Nuclear Energy University Programs (NEUP)
Fiscal Year (FY) 2017 Annual Planning Webinar

RC-04: Computational Methodologies to Support Design and Analysis of Generation IV Reactors

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ART Methods Program Objectives

U.S. DEPARTMENT OF

ENERGY

Nuclear Energy

- **Develop and validate computational tools to support design and analysis of Generation IV reactors**

  - RC-4.1 Sodium cooled fast reactors,

  - RC-4.2 High temperature gas reactors,

  - RC-4.3 Molten salt reactors including Fluoride salt cooled reactors
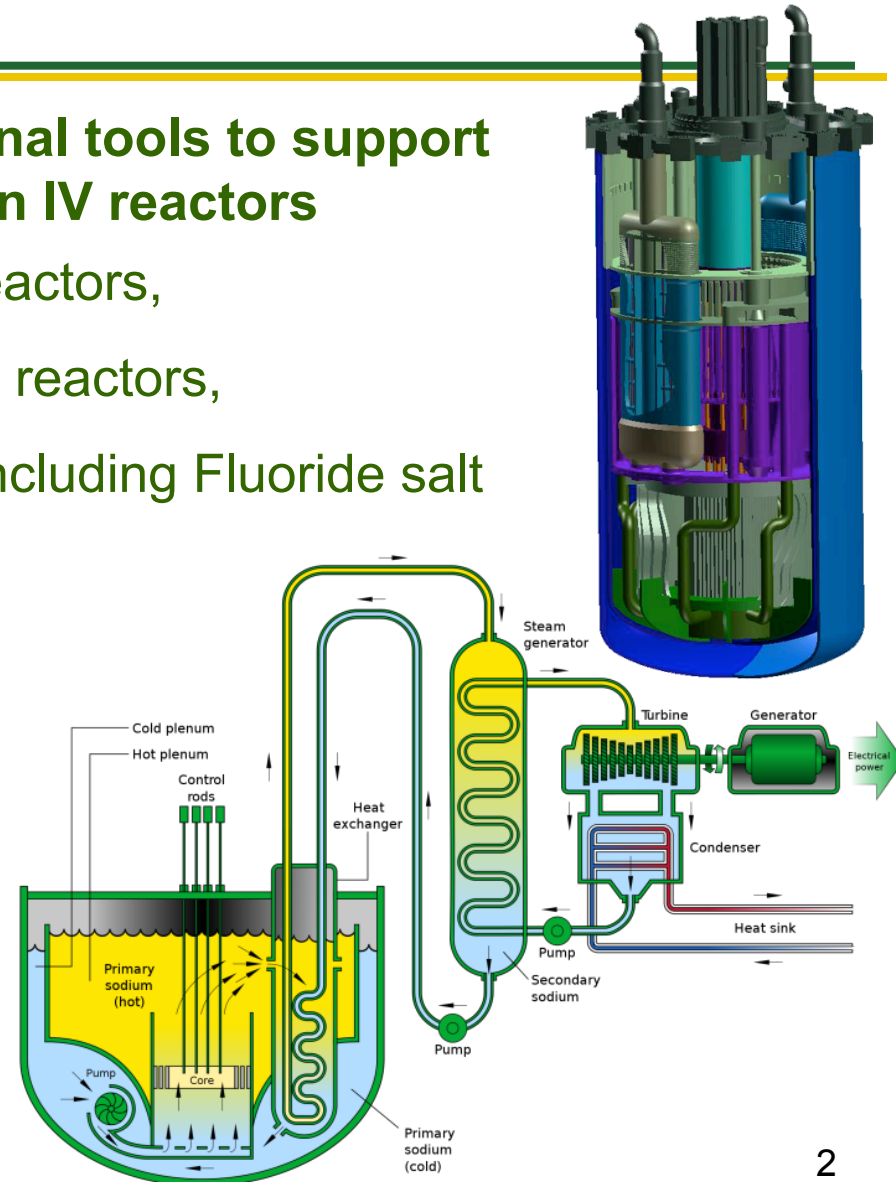
ART Fast Reactor Methods Program

- **Sodium-cooled Fast Reactor neutronics analysis tools and methods**
  - Complex reactivity feedback mechanisms
    - Doppler, sodium density and void worth, fuel/clad axial expansion, core radial expansion etc.

- **Thermal-Hydraulics analysis tools**
  - Systems analysis codes for whole-plant transient analyses and modeling inherent safety behavior
  - Computational Fluid Dynamics (CFD) methods for component modeling with very low Prandtl-number liquid metal flow and heat transfer

- **Thermo-structural analysis tools**
  - Time dependent thermal stresses on reactor vessel and upper core structures
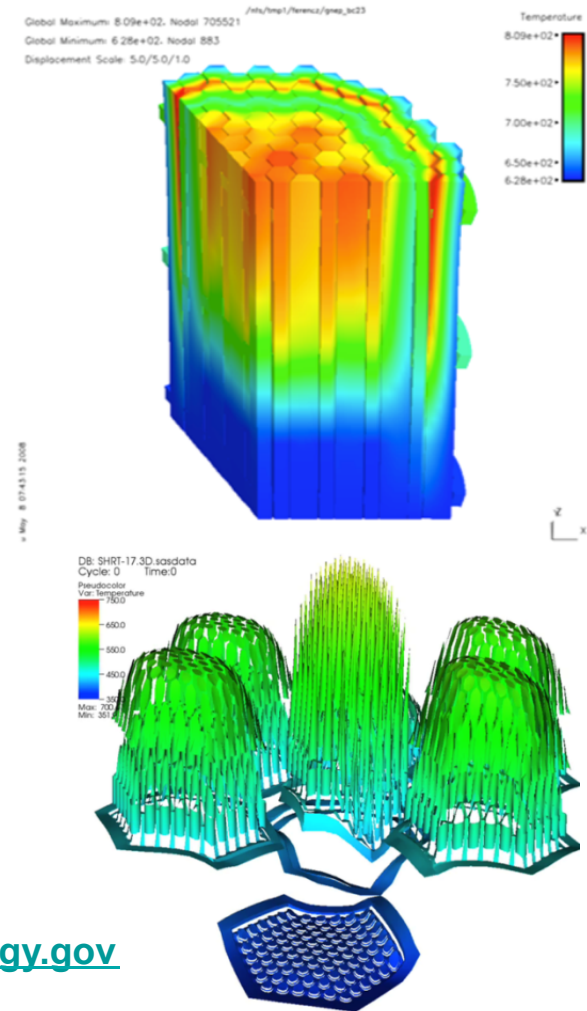
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ART Fast Reactor Methods Program

Code development activities

- Enhancement of SAS4A/SASSYS-1 systems analysis code to support accident analysis

- Incorporating sodium accident analysis capabilities of CONTAIN-LMR under MELCOR code to support containment design-basis assessments with respect to sodium fires

- Develop integrated multi-physics analysis tool suite for validation to raise technical readiness of SFR concepts

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FY17 Fast Reactor Example Areas of Interest

- **Sodium fire modeling**
  - Reduced order modeling of air entrainment around the top of a sodium pool fire

- **CFD validation for wire-wrapped rod bundles to develop high-quality, high resolution heat and flow datasets**
  - High-resolution, three dimensional concurrent measurements of velocity, temperature, and second order statistics such as RMS of the velocity components
  - Multiple bundle sizes, at least 7 rods, range of Reynolds numbers including low flow
  - Natural, mixed, and forced convection are encouraged
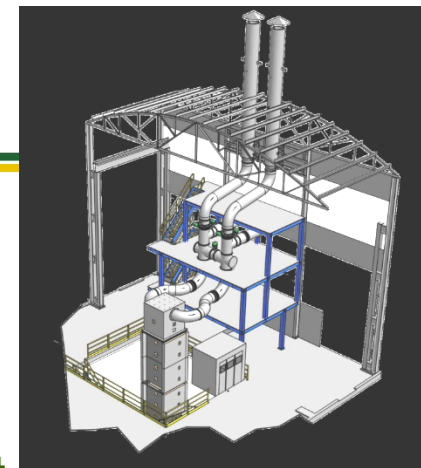 - Time dependent measurements of wall shear and pressure

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ART High Temperature Reactor Methods Program

Experimental Validation

- System and Computational Fluid Dynamics models for high temperature gas reactors lack high quality data for validation

- Validation of models requires completion of separate effect (SET), mixed effect (MET), and integral tests scaled to reproduce the thermal fluid conditions in nominal and accident scenarios

- General Atomics 350 MWt MHTGR and 600 MWt GT-MHR are reference designs for scaling of existing experiments

- Integral testing facilities generally beyond scope of NEUP awards. However, facilities were built using other sources of funding.

  - High Temperature Test Facility (HTTF)
  - Natural circulation Shutdown Test Facility (NSTF)

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ART High Temperature Reactor Areas of Interest

FY17 focuses on phenomena associated with loss-of-forced-cooling scenarios with or without a break in the primary coolant boundary.

Proposals will be accepted for high fidelity experimental and computational investigation of phenomena:

- Core channel to plenum flow exchange

  High fidelity investigations of fluid dynamics of buoyancy-driven flow through multiple, non-uniformly heated channels into common inlet and outlet plena. Similar investigations of plenum-to-plenum flow within packed (pebble) bed cores are of interest.

- Mixing of helium jets with cavity air

  In the event of pipe break, helium emerges from leak into reactor cavity forcing air out of building. The nature of stratification and/or mixing of the helium and air near the break and the geometry of the cavity determine how much air may leak back into the vessel after depressurization.

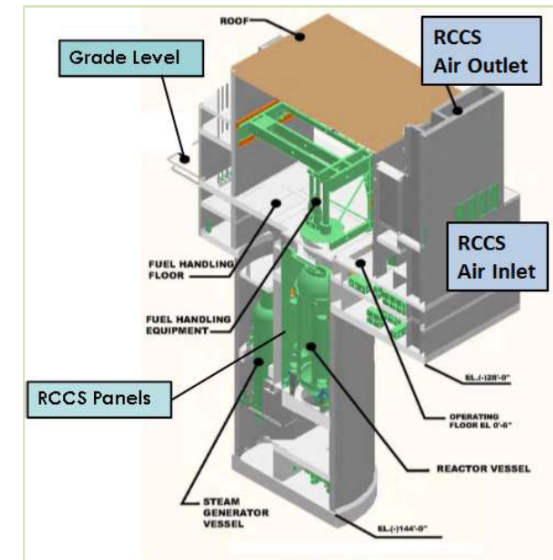Federal POC – Diana Li: Diana.LI@nuclear.energy.gov
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ART High Temperature Reactor Areas of Interest

RCCS fluid behavior - Without active cooling, heat is transported from vessel to reactor cavity cooling system (RCCS) panels lining the cavity. RCCS transports heat to outside atmosphere by natural circulation. Non-uniform heating of panels and mixing of streams in the plenum may lead to reverse flow and other complex behavior that affects system performance. Proposals sought for:

- *Global analysis of air-cooled RCCS and related data along with scaling studies for a full scale model.*

- *Development of advanced computational methods to model water-based Natural circulation Shutdown Test Facility (NSTF). RCCS including radiation heat transfer, conduction, convection, and boiling under various flow conditions including flow instabilities.*

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ART High Temperature Reactor Areas of Interest

Well-controlled small-scale experiments with high-resolution (time and spatial) transient two-phase measurements (especially during various types of two-phase flow instabilities) will also be considered. These experiments would support development of two-phase modeling capabilities. Of particular interest are:

- *Scaling between number of riser tubes (which can be as high as 100 tubes per chimney) and chimney piping section dimensions*

- *Evaluation of fluid-structure interactions and the resulting loading on piping systems during two-phase flow that may feature instabilities and 'geysering' in the water-based system under anticipated operating conditions.*

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ART Molten Salt Reactor Areas of Interest

ART program Fluoride salt-cooled High Temperature Reactor (FHR) and Molten Salt Reactor (MSR) R&D currently seeks demonstrations and models of salt thermal hydraulic phenomena to validate FHR and MSR safety codes.

- **Proposals are sought to validate principals of similitude for fluids used to simulate salts.**

Above 700 C, radiative heat transfer becomes an important heat transfer mechanism in molten salts. Heat transfer determines temperatures under normal and accident conditions, therefore reliable heat transfer predictions are sought. To achieve this capability, measurements of optical properties of salts over required temperature ranges and accurate computational fluid dynamic models are desired.

- **Proposals are sought to measure salt properties and/or develop computational models to accurately predict salt temperatures in radiative heat transport regime.**

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ART Molten Salt Reactor Areas of Interest

During a recent Molten Salt Reactor technology specific workshop hosted by GAIN, the following area of interest was identified:

- **Liquid fuel reactor modeling and simulation tools – Existing reactor modeling and simulation tools are designed for solid, immobile, heterogeneous fuel systems. Issues such as delayed neutron precursor flow, bubble formation and collapse, and fuel thermal expansion outside of the critical region are not readily modeled using existing simulation tools.**

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Summary

- **Tools and experiments are sought to support design and analysis of Gen IV reactors, thereby raising technical readiness in support of licensing and commercial deployment**

- **Strong consideration is given to verification and validation of state of the art codes and analysis capabilities**

- **Separate and Mixed Effects experiments should be scaled to specific reactor designs and integral experiments**

- **All experiments and model validation must be performed to NQA-1 standards.**