Development of Molten Salt Capabilities at Canadian Nuclear Laboratories

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Outline

• What’s happening at CNL
  • Demonstration reactor
• MSR Modelling and Simulation
• Fission Product Release tests in molten salt
• Development of Thermophysical Properties Measurement
Our Vision

• “demonstrate the commercial viability of the small modular reactor by 2026.”

• “recognized globally as a leader in SMR prototype testing and S&T support.”

• “be a recognized hub for SMRs, where multiple vendor-supported prototypes are built and tested.”

• “in the next 10 years ... host a prototype”

Excerpts from our 10 Year Plan (www.cnl.ca/strategy)
SMR Demonstration at Canadian Nuclear Laboratories

Strong response to the first intake

- Four responses to CNL’s initial Invitation
- Three respondents to “Stage 1” and one to “Stage 2”
- Canadian and International responses
Generic Siting Activities

Technology neutral undertaking, CRL and WL

- Generic SMR siting study using broad vendor feedback
- At least 10 areas have been identified at CRL, and another 12 at WL
  - Some will be more suitable than others
  - Some will be more suitable than others for different technologies
  - Some of these areas could handle more than one SMR

The number of SMRs not likely to be limited by the # of sites...
Building momentum

**RESEARCH**
- Construction
- Remote inspection and monitoring
- Human Performance Modelling & Simulation
- Computational tools
- Waste management
- Hybrid energy systems
- Passive safety systems
- Severe accidents

**CAPABILITY**
Continue to invest into the facilities and capabilities needed to support SMR development, including molten salts

**COMMERCIAL**
- 18 NDA
- 7 MOUs
- 8 MTA
- 6 contracts
- 22 more in discussion

**SITING**
- Generic siting studies completed
- Vendor-specific siting studies underway
- Site application invitation issued
Modelling of Advanced Reactors at CNL

- Coupled reactor transient simulation toolset suitable for different reactor technologies.
- Scope: Molten salt, gas-, lead-cooled reactor concepts.
- Selected codes for testing includes:
  - Monte Carlo (SERPENT), deterministic (Rattlesnake)
  - System thermal-hydraulics (RELAP5-3D)
  - Computational fluid dynamics (Siemens STAR-CCM+).
ORNL MSRE Transient simulations

Serpent

Relap5-3D

Power

Temperature

and density

MSRE Reactivity Transient Simulations with Fuel Temperature Feedback
- Rods Out (12.5 mk Supercritical)
- Rods In (8.7 mk Subcritical)
- Rods Steady (Critical)

MSRE Rod-Insertion Transient Simulation with Fuel Temperature Feedback
- Temperature Change [K]
- Reactivity Insertion [mk]
- Thermal Power [MW]
ORNL MSRE CFD simulations

- Stand-alone (STAR-CCM+) and coupled (STAR-CCM+ and RELAP5-3D) calculations are being executed,
- Good agreement was obtained against measurements.

*Podila et al., (2018), G4SR1 conference proc.
Fission Product Release Tests

- Six tests were performed on fission product release from molten salt mixtures in March 2018 using a uranium/fluoride salt and a uranium fluoride/chloride salt.
- Test temperature was 1000°C, under what we considered to be beyond-design-basis-accident conditions.
- The data from the experiments will be analyzed in 2018/19, and published in the open literature by March 2020.
Molten Salt Capability Development

Thermophysical properties

- Currently have wide capabilities in measurement of thermophysical properties of solid fuels
- Expanding to molten salts
- Developing sample encapsulation techniques, purchasing new equipment
  - Liquids → non-active molten salts → active molten salts

DryBox for non-active molten salts

DryBox for active molten salts

Differential Scanning Calorimeter (DSC)
- Melting points
- Heat capacity
- Phase diagrams

Laser Flash (LFA)
Thermal diffusivity measurements

Dilatometer
Liquid density measurements
Molten Salt Capability Development

Thermal diffusivity/conductivity measurements of molten salts by the laser flash technique

- Designed and manufactured a holder for liquid samples
- Demonstrated powdered sample encapsulation for thermal diffusivity measurements on KNO₃ ensuring plane parallel disc sandwiched between the lid and crucible of the holder
- Measured reproducible thermograms of a molten nitrate salt encapsulated in a graphite holder

KNO₃ powder loaded into graphite crucible

Encapsulation & pre-melting in a vacuum furnace

KNO₃ after LFA measurement

Lid

Crucible

Liquid sample

Three layer model based on the classic multilayer representation of Lee et al

Lee et al., Thermal conductivity 15, Springer, Boston, 1978

Melting point of KNO₃

Tₚ = 334 °C

Experimental Fit

Radiative contribution not included in the model

T = 350 °C

Three layer model based on the classic multilayer representation of Lee et al
Molten Salt Capability Development

Thermophysical properties: ongoing and future work

**Thermal diffusivity/conductivity of molten salts**
- Development of sample encapsulation for high temperature applications
- Application of an alternative model combining simultaneous heat loss and finite pulse correction
- Finite element analysis and modelling of the experimental thermograms taking into account the radiative heat transport component

**Thermodynamic property measurement of molten salts**
- Development of sample encapsulation for DSC for high temperature applications
- Development of experimental protocol for liquid density measurements for high temperature corrosive salts
- Benchmark calorimetry procedures for thermodynamic measurements
COME HEAR FROM LEADING WORLD EXPERTS ON:

- Canada’s nuclear advantage for the deployment of Gen IV and SMRs
- Prominent showcases in Gen IV advanced reactors & SMR development
- The international landscape in advanced reactor deployment
- Policy levers to enable SMR deployment

... and many other engaging workshops, panel discussions and events!