Overview: Approach to FHR Technology and Licensing Challenges (FHR-IRP)

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FHR Workshop
UCB, Berkeley
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IRP Team

- Lead Organization:
  - Georgia Institute of Technology, Atlanta, Georgia
  - Farzad Rahnema (PI), Bojan Petrovic (Co-PI), Anna Erickson, Srinivas Garimella, Preet Singh
- Partnering Organizations:
  - Academia: OSU: Xiaodong Sun (Co-Pi), Jinsuo Zhang (Co-Pi); TAMU: Pavel Tsvetkov (Co-Pi); TAMU-Kingsville" Yousri Elkassabgi (Co-PI)
  - Industry:
    - AREVA Federal Services LLC: Kim Stein (Co-PI)
    - Southern Company Services; Research and Environmental Affairs, Research and Technology Management: Nicholas Smith
  - National Laboratory Collaboration: ORNL: Grady Yoder (Co-PI)
  - International Research Collaboration:
    - Politecnico di Milano, Milano, Italy: Antonio Cammi (Co-PI), Lelio Luzzi (Co-PI), Marco Ricotti (Co-PI)
    - University of Zagreb, Zagreb, Croatia: Davor Grgic (Co-PI), Nikola Cavlina (Co-PI), Dubravko Pevec (Co-PI)
    - Shanghai Institute of Applied Physics, Chinese Academy of Sciences, Shanghai, China: Kun Chen (Co-PI)

Major tasks

- Tritium Generation & Management- Petrovic & Sun
  - improve accuracy of tritium generation thru fission, lithium, & beryllium
- Redox Control & Impurity Removal – J. Zhang
  - Develop innovative salt cleanup systems for mitigating contaminants & corrosion
  - Develop electrochemical sensor for measuring & controlling redox potential
- Identification & Prioritization of V&V – Rahnema/Petrovic/Xiaodong
  - Through PIRT – like exercise
- Visual Instruments & Fiberoptics – Tsvetkov
  - Assess capabilities and limitations of visual instrumentation approaches
  - Develop novel sensing technologies for monitoring reactor condition

Major tasks, cont'd

- Qualification of alloys for structural application in FHR – Singh
  - Evaluate the corrosion performance of Ni based alloys, SiC & nuclear grade graphite
- Heat Exchangers – Xiaodong/Christensen/Garimella
- V&V of Modeling and Simulation Tools – Rahnema/Petrovic/Tsvetkov/Xiaodong/D. Zhang
- ORNL Contributions – Yoder
  - Support thermal hydraulics & material performance experimental research
- AREVA Contributions – Varies depending on the area
  - Support mostly the PIRT effort

PIRT activities

- Neutronic issues have been identified via a PIRT workshop
- Results will help address the verification and validation of neutronics codes in support of licensing
- Thermal hydraulics PIRT is planned for May 24-26 at OSU
- Other planned PIRTs
  - Combined neutronics/thermal hydraulic
  - Combined N/TH/Material
  - Two workshops on V&V of tools

PIRT results & path forward

Phenomena	Importance		Knowledge Level	Path forward
	FoM_1	FoM_2		
	Core Physics PIRTs for Fundamental Cross Section Data			
Moderation by FLiBe	H	L	P	Do a formal review of existing libraries; Compare ENDF to other cross-sections; Do a critical review of covariances for this design.
Thermalization by FLiBe	H	M	U	There is currently S(α,β) data under development for FLiBe and scheduled to be released in the Fall of 2016.
Thermalization in Carbon	H	H	U	Development of S(α,β) data of ENDF quality is recommended for C-C composite
Absorption in FLiBe	M	L	U	The uncertain impact on the reactivity coefficient needs to be determined
Absorption in Carbon	H	M	P	Transmission measurements of typical samples for total cross-section, correlated for impurities, and over several thermal energies representative of graphite temperatures are recommended.

PIRT results & path forward (cont.)

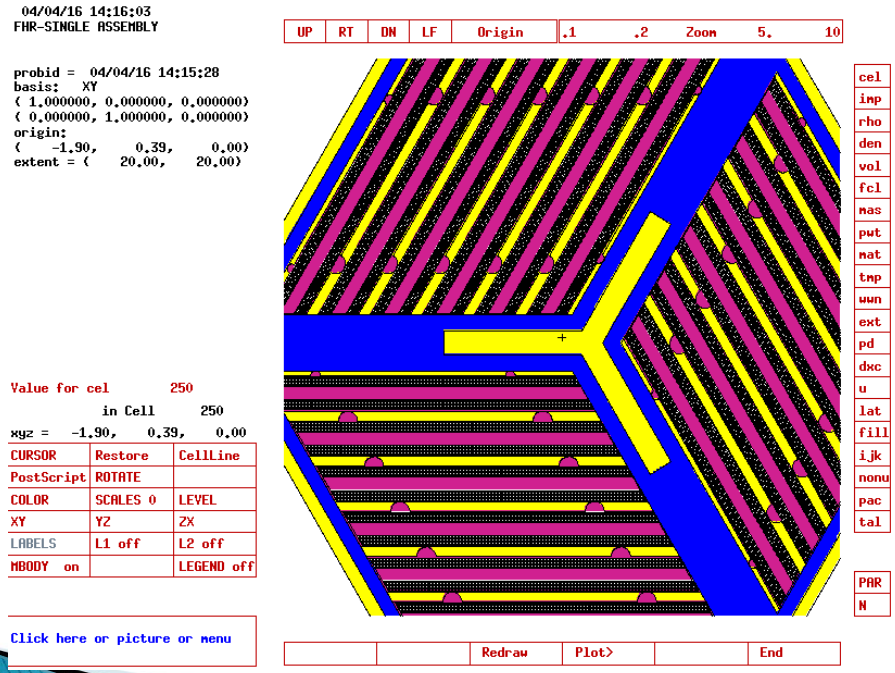
	Material Composition			
Fuel Particle Distribution	M	L	U	Interact with fuel fabricators to determine realistic particle distributions in the plate. If unusual non-uniformity is a possibility, then study the effect on $k_{effective}$ and local peaking factor
	General Depletion			
Spectral History Effects	H	H	U	Adapt methods currently employed in Light Water Reactors to FHR and test.

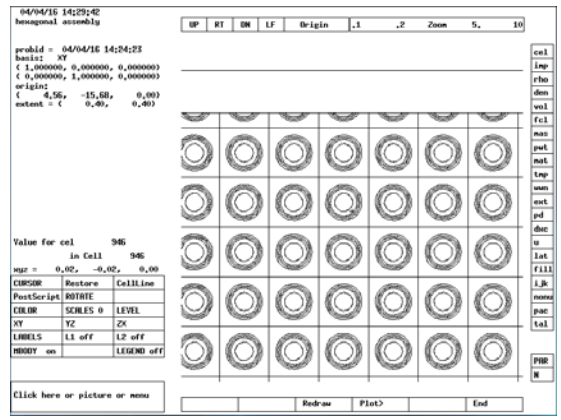
PIRT results & path forward (cont.)

Computational Methodology				
Solution Convergence	L	H	P	Study the underestimate of statistical uncertainty and the magnitude of the fission density tilt. Develop methods to improve fidelity.
Granularity of Depletion Regions	H	H	U	The analysis needs to be performed to determine what the effects on the FoMs are.
Multiple Heterogeneity Treatment for MG x-Sections	H	H	U	Develop methods for generating multi-group cross-sections. Stochastic continuous energy response methods may prove to be a good candidate for this purpose.
Selection of Multi-group Structure	H	H	U	Perform a sensitivity study at the assembly level with control rods and burnable absorbers to determine the minimum number of energy groups and structure. Consider generalized condensation theory as a candidate.
Boundary Conditions for MG x-section Generation	H	H	U	Develop methods for generating multi-group cross-sections. Stochastic continuous energy response methods may prove to be a good candidate for this purpose.
Burnable Poison Cell	H	H	U	Review the burnable absorber candidates and develop models for treatment of the most probable choice.
Scattering Kernel	H	H	P	Develop methods for generating multi-group cross-sections. Stochastic continuous energy response methods may prove to be a good candidate for this purpose.
Spatial Mesh	M	H	U	Explore various subdivisions of the fuel assembly.
Diffusion Approximation	H	H	P	Test methods to determine level of accuracy compared to full transport. If method is not satisfactory, explore higher order diffusion.
Dehomogenization	[illegible]	H	U	Develop a method to reconstruct the plate power and compare to detailed results.

FHR Reactor Neutronic Code V&V

- Code Verification and Validation using MCNP and SCALE, COMET
  - Neutronics benchmark problems are developed

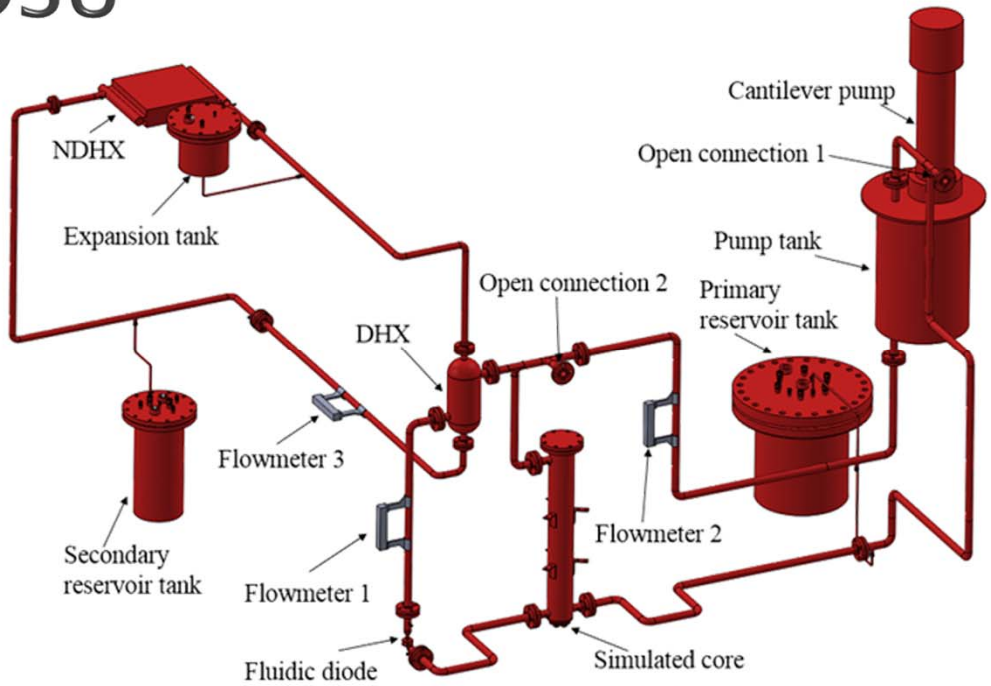




Corrosion Resistance of Alloys in Molten FLiBE and FLiNaK – GT

- So far have focused on validating in-house procedure for static exposure to tests in molten FLiNak
- Performed exposure tests of Ni alloys in dried molten FLiNak
- Similar tests performed for SS: 304, 316, 321, 347

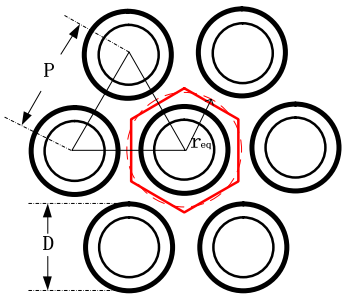
DRACS Facility Under Construction at OSU

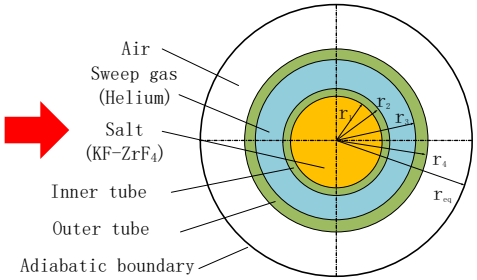


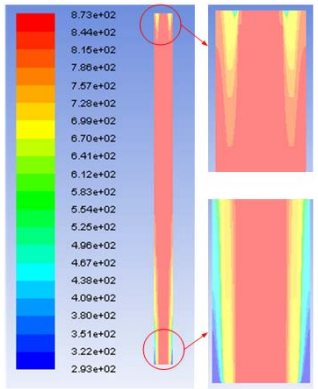
- Designed per ASME code
  - Maximum power of 70 kW
  - Operable to 750°C
  - FLiNaK and KF-ZrF_4: Primary and secondary coolants
  - Construction close to completion

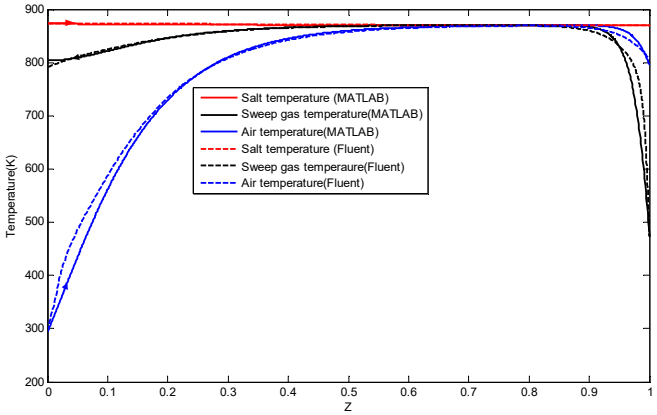
Double-wall Heat Exchanger Design at OSU

- Developed heat and mass transfer models
  - 1D model for NDHX design
  - One unit cell for modeling (salt, inner wall, sweep gas, outer wall, and air)
- Heat transfer model benchmarked against fluent Results



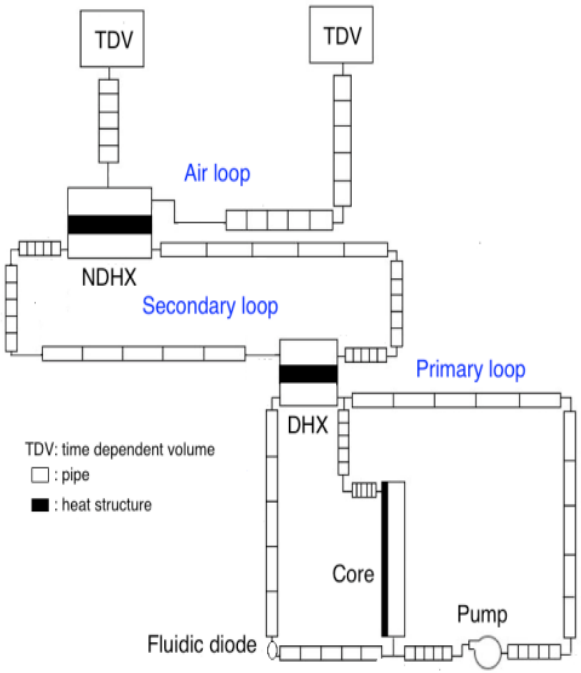


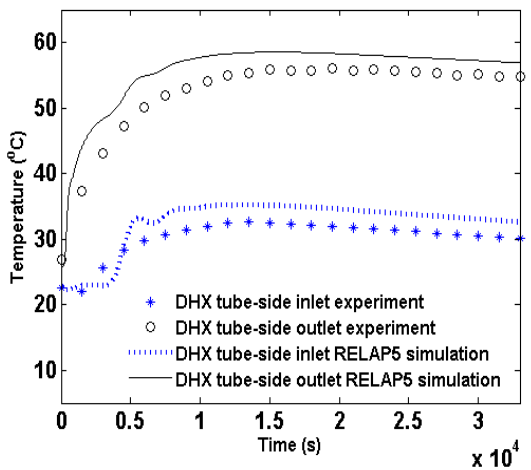


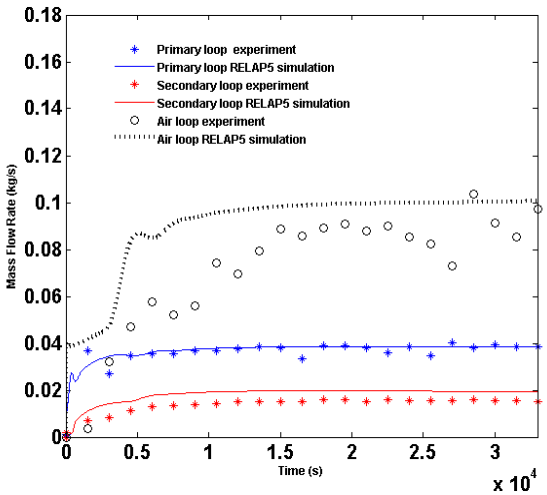


Computational Analysis of DRACS Test Facilities in RELAP5 at OSU

- Code Verification and Validation using RELAP5 MOD 4.0
  - Benchmark study using data from the low-temperature test facility (LTDF) at OSU

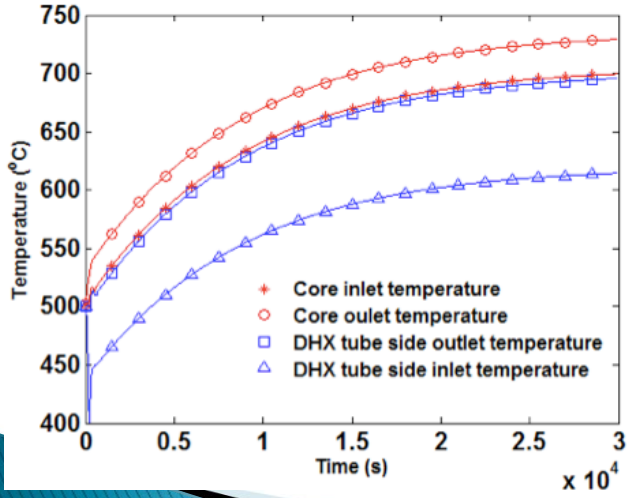


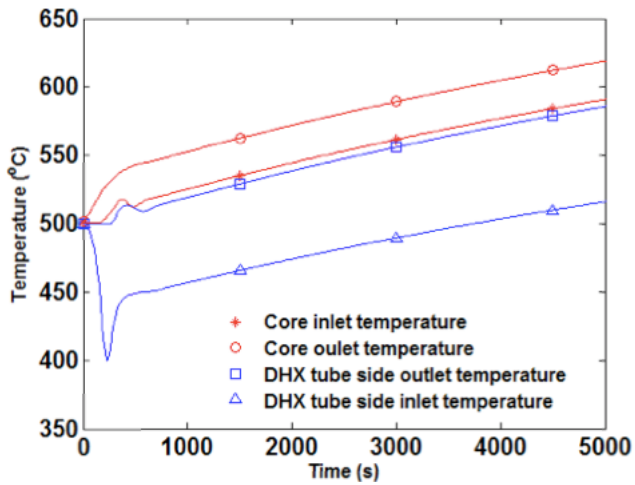


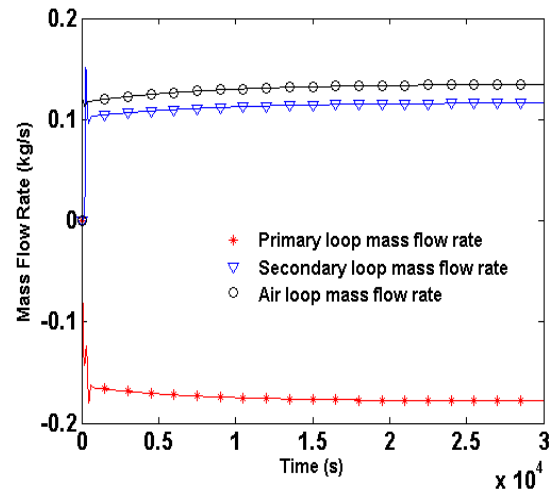


Computational Analysis of DRACS Test Facilities in RELAP5 at OSU

- Code Verification and Validation using RELAP5 MOD 4.0
  - Salt properties implementation into RELAP5
    - The properties of FLiNaK and KF-ZrF_4 have been implemented into the code
  - Simulation on high-temperature test facility (HTDF) at OSU
    - Using FLiNaK and KF-ZrF_4 as working fluid in primary and secondary loop

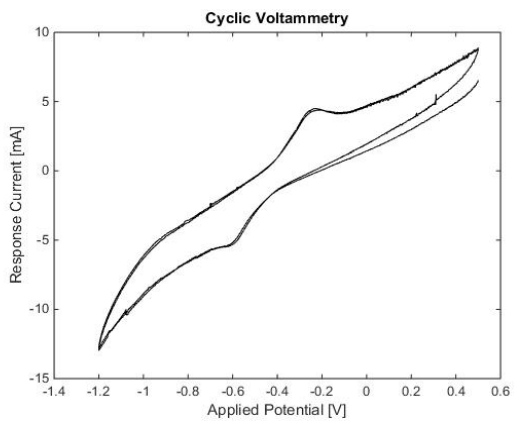




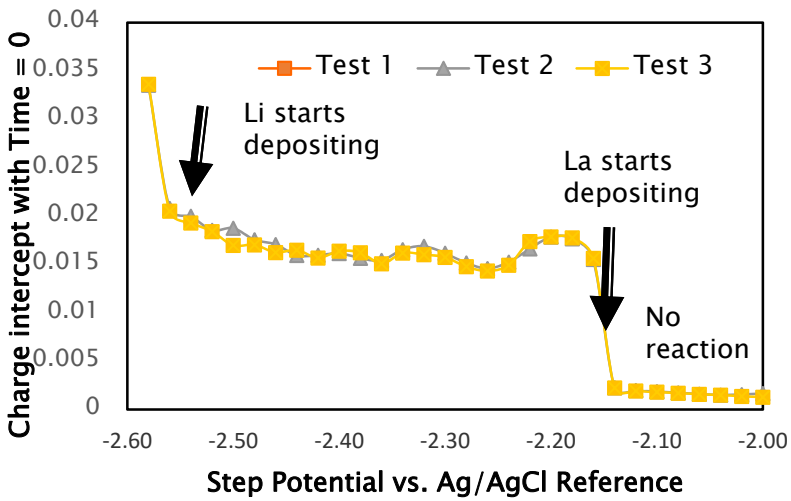


Molten Salt Chemistry at OSU

- Fluoride salt on-line purification system development
- Fundamental data measurement of rare earth elements in fluoride salt and chloride salt
- Electrochemical sensor development for material concentration measurement in molten salt
- Electrochemical studies of molten salt corrosion



Cyclic Voltammogram in FLiNaK. T = 600 C. v = 100 mV/s. C = 0.25 mol% LaF_3



Result for Coverage VS. Step Potential of 3 wt% La at 773 K in KCl-LiCl

Instrumentation systems in optically transparent FHR media at TAMU

- Limited scope irradiation tests have been conducted using radiation sources as well as HFIR at ORNL
- The tests use fibers and manufactured sensor probes developed for VHTR
- Have collected data sets characterizing TRIGA operation in support of visual instrumentation development effort