

Molten Salt Reactor Workshop

DOE's Enhanced R&D Focus on MSRs

Brian K. Robinson

Program Manager, Molten Salt Reactors

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Advanced Reactor Technologies Program Overview, Mission & Structure

- **Program Mission:**
 - Identify and resolve the technical challenges to enable transition of advanced non-LWR reactor technologies and systems to support detailed design, regulatory review and deployment by the early 2030's.
- **POC's**
 - Director – Alice Caponiti (DOE-HQ)
 - MSR Program Manager – Brian K. Robinson (DOE-HQ)
 - National Technical Director – Lou Qualls (ORNL)

Advanced Reactor Technologies Research Questions

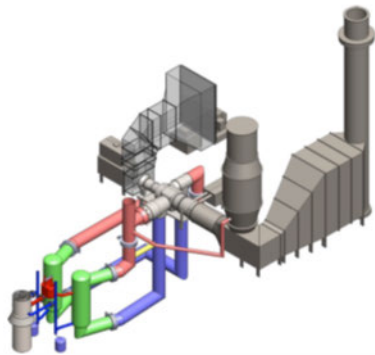
- **R&D programs are working to address several high level questions related to advanced reactor development and deployment, including:**
 - How can we improve the affordability of nuclear power?
 - How can we improve the inherent safety of advanced nuclear reactors?
 - How can we improve on the proliferation resistance of advanced reactors?
 - How can we expand nuclear technologies into non-traditional nuclear energy markets?
 - How can we increase the performance and efficiency of advanced nuclear plants through new materials, advanced systems or components?

Advanced Reactor Technology R&D Activities

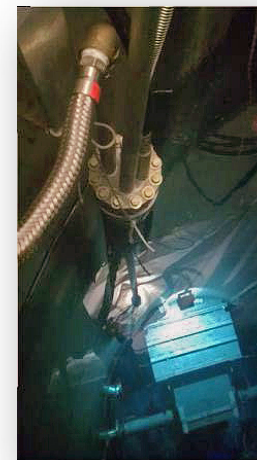
- The previous MSR Workshop (2016) identified two initiatives:
 - *“Develop multiscale models to understand the chemistry of fission products in operating reactors (high performance computing, integration with neutronics and thermohydraulics)”*
 - *“Develop databases and computational methods for phase diagram development”*
- The following resulting activities being considered for future R&D activities:
 - Salt property data collection and salt property database development
 - Salt property predictive modeling (fundamental salt chemistry)
 - Salt and materials interface behavior
 - Salt constituent evolution due to exposures under reactor conditions
 - Salt processing during reactor operations (fission product management)
 - Salt monitoring and processing during reactor operation (salt corrosion chemistry)

Advanced Reactor Technology MSR Activities

- Nuclear Energy University Program (NEUP), 2011-2017
 - \$800K (FHR)
 - *Design of a Commercial-Scale, Fluoride-Salt-Cooled, High-Temperature Reactor, Investigation of Overcooling Transients that include Freezing,*
 - *In Fluoride-Salt Cooled High-Temperature Reactors (FHRs)*
 - \$4.6M (MSR) NuSTEM, *Methods to Predict Thermal Radiation and to Design Scaled Separate and Integral Effects Testing*
 - \$800K (Materials) *Bimetallic Composite (Incoloy 800H/Ni-201) Development and Compatibility in Flowing FLiBe*
- Integrated Research Projects (IRP)
 - \$7.5M (FY11) MIT, Wisconsin, UC Berkeley; *High-Temperature Salt-Cooled Reactor for Power and Process Heat*
 - \$10M (FY14) MIT, Georgia Tech, *Integrated Approach to FHR Technology and Design Challenges*
 - \$3M (FY17) TAMU, UC-Berkey, SAMOFAR, *Grand Challenge Problem for Nuclear Energy*



Kairos Power
UCB PB-FHR



Advanced Reactor Technology MSR Interfaces 1/2

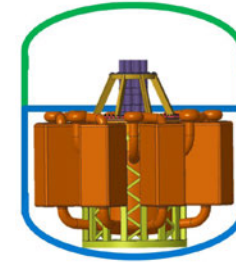
- Gateway for Acceleration Innovation in Nuclear (GAIN)
 - FY16 - 2 salt related awards in FY16 (\$0.4M)
 - FY17 - 7 salt related awards in FY17 (\$2.1M)
- Industry Engagements

Company	Concept Type	DOE Supported Work
TerraPower (MCFR)	MCFR	ARC 15 (partnered with Southern Co. Services)
Elysium	MCFR	GAIN Voucher (FY17)
Kairos	MSR solid fueled	GAIN Voucher (FY17)
Terrestrial Energy	MSR liquid fueled	GAIN Voucher (FY16 and FY17)
Transatomic Power	MSR liquid fueled	GAIN Voucher (FY16 and FY17)
Southern Company Services	MCFR	ARC 15 (Molten chloride fast reactor development)

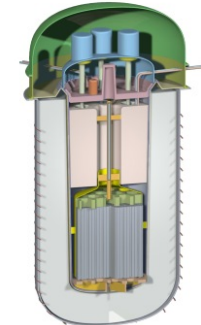
Topics	Awardees
IMSR® Fuel Salt Property Confirmation: Thermal Conductivity and Viscosity	ANL
Evaluation of Power Fluidic Pumping Technology for Molten Salt Reactor Applications	ORNL
Fuel Salt Characterization	ANL
Synthesis of Molten Chloride Salt Fast Reactor (MCSFR) Fuel Salt from Spent Nuclear Fuel (SNF)	INL
NEAMS Thermal-Fluids (T/F) Test Sand (T/F-TS) for Fluoride-Salt-Cooled, High-Temperature Reactor (FHR) Development	ANL
Conversion of LWR SNF to Fluoride Salt Fuel	ORNL
Development of the Micro-scale Nuclear Battery Reactor System	INL

Advanced Reactor Technology MSR Interfaces 2/2

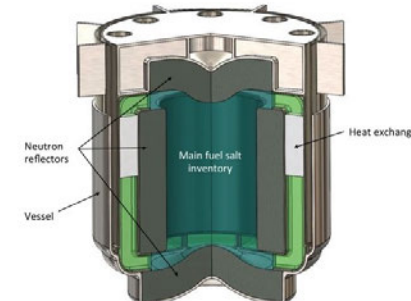
- Advanced Reactor Working Group (NEI)
 - Quarterly meetings
 - January 2017 - Presentations available on GAIN website Includes overview of current U.S. MSR modeling and simulation tools
- MSR Technology Working Group (TWG)
 - Quarterly meetings
 - December 2016 Letter outlining Separate Effects Test Program for MSRs
- Molten Salt Chemistry Workshop
 - April 2017 Emphasized identifying fundamental knowledge gaps
- Office of Science - Basic Energy Science (BES)
 - August 2017 – Establish the science base to realize molten salt coolants and liquid fuels
- Small Business Innovation Research (SBIR)



Elysium USA
MCSFR



Terrestrial Energy USA
IMSR



TerraPower
MCFR

Potential MSR FY18 R&D Activities

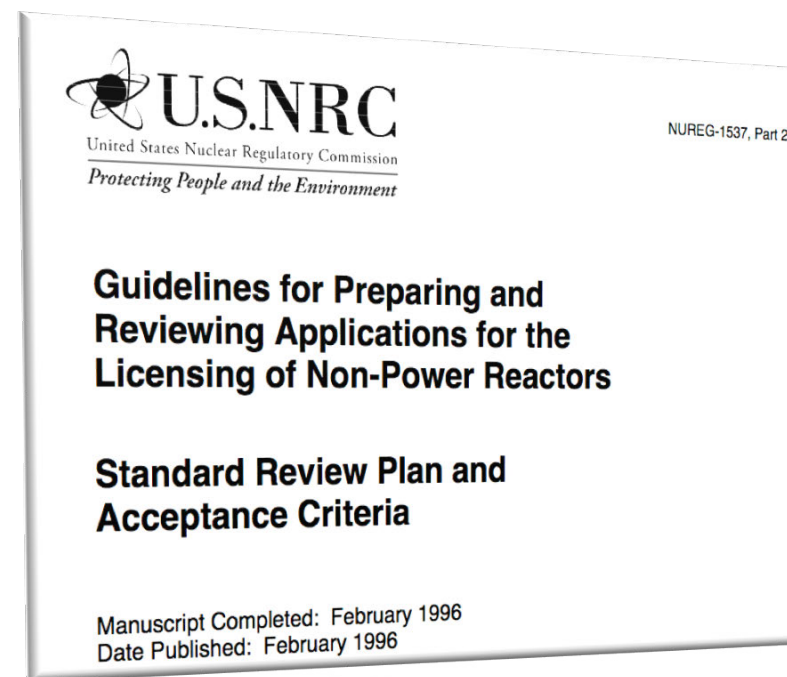
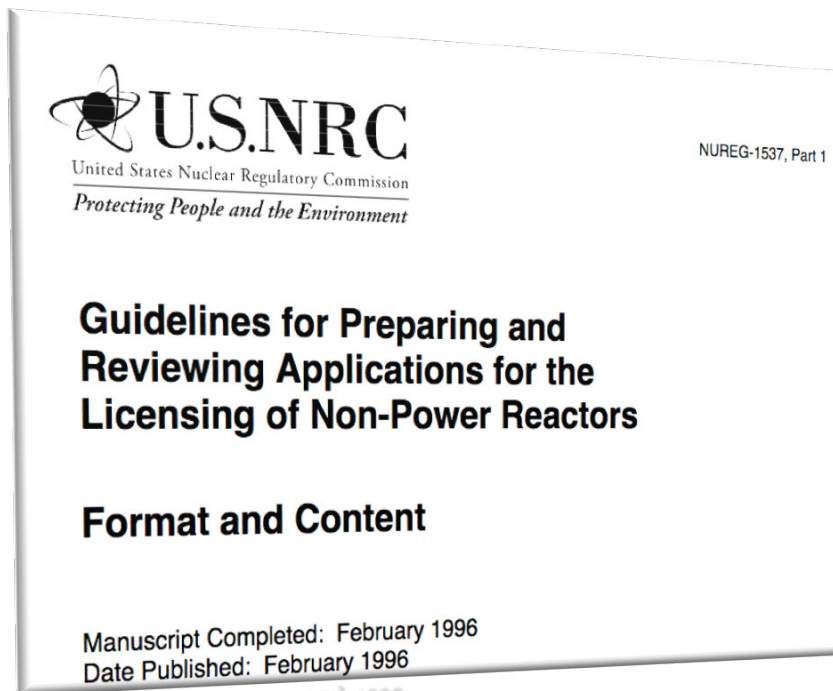
- **Technology Development and Demonstration**
 - *Hardware and instrumentation needs are evaluated to ensure enabling capabilities exist for chemistry monitoring, corrosion testing, instrumentation and control, and component development*
- **Methods, Modeling and Validation**
 - *Ensure neutronic and thermal-hydraulic models are readily adaptable for MSRs; predictive chemistry models related to salt property evolution, salt and material interactions, and salt constituent inventory tracking*
- **Fuel Qualification**
 - *Develop and understand fuel salt chemistry and associated regulatory challenges*
- **Advanced Materials Development**
 - *Develop and qualify of advanced structural materials by leveraging international collaborations (DOE, KAERI, EU, JAEA, PBMR) to ensure compliance with ASME Section III Division 5 for High Temperature Reactors*
- **Coolant Chemistry**
 - *Establish a DOE database and develop predictive modeling frameworks*

American Nuclear Society Standards

- Currently there are four standards under development supporting MSR.
 - ANS-20.1, “Nuclear Safety Design Criteria for Fluoride Salt-Cooled High-Temperature Reactor Nuclear Power Plants” (in development)
 - ANS-20.2, “Nuclear Safety Design Criteria and Functional Performance Requirements for Liquid-Fuel Molten Salt Reactor Nuclear Power Plants” (in development)
 - ANS-30.1, “Integrating Risk and Performance Objectives into New Reactor Nuclear Safety Designs” (in development-first draft)
 - ANS-30.2, “Categorization and Classification of Structures, Systems, and Components for New Nuclear Power Plants” (in development)

ANS Standards for Research Reactors: NUREG 1537

- In NUREG 1537 eleven ANS standards for research reactors are referenced
- All will need to be examined to determine applicability for use in licensing a MSR test reactor



Summary

- Over the past few years DOE has Enhanced R&D Focus on MSRs
- While there are many MSR challenges, most can be overcome through collaborative efforts of industry, national laboratories and universities.
- Thank you for your support and we look forward to working with you.