Development of Molten Salt Capabilities at Canadian Nuclear Laboratories

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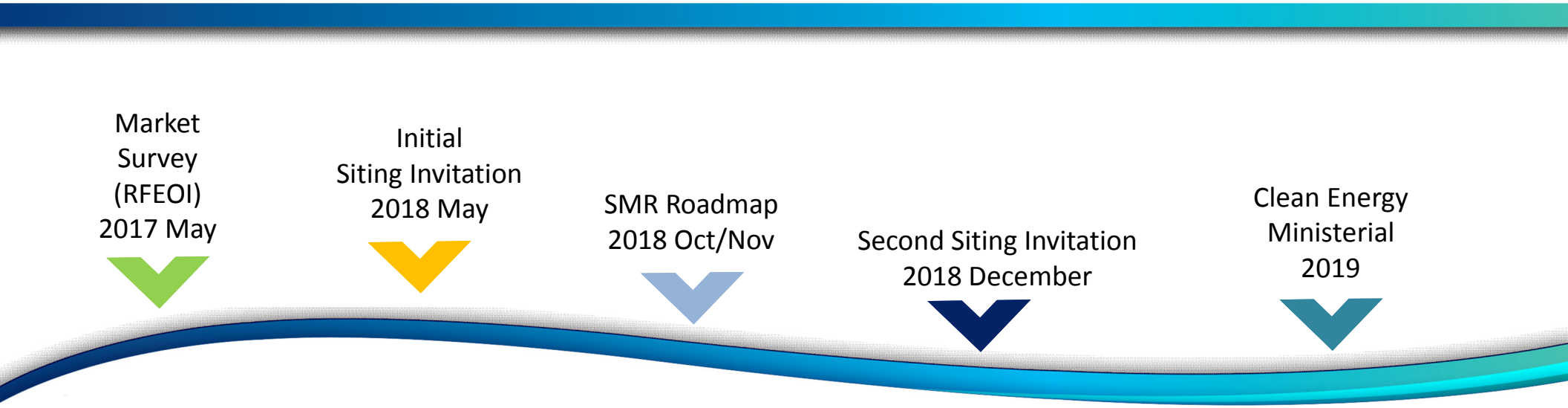
Outline

- 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

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Science of tomorrow. *La science de demain.*

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

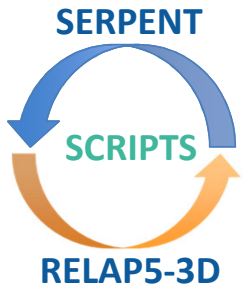
Generic siting studies completed

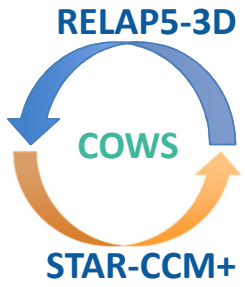
Vendor-specific siting studies underway

Site application invitation issued

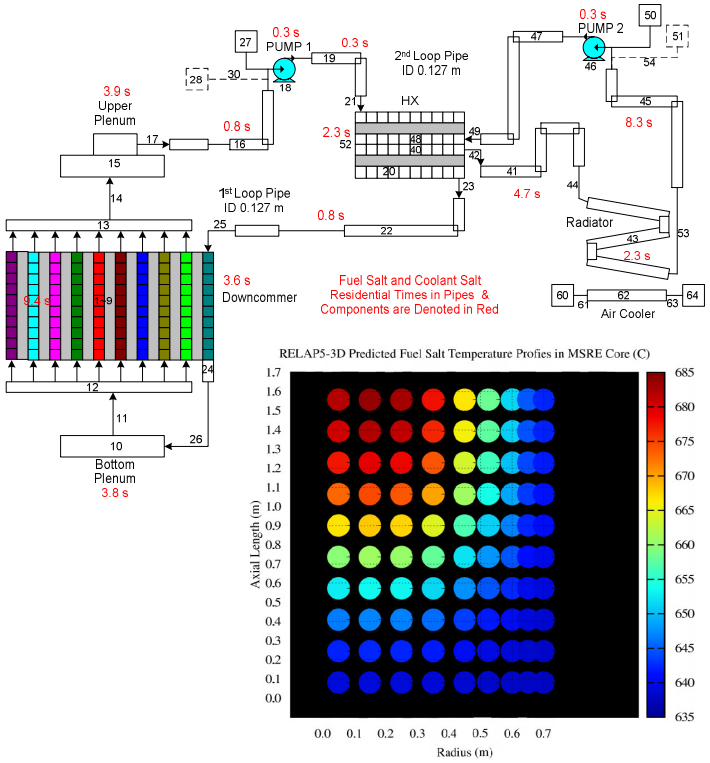
Modelling of Advanced Reactors at CNL

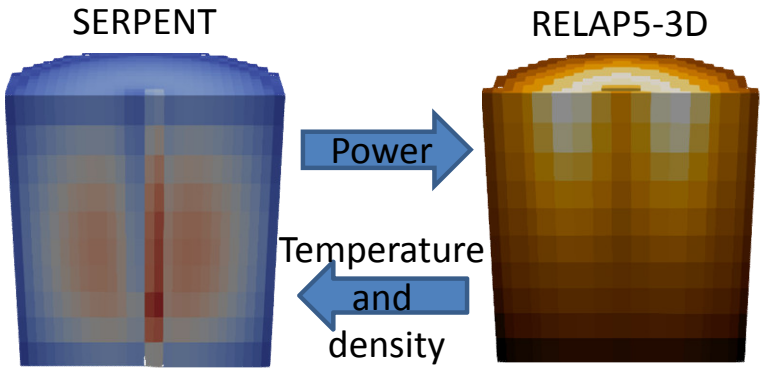
- Coupled reactor transient simulation toolset suitable for different reactor technologies.
- Scope: Molten salt, gas-, lead-cooled reactor concepts.
- Selected codes for testing includes:
  - Monte Carlo (SERPENT), deterministic (Rattlesnake)
  - System thermal-hydraulics (RELAP5-3D)
  - Computational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

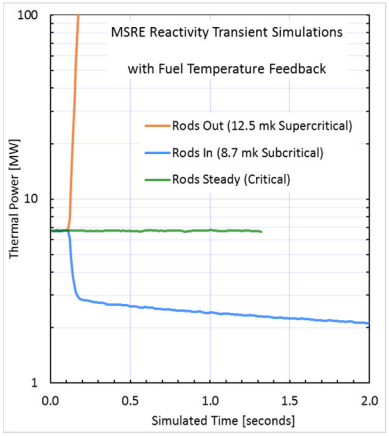


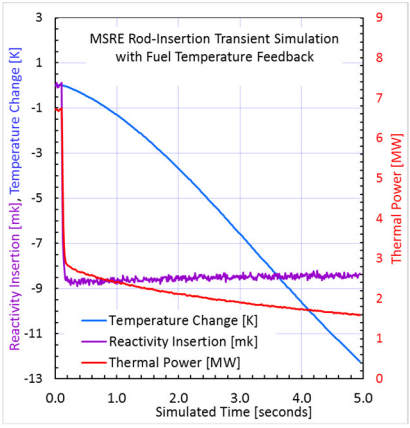


ORNL MSRE Transient simulations









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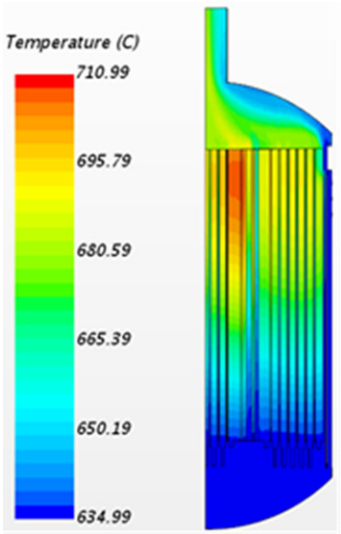
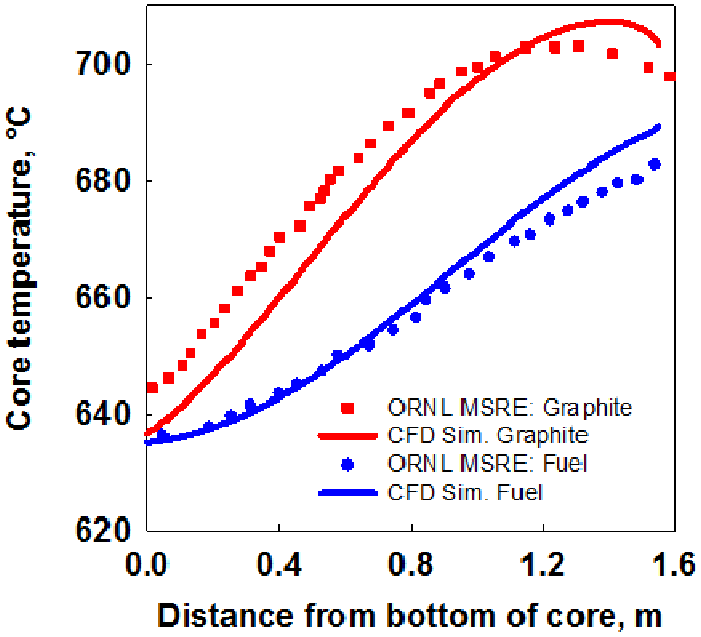
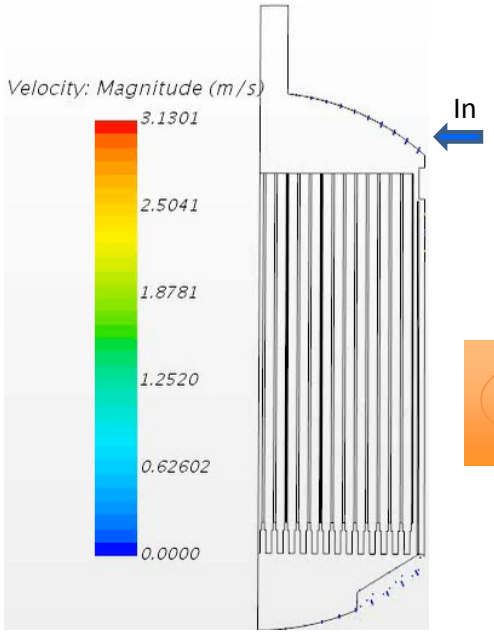
ORNL MSRE CFD simulations

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







Animation will not play in .pdf

*Podila et al., (2018), G4SR1 conference proc.

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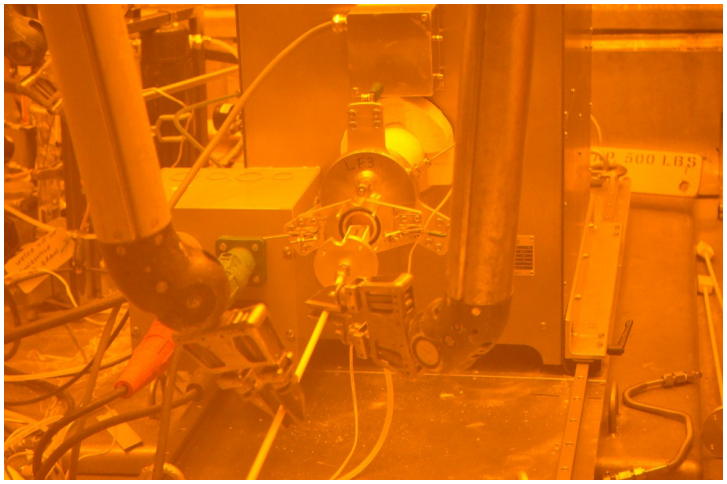
Fission Product Release Tests

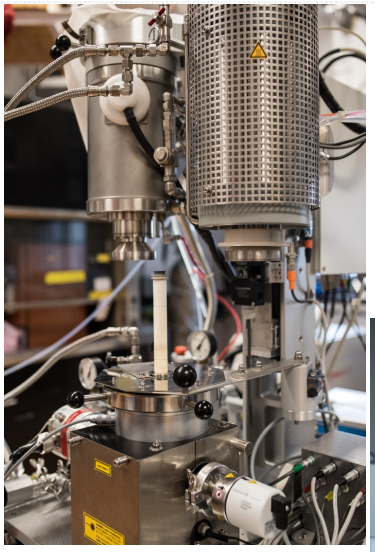
- Six tests were performed on fission product release from molten salt mixtures in March 2018 using a uranium/fluoride salt and a uranium fluoride/chloride salt.
- Test temperature was 1000°C, under what we considered to be beyond-design-basis-accident conditions.
- The data from the experiments will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



Molten Salt Capability Development

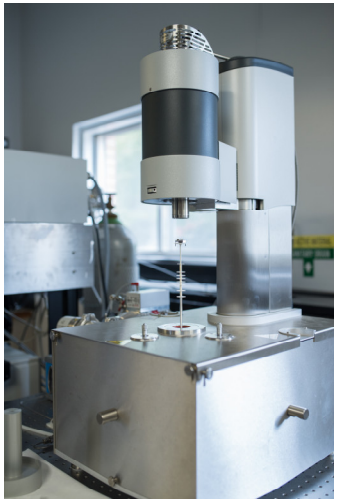
Thermophysical properties

- 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



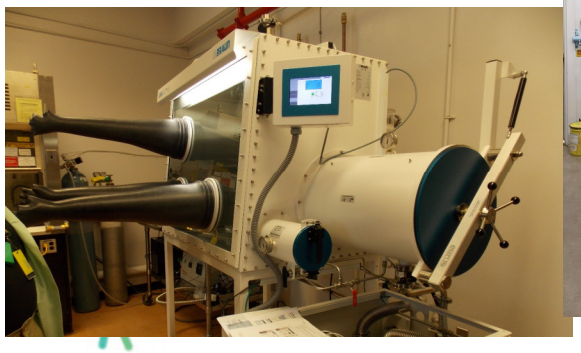
Differential Scanning Calorimeter (DSC)

- Melting points
- Heat capacity
- Phase diagrams



Laser Flash (LFA)
Thermal diffusivity measurements

DryBox for non-active molten salts



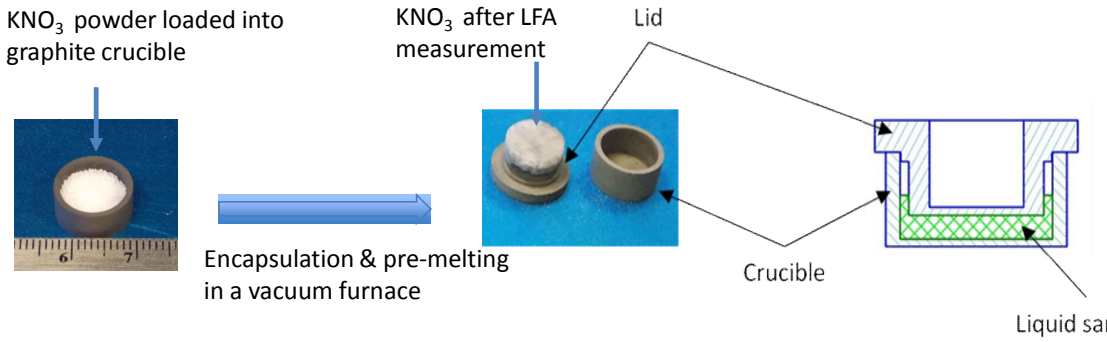
DryBox for active molten salts

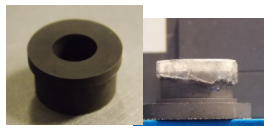
Dilatometer
Liquid density measurements

Molten Salt Capability Development

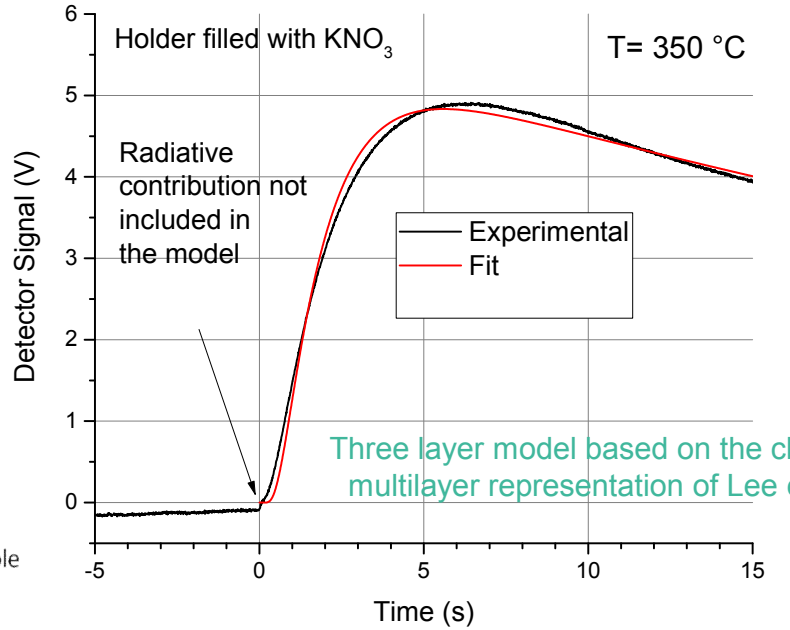
Thermal diffusivity/conductivity measurements of molten salts by the laser flash technique

- Designed and manufactured a holder for liquid samples
- Demonstrated powdered sample encapsulation for thermal diffusivity measurements on KNO_3 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





Melting point of KNO_3
T_p = 334 °C



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

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

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

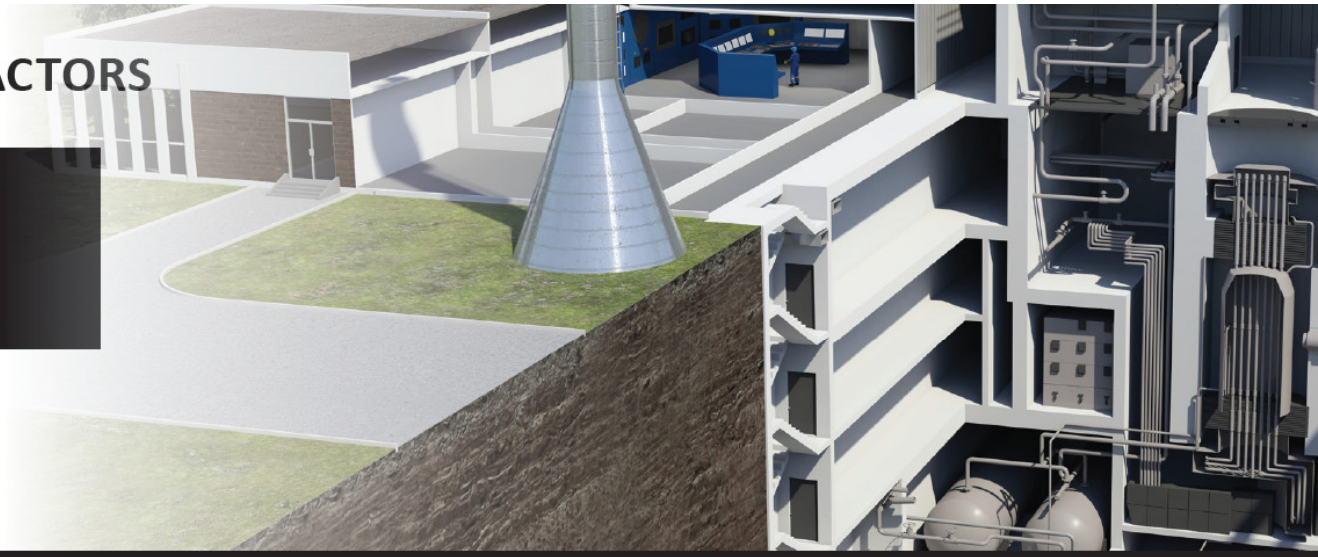
Thermodynamic property measurement of molten salts

- 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

GENERATION IV & SMALL REACTORS

G4SR-1

INTERNATIONAL CONFERENCE



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