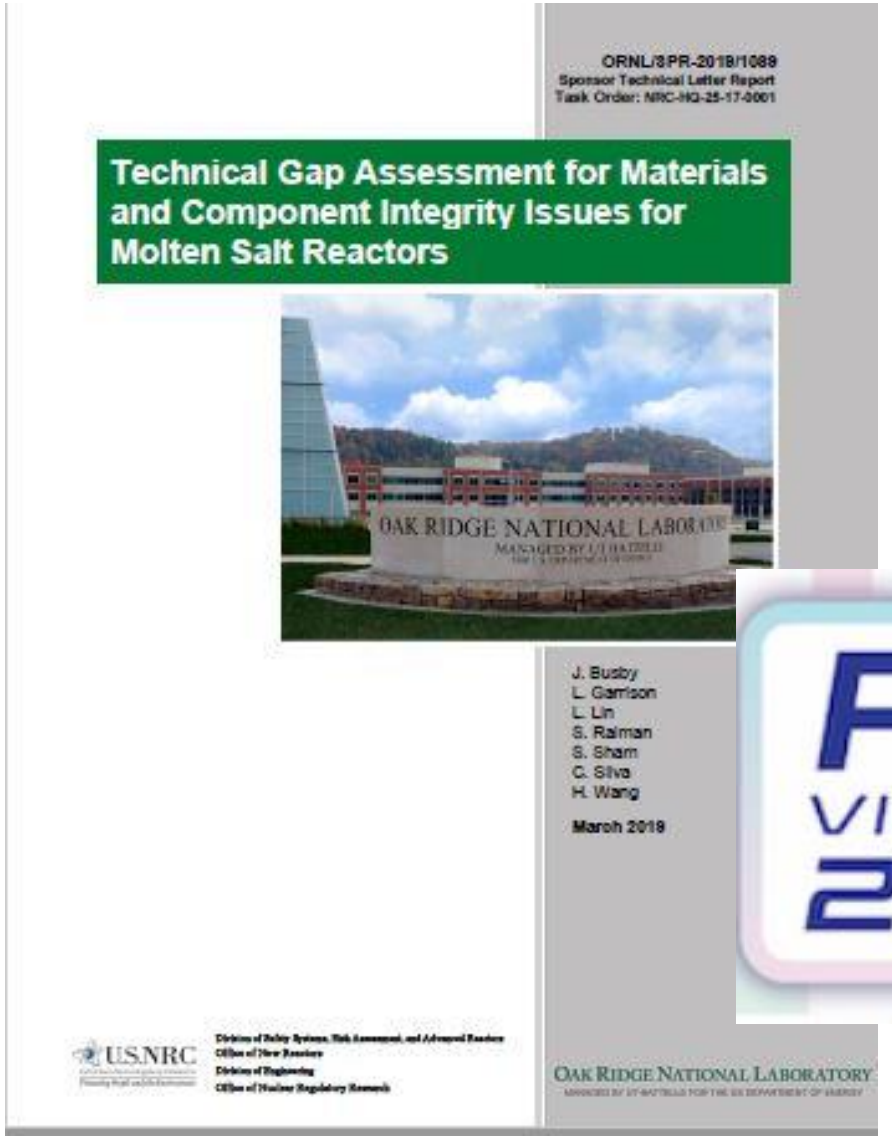
Material Compatibility; Codes and Standards

Capsules filled with KCl-$MgCl_2$ and model Ni-Cr alloys for 700°C tests

Fuel Cycle

Completed Activities - MSR

- "Technical Gap Assessment for Materials and Component Integrity Issues for Molten Salt Reactors" (ADAMS ML19077A137)
- "Technical Assessment of Materials Compatibility in Molten Salt Reactors" (ADAMS ML21084A039)
- RIC 2022 Technical Session: : Molten Salt Reactors: Rethinking the Fuel Cycle https://www.nrc.gov/public-involve/conference-symposia/ric/index.html

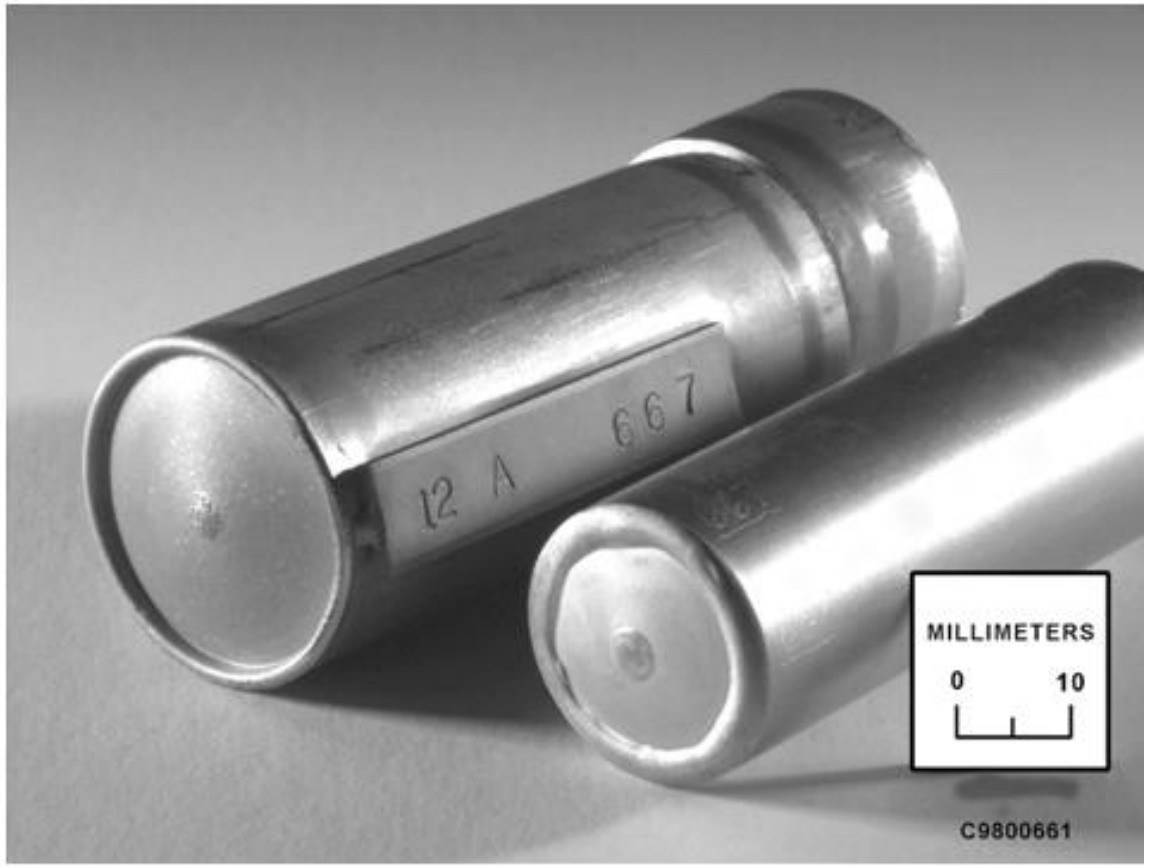


RIC VIRTUAL 2022

Current MSR Research

- Technical Assistance Pertaining to Advanced Reactors in the Areas of Corrosion Experiment Methodology and Evaluation

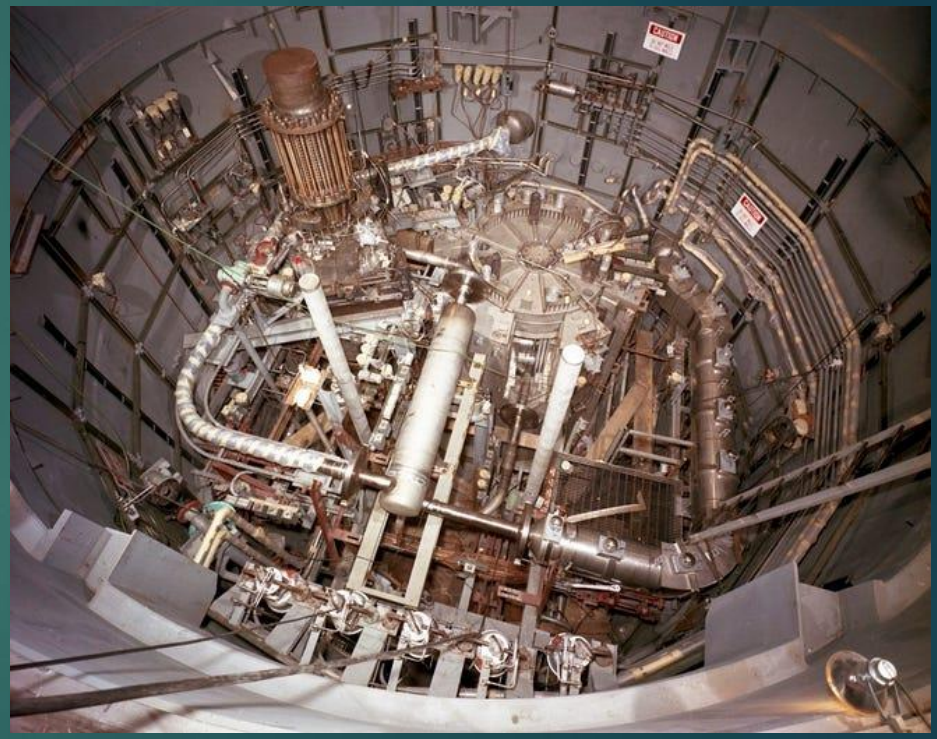
- Performing comparative evaluation of three most corrosion experiment methodologies and capsule materials.



Molten Salt Reactors - Prior Operating Experience

- ORNL operated two MSR experiments
- Prior front-end activities performed at Y-12 National Security Complex
- Lessons-learned from MSRE decommission
- No NRC regulatory precedent for front/back-end activities for MSRs

Aircraft Reactor Experiment (ARE) (1954)



Molten Salt Reactor Experiment (MSRE) (1965-1969)

Front-End Considerations

- Fuel salt enrichment, production, blending
  - Chemical reactivity hazards of halide salts
  - Production of uranium and thorium fuel salts from source material
- Transportation packages designs to support off-site operations
  - Moderator inclusion / Criticality
  - Containment performance

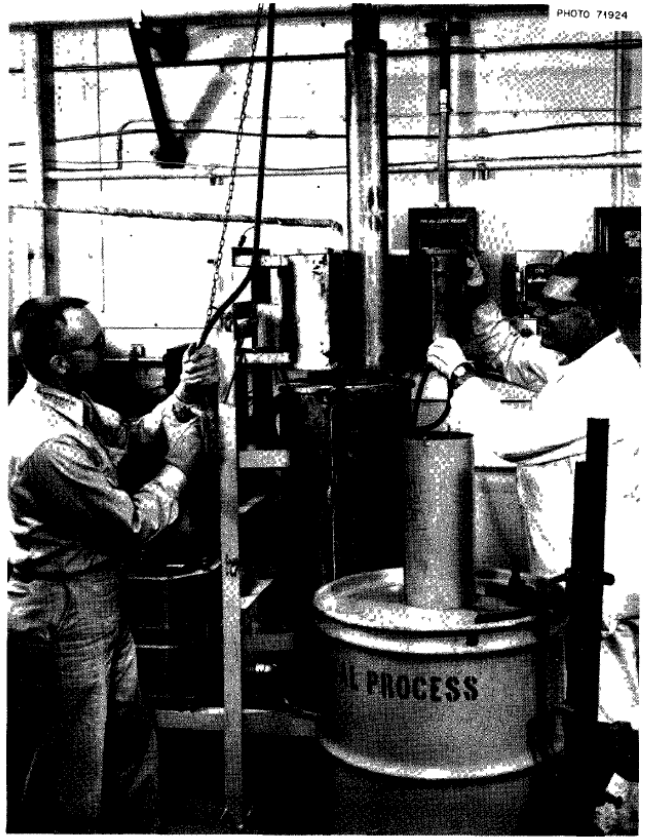
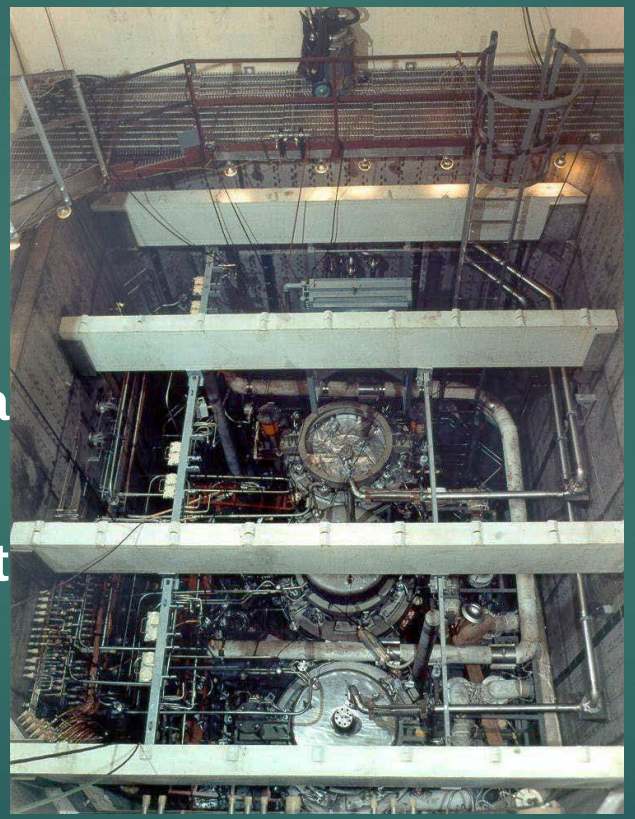


Fig. 26. Fluoride Production for MSRE – Storage Container and Holder for Enriched Fuel Concentrate Mixture.

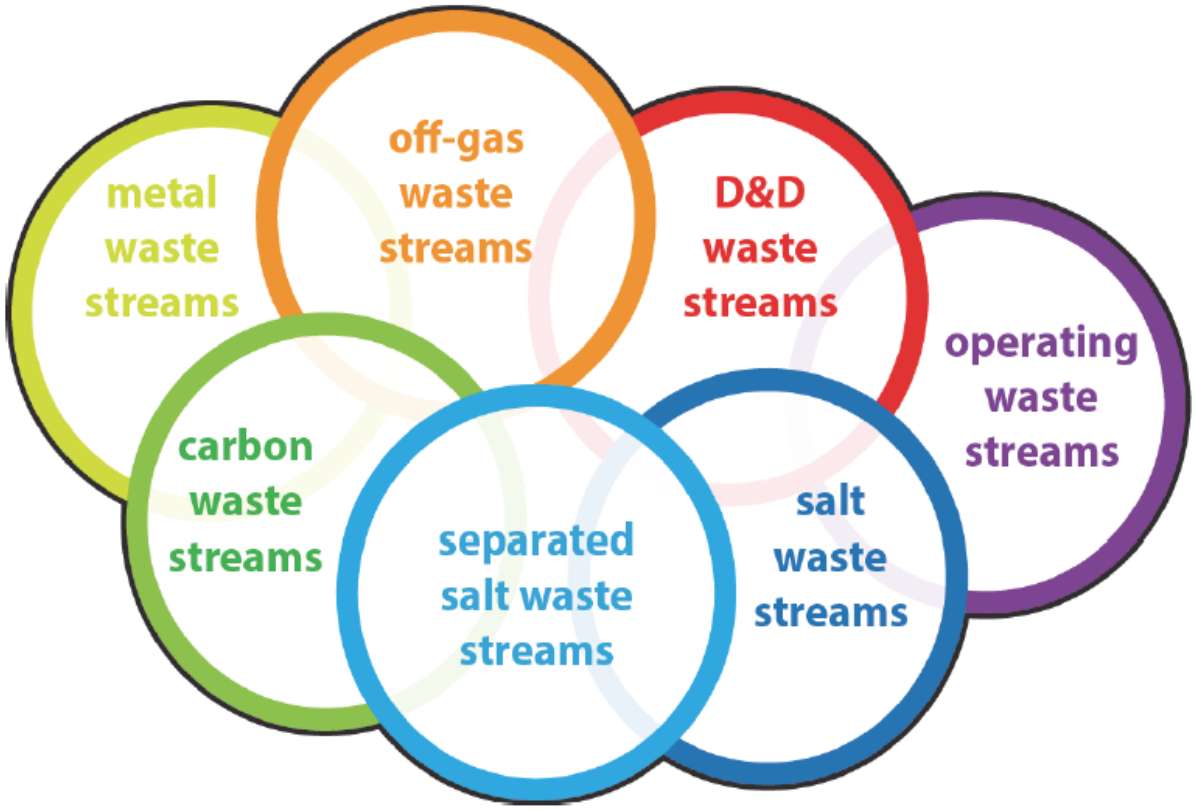
Back-End Considerations

- Confinement materials compatibility/performance
- Dose management
- Fluorine gas generation: Radiolysis from beta/gamma radiation
- Graphite waste management



Fuel Drain Tanks/Fuel Flush Tank in MSRE Drain Tank Cell

Dry Spent Fuel Casks on Concrete Pad at Nuclear Power Plant Site



MSR Waste Streams

(Riley et al., 2018)

Planned MSR Work

- Holistic look at the MSR Fuel Cycle
  - Front-end of ANLWRs, including HALEU fuel transport and molten salt reactor fuel types
  - Back-end of molten salt fuel cycle, including novel waste types, and graphite waste
- Reactor Specific Topics
  - Salt Properties and Performance
  - Chloride Salts
  - Electrochemical Monitoring and Advanced Sensors
  - Graphite Performance

Summary

Molten salt reactors pose unique challenges for front-end and back-end operations

RES collaborating with program offices on establishing future activities to ensure readiness for licensing and certification reviews

Continued / expanded engagement with DOE and industry will support mutual understanding of technical and regulatory information needs

References

- Rosenthal, M.W. "An Account of Oak Ridge National Laboratory's Thirteen Nuclear Reactors," Report No. ORNL/TM-2009/181. Oak Ridge, TN: Oak Ridge National Laboratory. 2010.
- Fredrickson, G., G. Cao, R, Gakhar, and T. Yoo. "Molten Salt Reactor Salt Processing – Technology Status," Report No. INL/EXT-18-51033. Idaho Falls, ID: Idaho National Laboratory. 2018.
- Riley, B.J. et al., "Identification of Potential Waste Processing and Waste Form Options for Molten Salt Reactors". Report No. PNNL-27723. Richland, WA: Pacific Northwest National Laboratory. 2018.