SAND2011-1028C

Experimental Correlation of an RPCSIM Model

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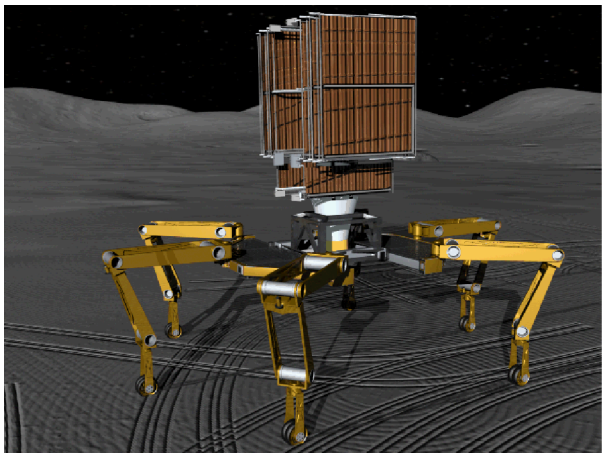
Experimental Correlation of an RPCSIM Model

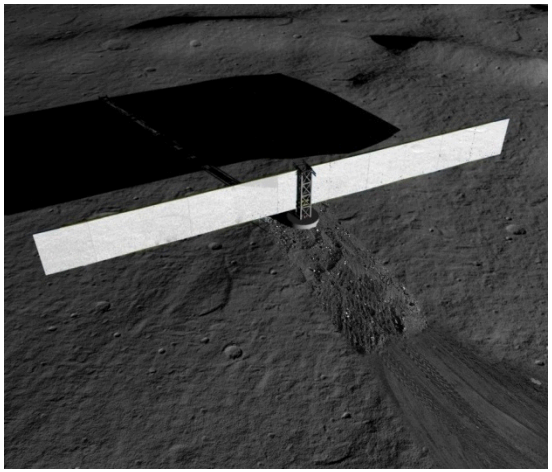
FSP BACKGROUND

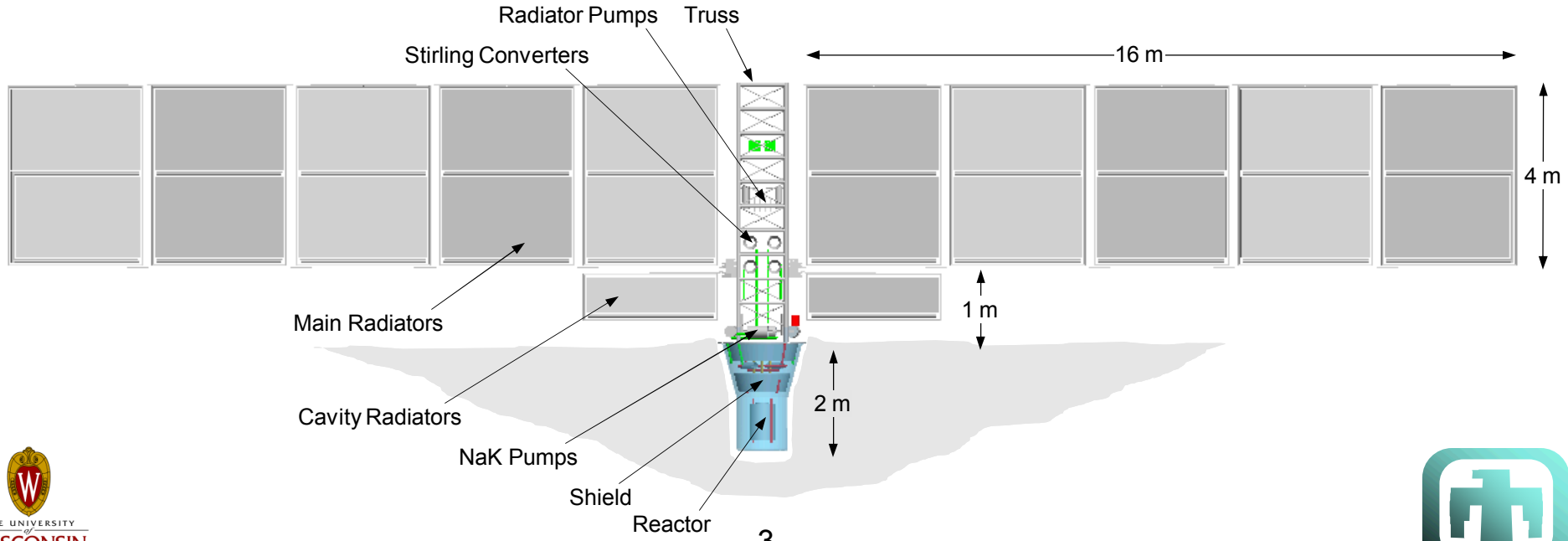
Fission Surface Power System



FSP Overview[4,5]

- UO_2 Fuel
- Liquid-Metal Cooled Rx
- Modular 40 kWe System
- Stirling Power Conversion
- 8-Year Design Life
- Regolith Shielded



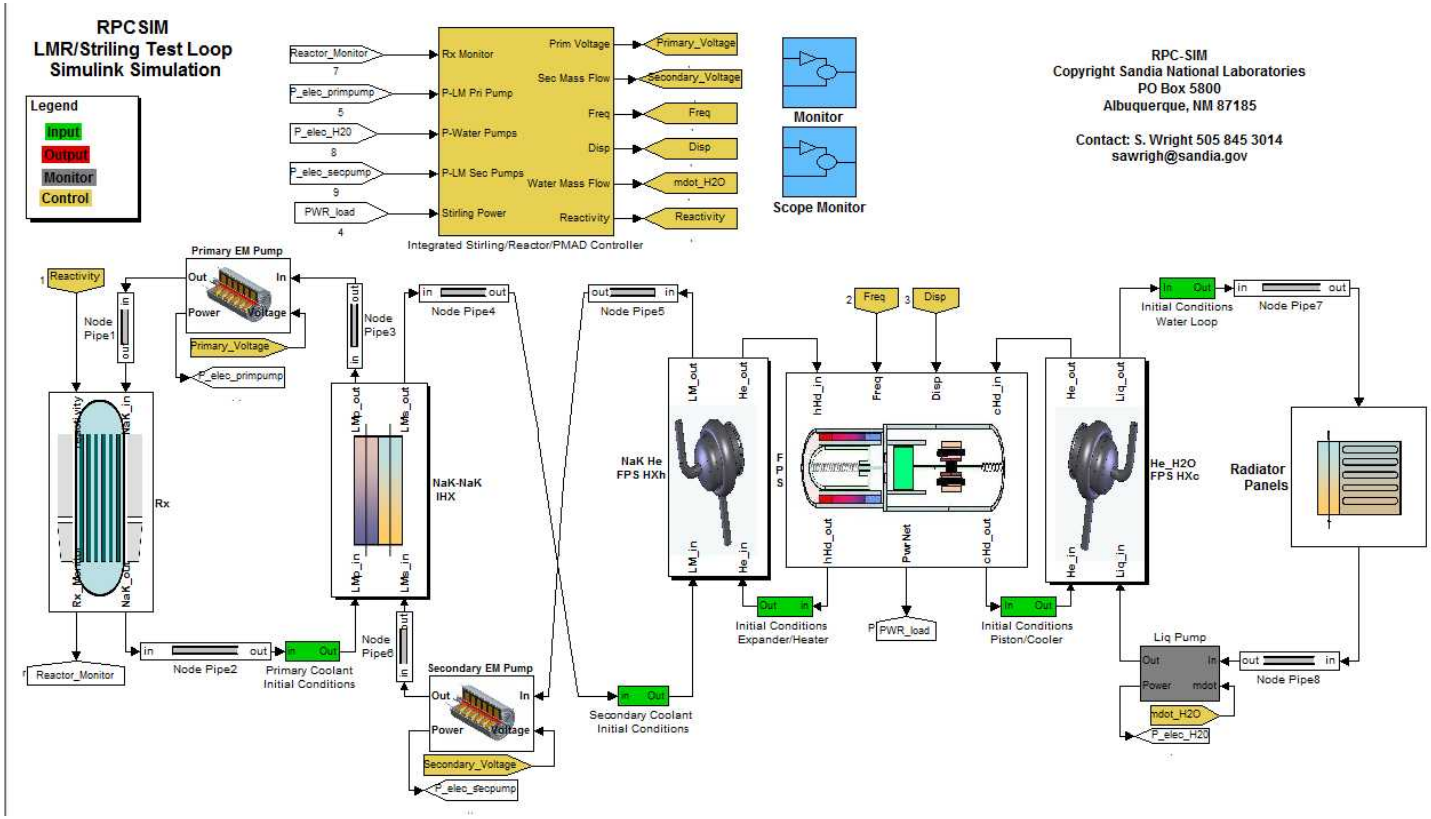


Experimental Correlation of an RPCSIM Model

RPCSIM BACKGROUND

RPCSIM Concept

- Reactor, Power, and Control SIMulation
  - Modern set of components to solve time dependant state flow systems



Advantages of RPCSIM

SPEED Quickly simulate reactor and power system transient behavior

FLEXIBILITY Object-oriented structure for rapid iteration of system components and layout

EASE OF USE Low barrier-to-entry coding environment

SUPPORTED Uses a commercially-supported simulation program and code base

EXPANDABLE Ability to run on massively parallel machines

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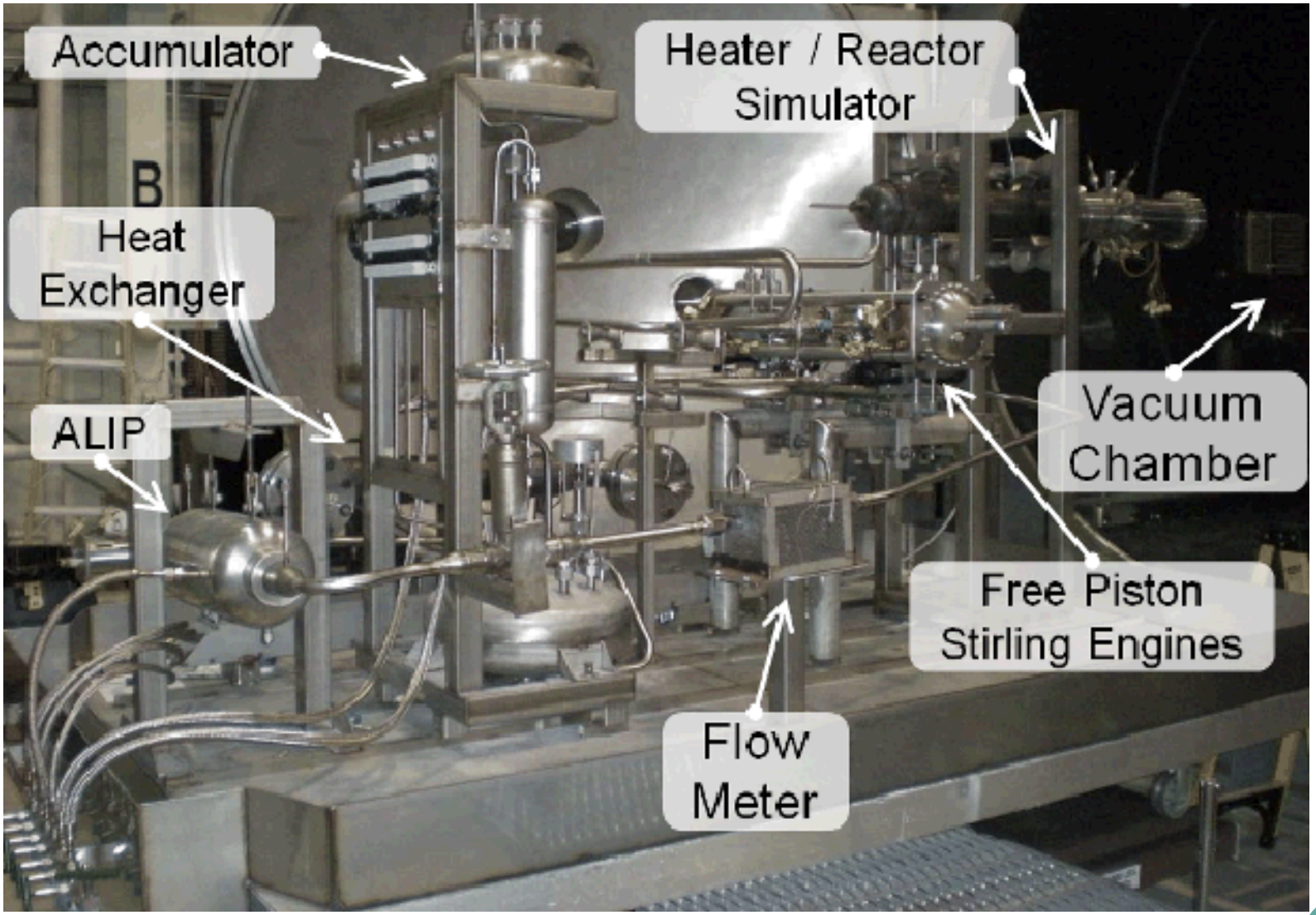
Experimental Correlation of an RPCSIM Model

PTC BACKGROUND

Primary Test Circuit - Reality



Primary Test Circuit – Test Data

Run ID #	Run Date	Run Description
1	7/13/2009	75% Flow, 500C
2	7/8/2009	75% Flow, 375 C
3	6/24/2009	100% Flow, 200C
4	6/25/2009	100% Flow, 375C
5	7/6/2009	100% Flow, 500C
6	6/24/2009	Stirling Engine Stall
7	7/13/2009	Loss of ALIP
8	6/24/2009	Loss of Heat
9	7/7/2009	Simulated Reactivity Feedback, - 1 mm Stirling Stroke
10	7/7/2009	Simulated Reactivity Feedback, + 1 mm Stirling Stroke
11	7/14/2009	Simulated Reactivity Feedback, - 2 mm Stirling Stroke
12	7/14/2009	Simulated Reactivity Feedback, + 2 mm Stirling Stroke
13	7/7/2009	Simulated Reactivity Insertion, Steady Stirling Stroke
14	7/8/2009	Simulated Reactivity Feedback, Decreasing Mass Flow
15	7/8/2009	Simulated Reactivity Feedback, Increasing Mass Flow
16	7/8/2009	Simulated Reactivity Feedback, Stirling Engine Stall

Experimental Correlation of an RPCSIM Model

COMPARISON STRATEGY

Comparison Strategy

COMPONENTS Assemble and / or develop generic components.

MODIFY Modify the geometric and other parameters of the generic components to estimate real-world system characteristics.

CORRELATE Simulate components in isolation and use correlation coefficients to match output measurements based on input signals.

SIMULATE Use the correlated RPCSIM model to simulate additional runs and characterize error to identify areas for improvement in both modeling and testing procedures.

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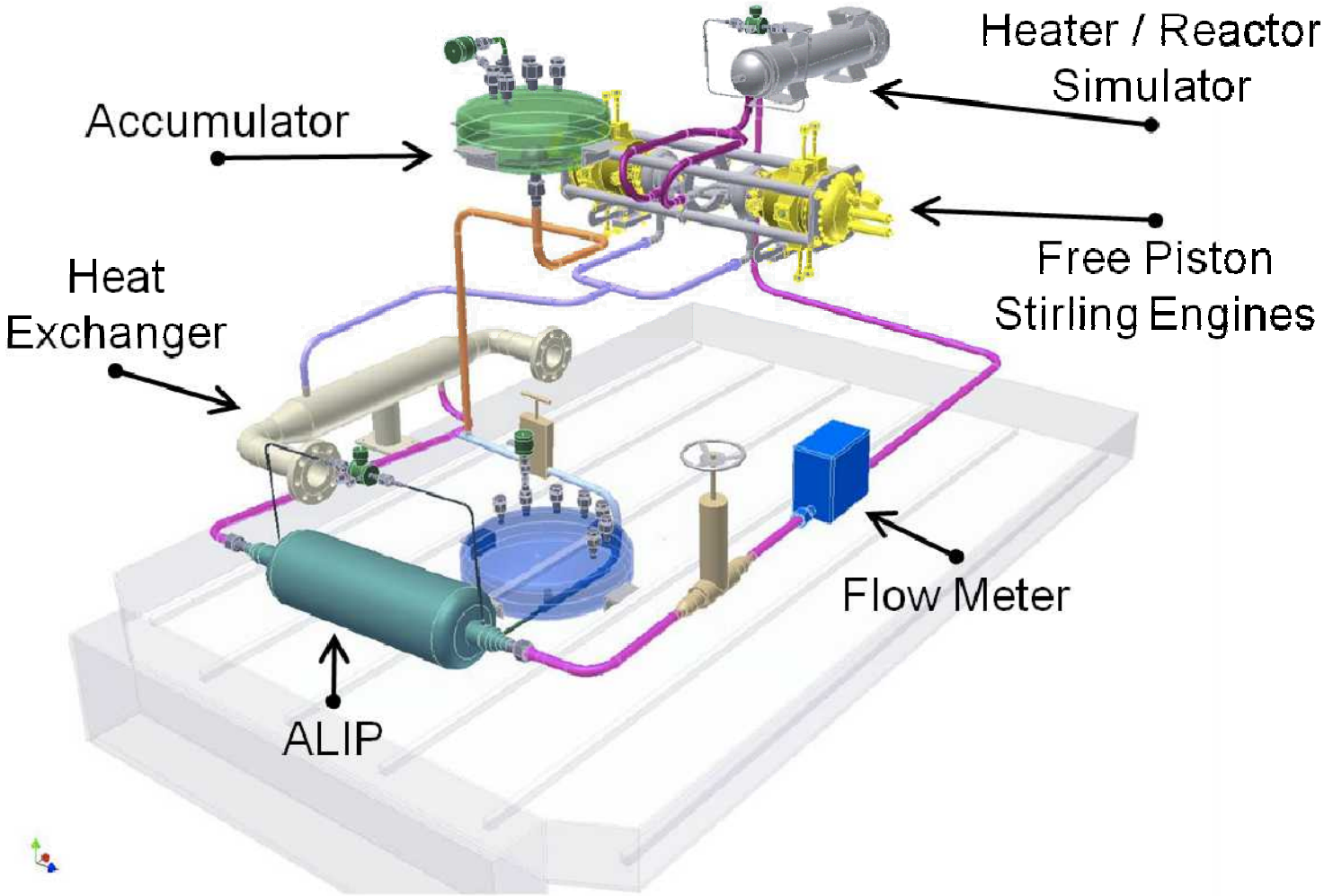
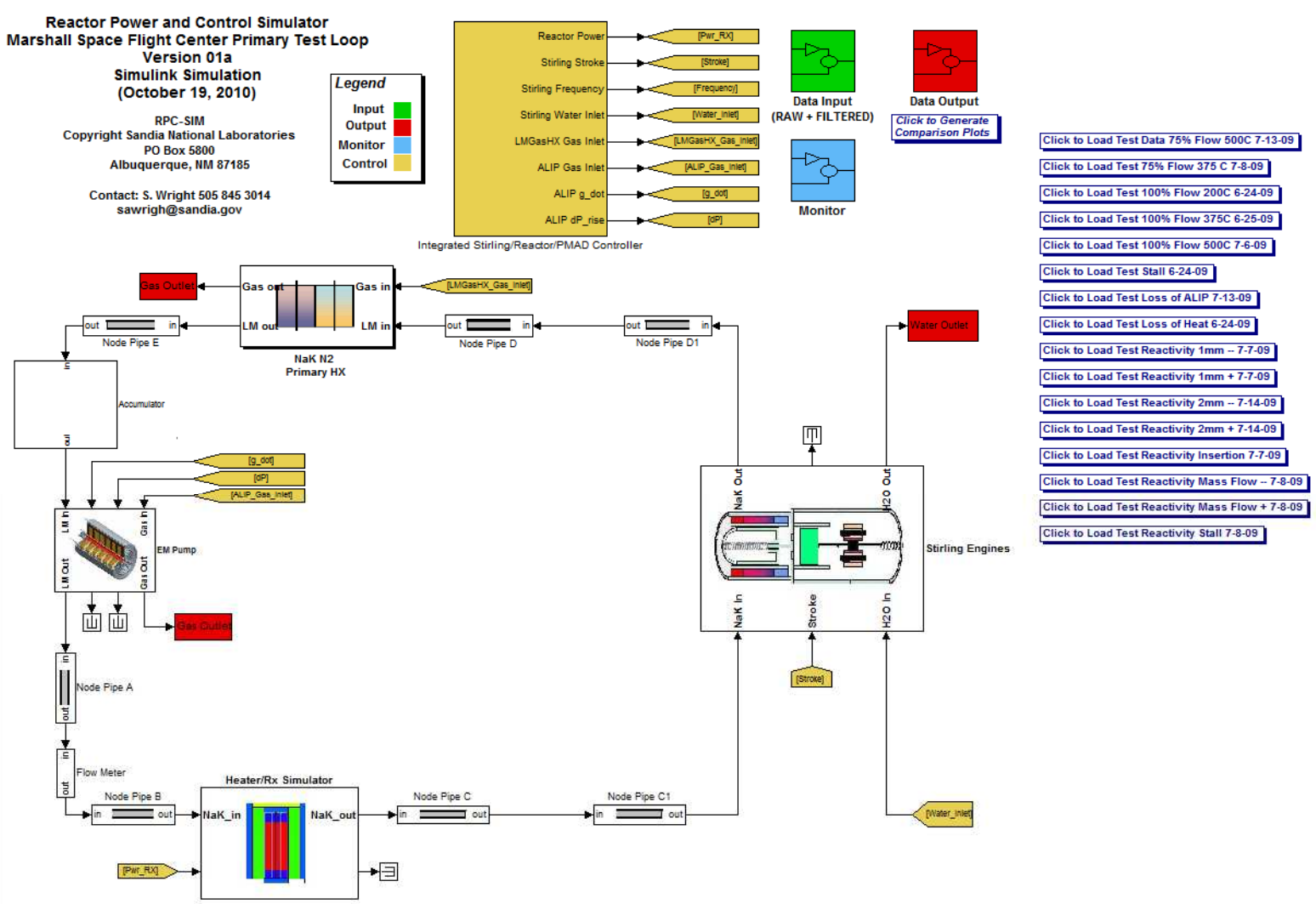
Experimental Correlation of an RPCSIM Model

ASSEMBLING COMPONENTS

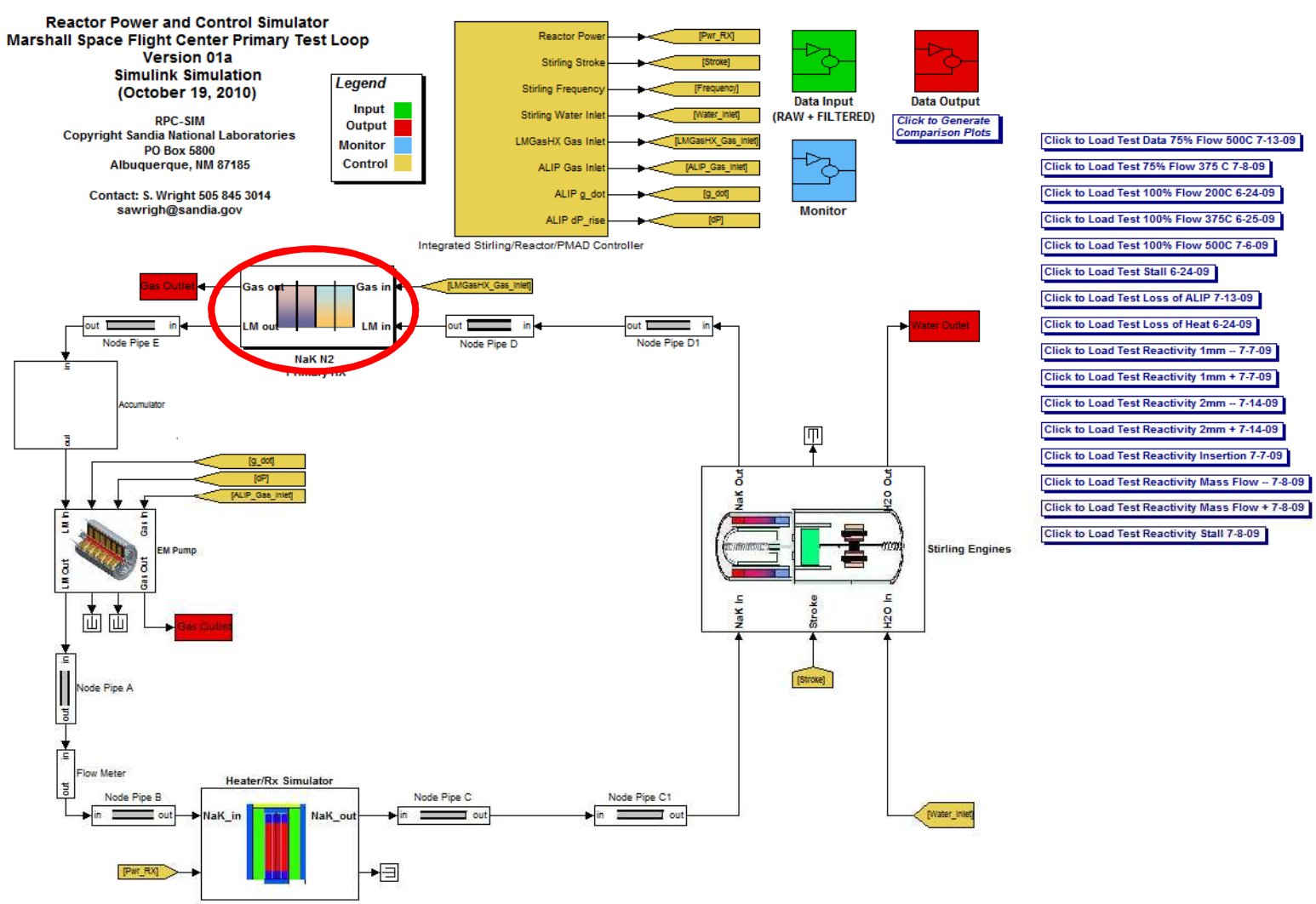
Primary Test Circuit - Diagram



Primary Test Circuit - Diagram



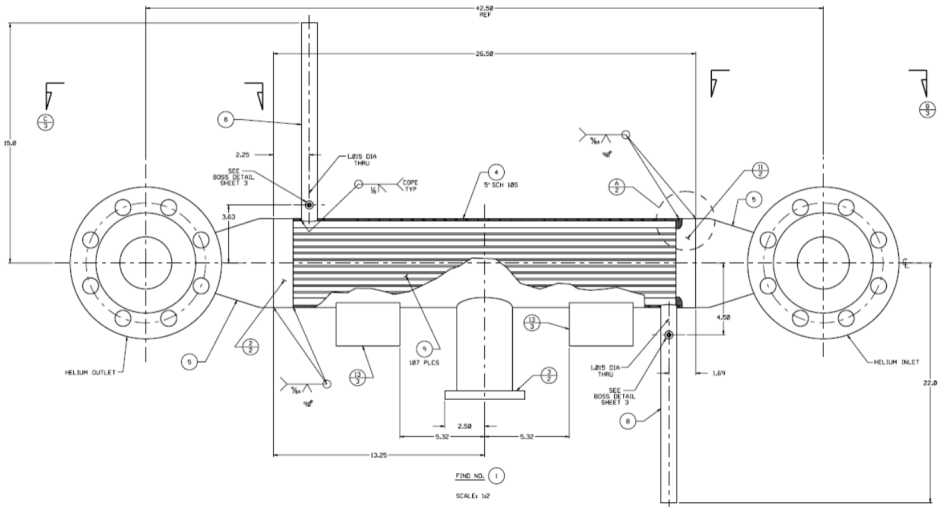
Primary Test Circuit - Diagram

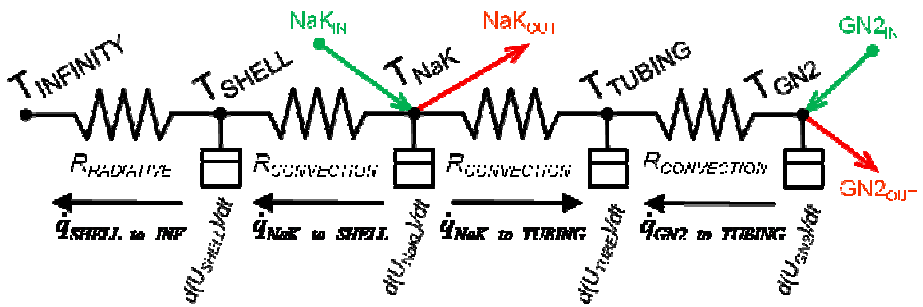


Experimental Correlation of an RPCSIM Model

COMPONENT CORRELATION

General Heat Exchanger Model

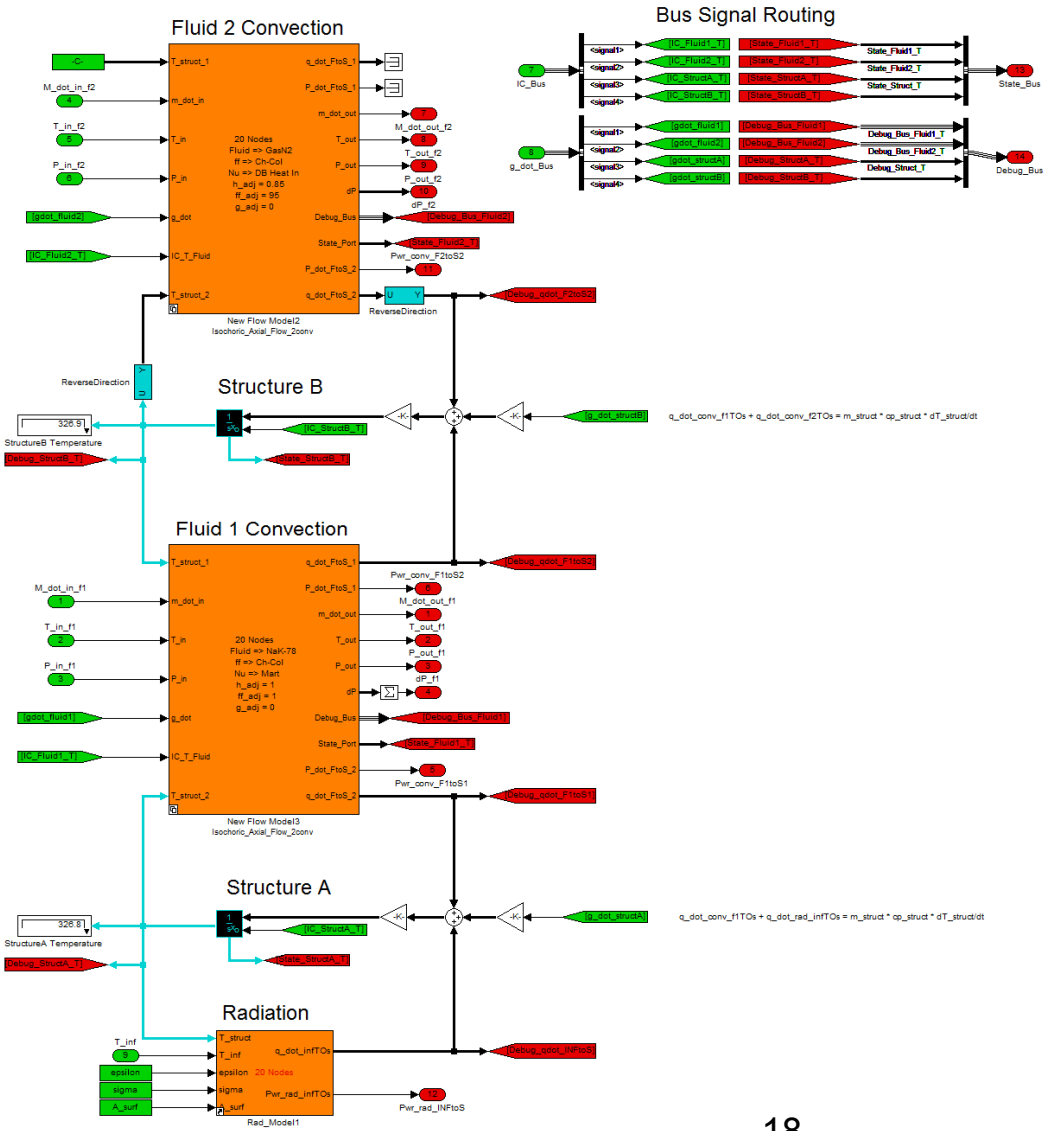




- Counter Flow
- Liquid Metal (Mixed, Shell-side)
- Gas (Un-Mixed, Tube Side)
- Divided axially into “n” nodes
- Assumptions
  - End effects neglected
  - Accounts for convection between fluids and structure as well as radiative loss
  - Conductive thermal resistance perpendicular to flow direction is negligible
  - All ***Structure*** *and* ***Fluid*** elements have thermal mass

Matlab™ Implementation

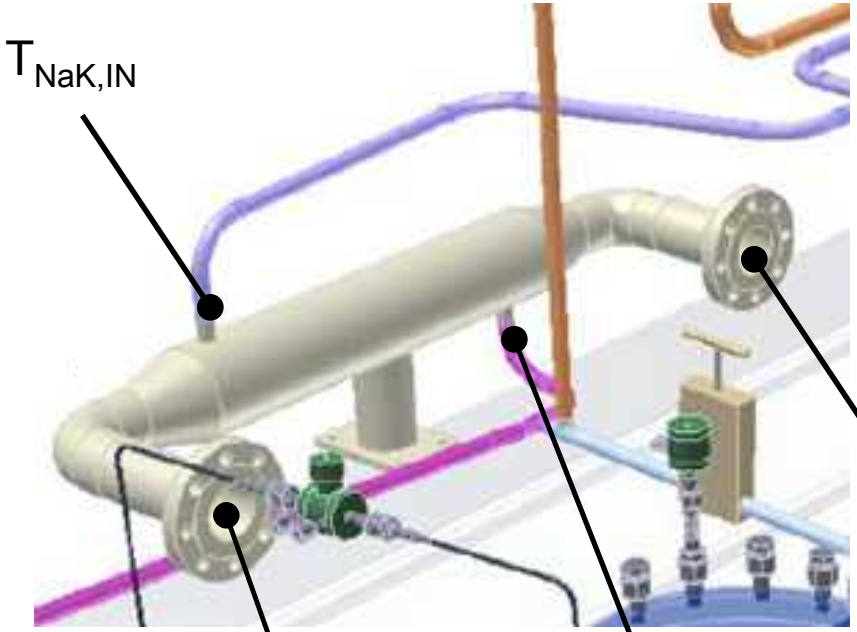
Fluid 1 to Fluid 2 Counter-Flow Heat Exchanger with Fluid 1 Radiative Loss
[Maximum number of nodes = 50]



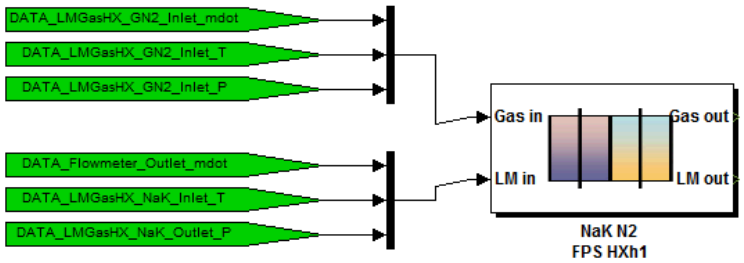
- Structured for quick comprehension
- Modular and scalable
- Simulated “Test Points” routed to clarify program flow
- Calls C functions fitting fluid equations of state
- Calls C functions of various heat transfer correlations

Correlation In Isolation

Existing PTC Test Points

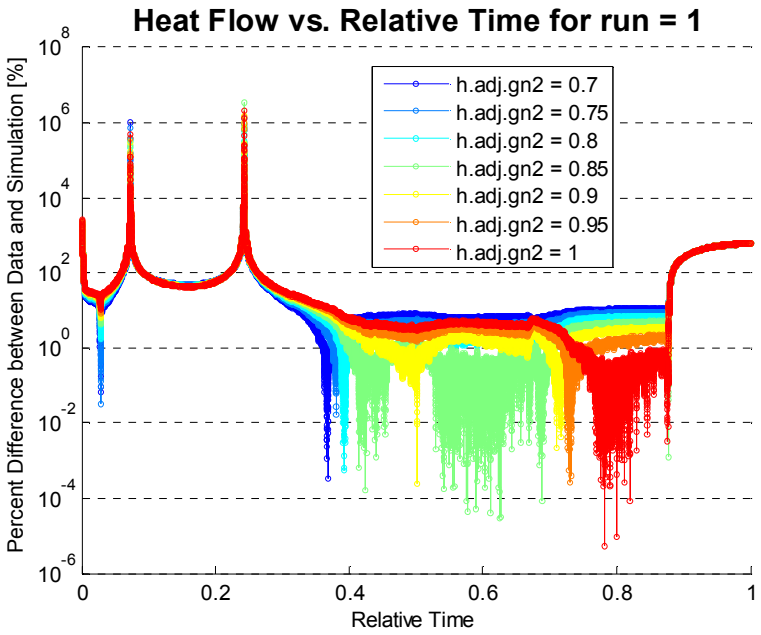


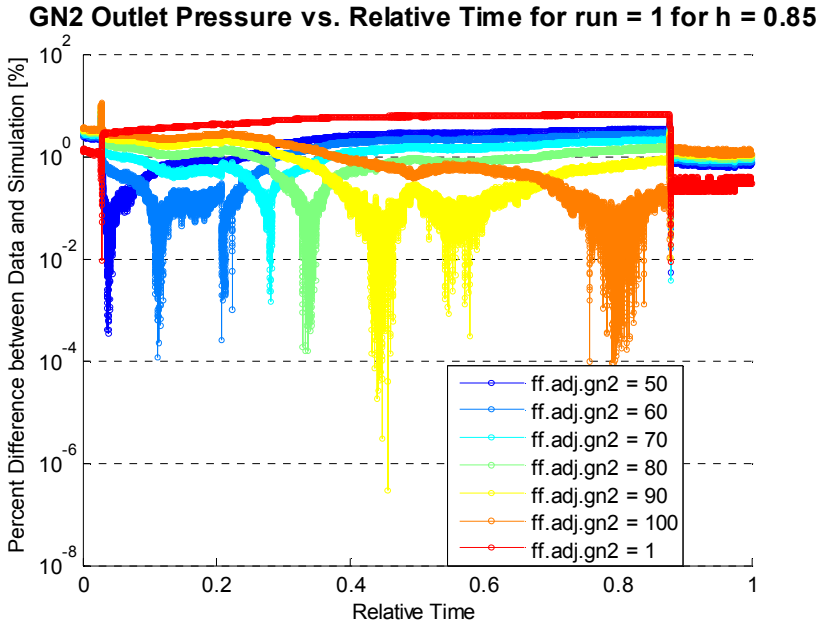
Isolated Model



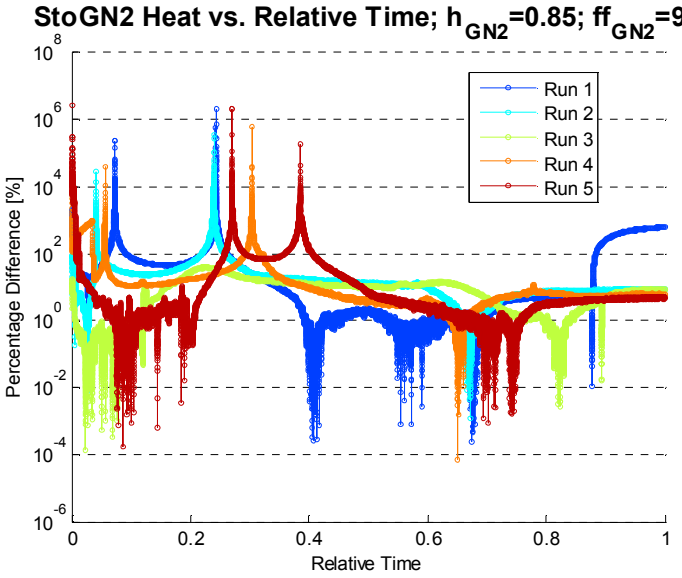
Correlation Results

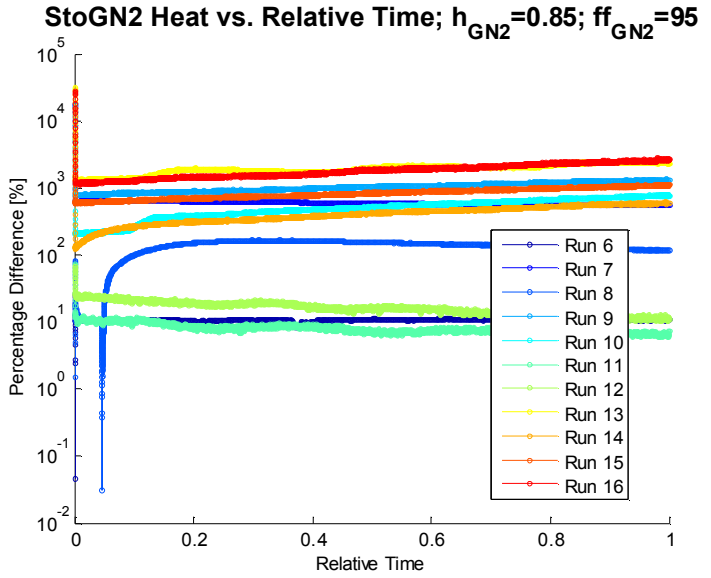
Variable	Value	Description
LMGasHX_ff_adj_1	1	Correction multiplier for local NaK friction factors
LMGasHX_Nu_adj_1	1	Correction multiplier for local NaK heat transfer coefficients
LMGasHX_ff_adj_2	95	Correction multiplier for local GN2 friction factors
LMGasHX_Nu_adj_2	0.85	Correction multiplier for local GN2 heat transfer coefficients

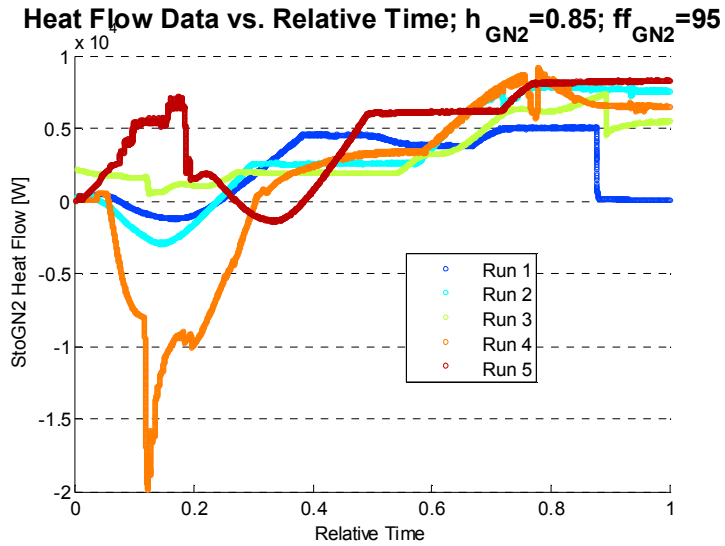


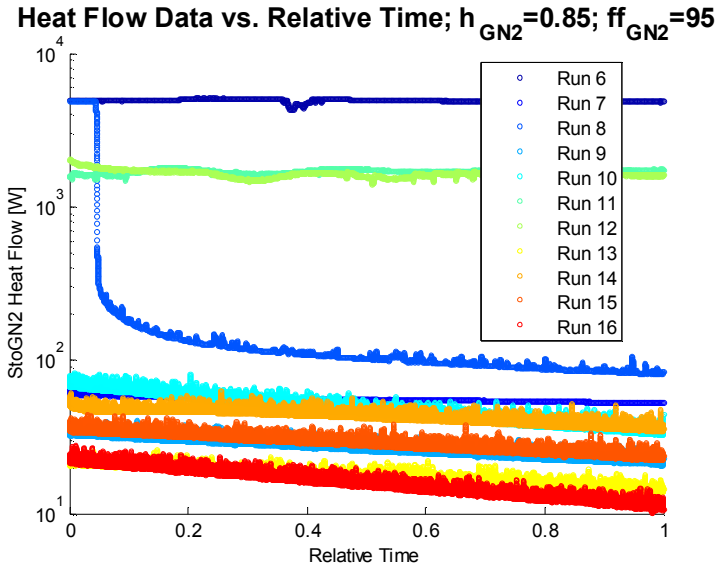


Correlation Results





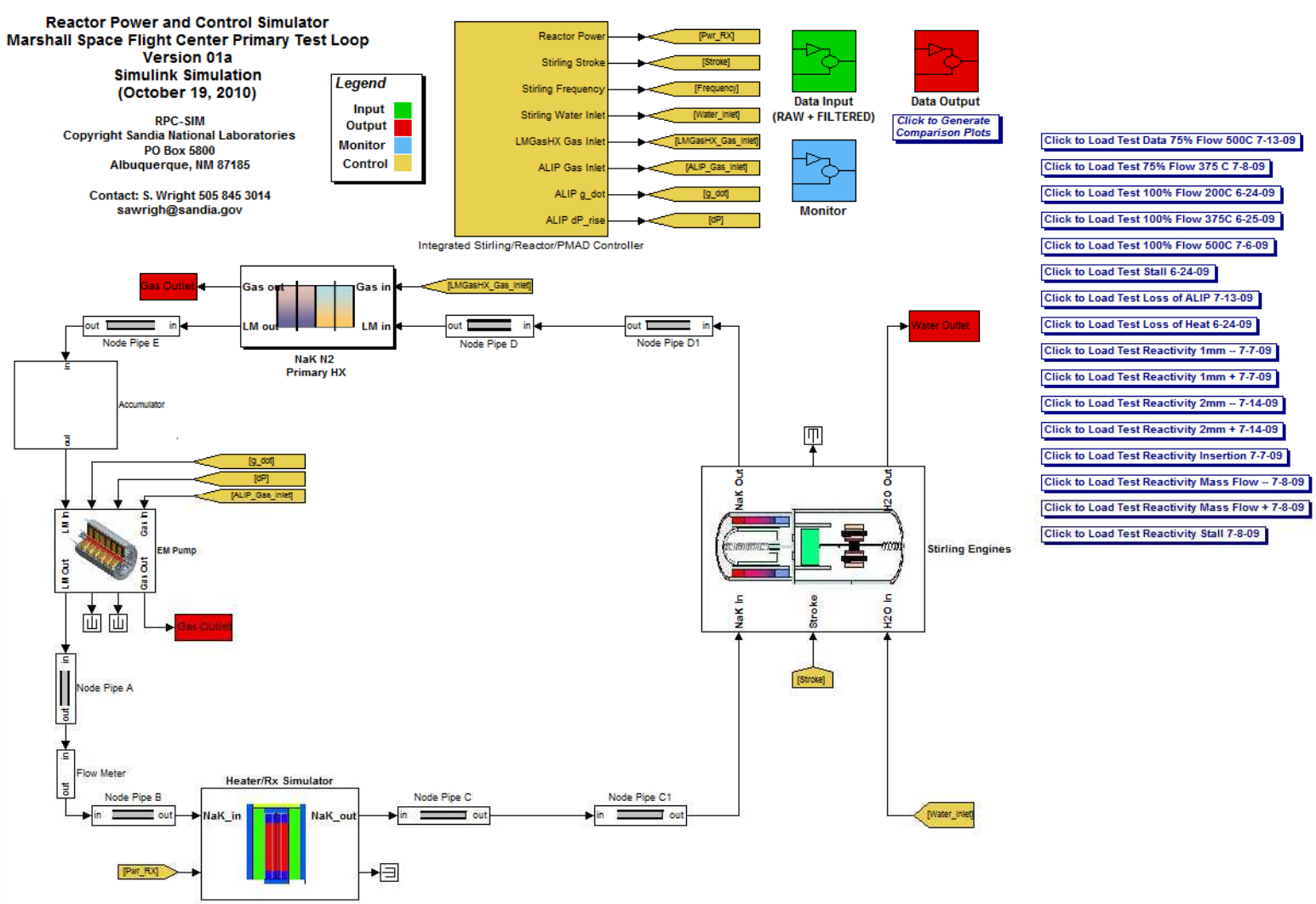




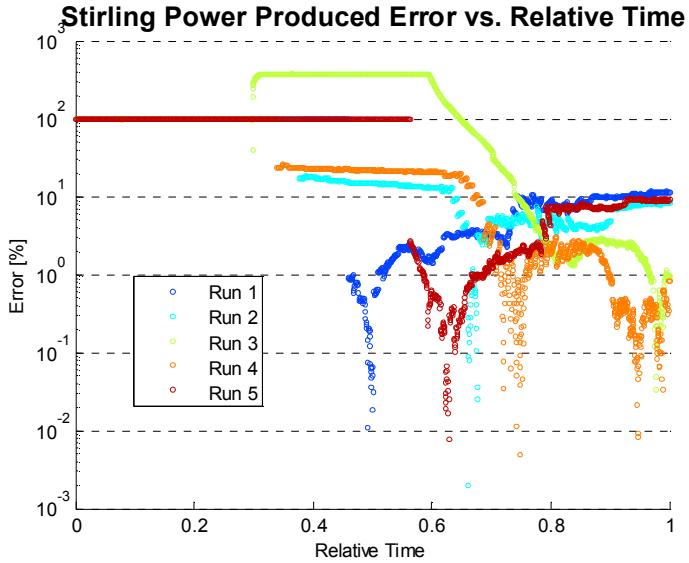
Experimental Correlation of an RPCSIM Model

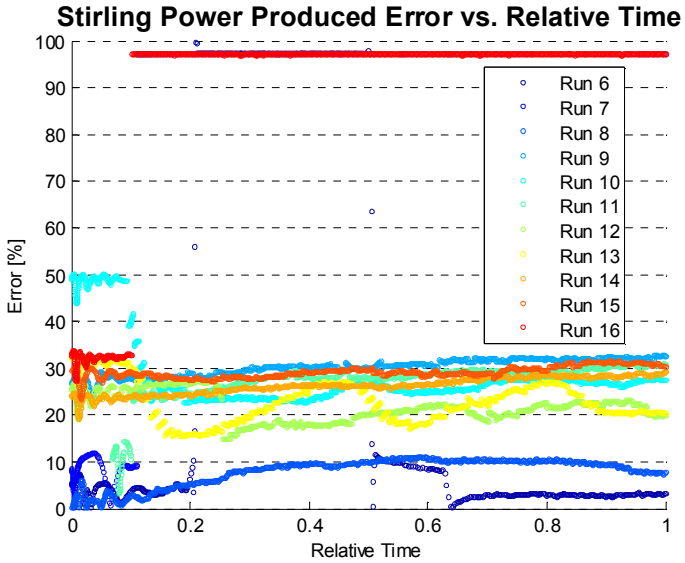
SIMULATION RESULTS

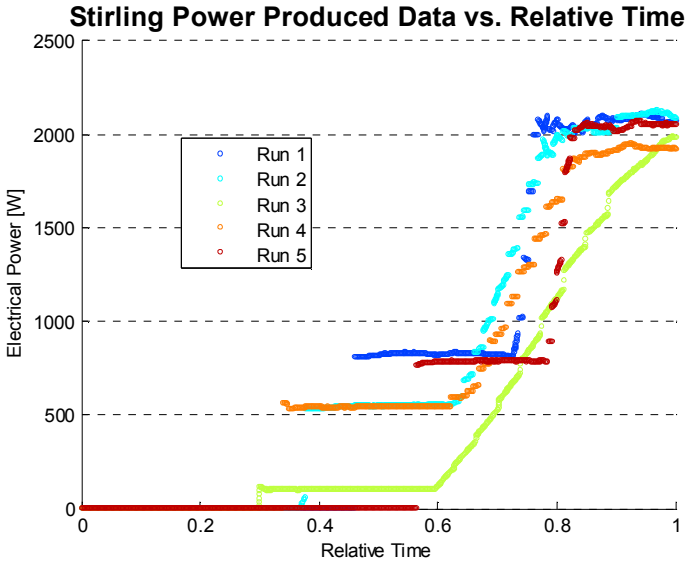
Primary Test Circuit - Diagram

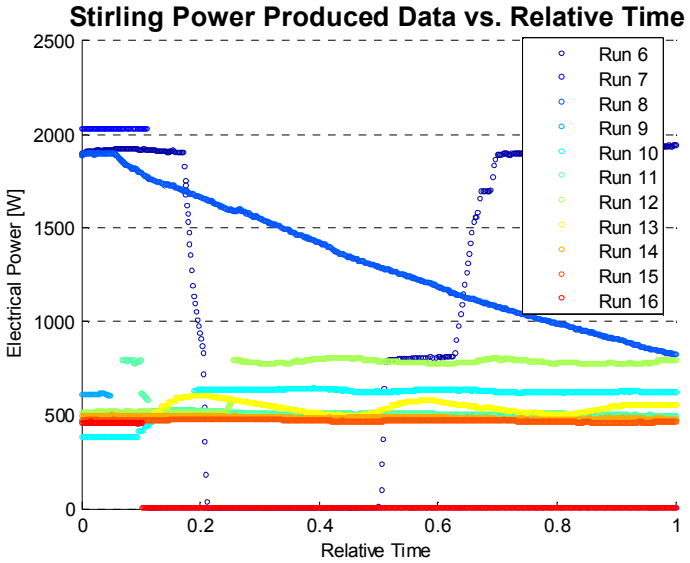


Simulation Results – Stirling Power

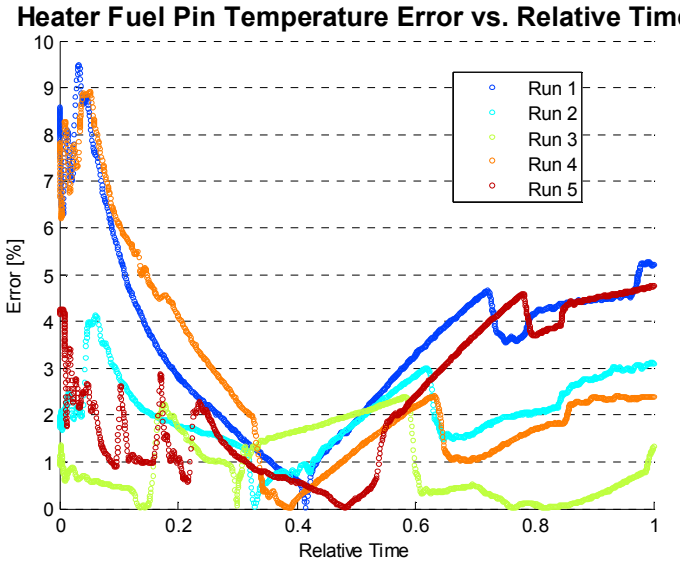


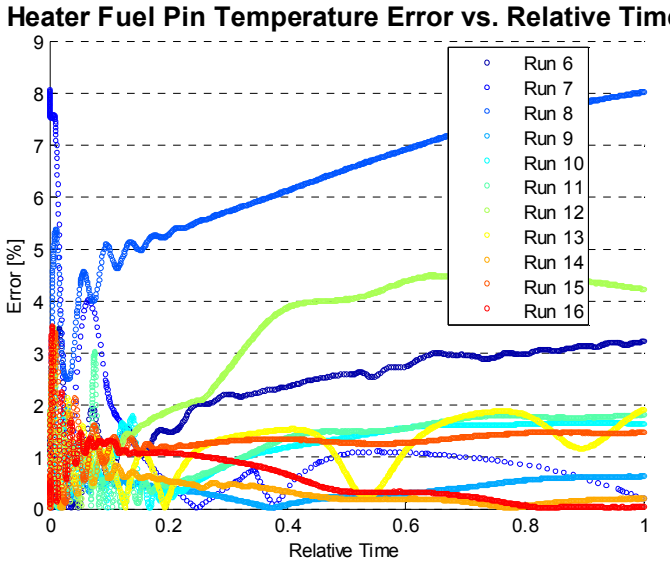


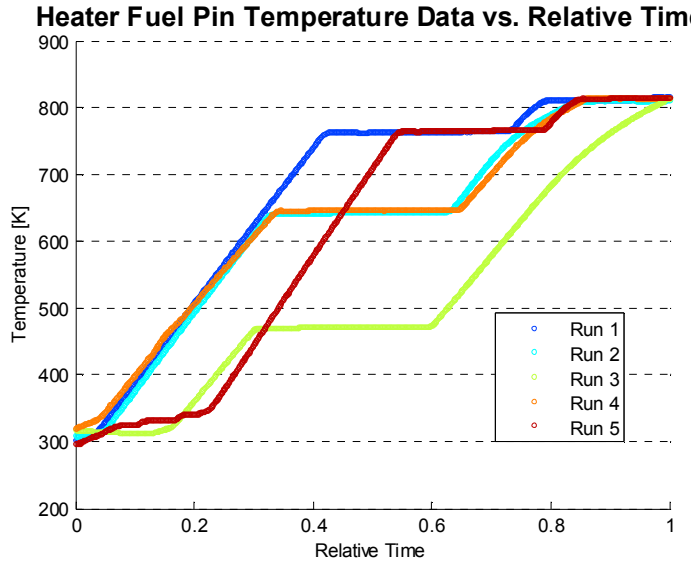


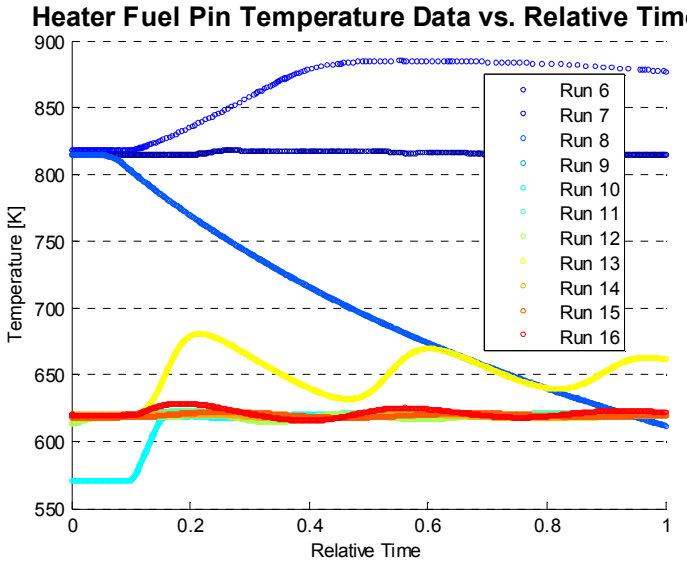


Simulation Results – Fuel Pin Temp









Experimental Correlation of an RPCSIM Model

CONCLUSIONS

Conclusions - Modeling

NUMERICS A numerical analysis should be carried out on the current RPCSIM methods to understand the accuracy and stability of the code.

CORRELATIONS The correlation functions used need to be expanded to include more specific correlations such as ones intended for fuel-pin geometries, and to handle varying flow regimes.

EQUATIONS OF STATE Current property-fitting equations should be replaced with equations of state suitable to the fluid regimes modeled.

VALIDATION Individual components should be validated using more detailed numerical analysis.

References

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3. J.M. Tournier and M.S. El-Genk. (Dec 2009). *Improvement to Sandia’s Reactor, Power, and Control Simulator (RPCSIM) Code: RPCSIM-33-UNM.* Institute for Space and Nuclear Power Studies, Department of Chemical and Nuclear Engineering ,University of New Mexico. Produced under Project and Task: 127006 0.02 ARS II-Z; PR 1105132 for Dr. Steven A. Wright 6771.
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7. R. Radel and S. A Wright (February 2009). TDU RxSim Control Options. TDU Preliminary Design Review Presentation given in Salt Lake City, Utah.

Questions?

Acknowledgements:

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Mike Houts

Department of Energy

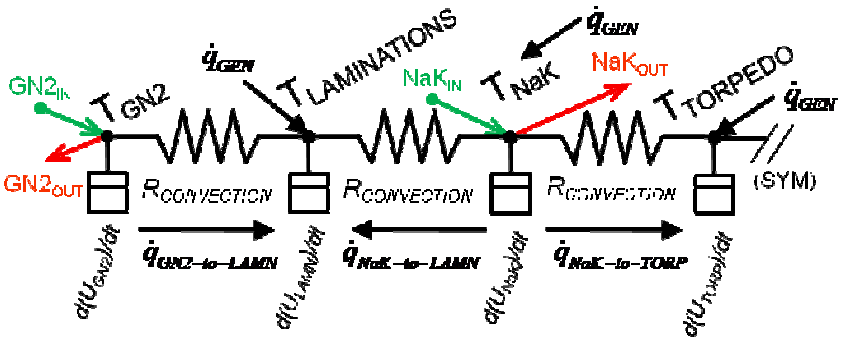
Ryan Bechtel

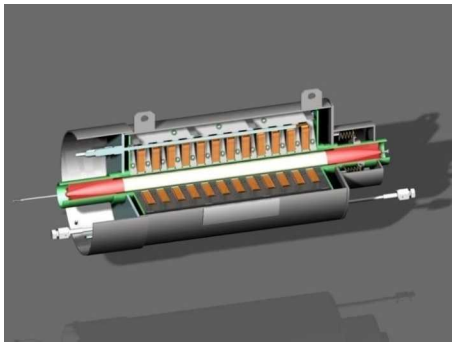
Improvements to RPCSIM Model Components

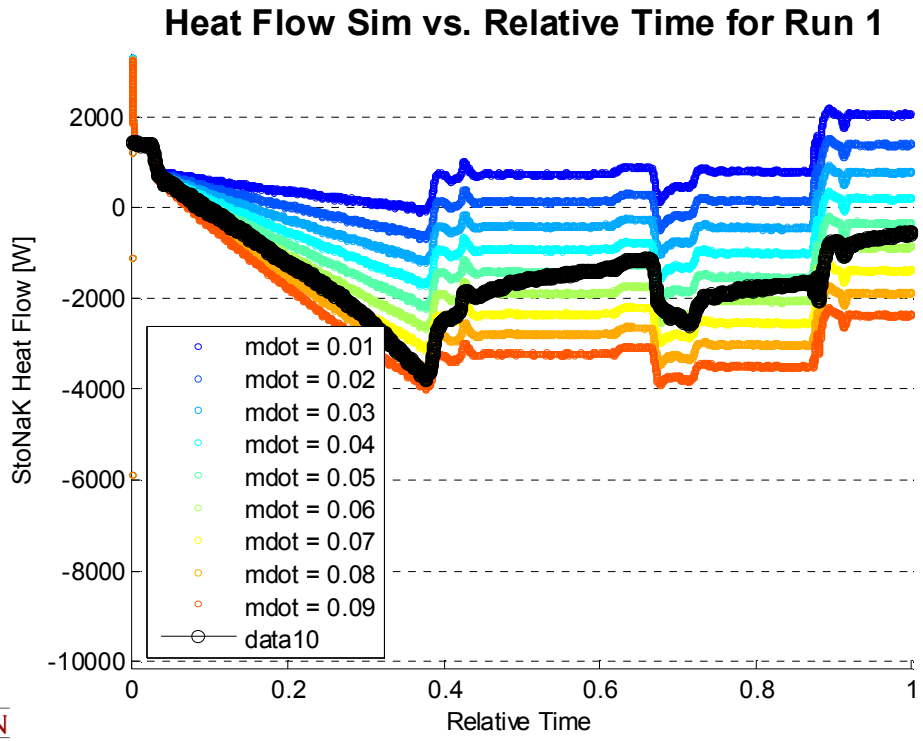
ADDITIONAL SLIDES

Correlation of RPC-SIM Models Using MSFC Primary Test Circuit Data

ALIP



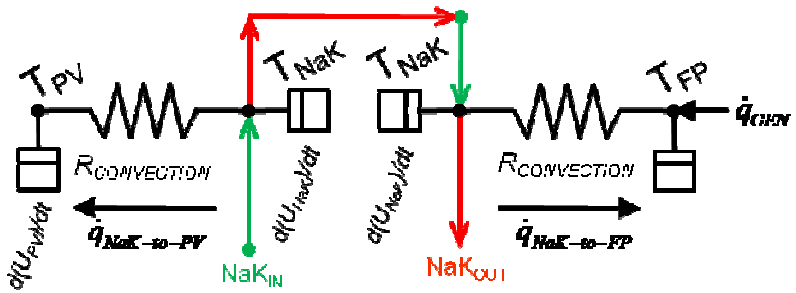


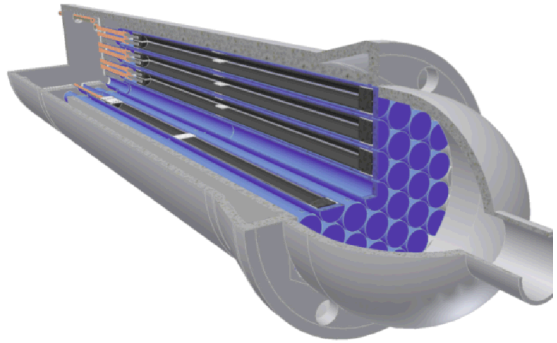


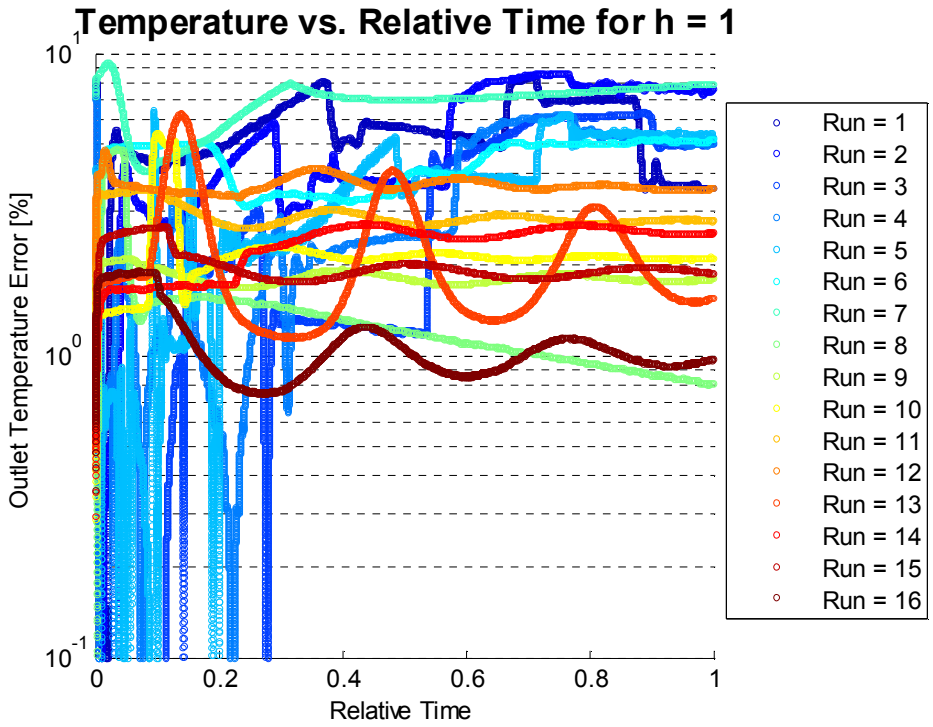
- Data correlated to allow for estimate of cooling flow along ALIP (unmeasured by experiment)

Correlation of RPC-SIM Models Using MSFC Primary Test Circuit Data

RX Simulator

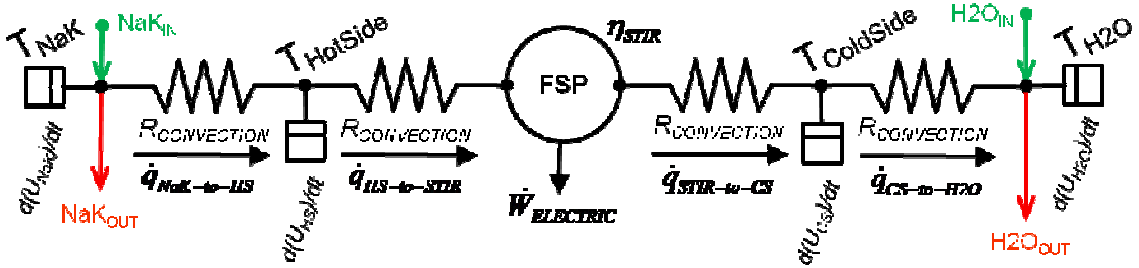


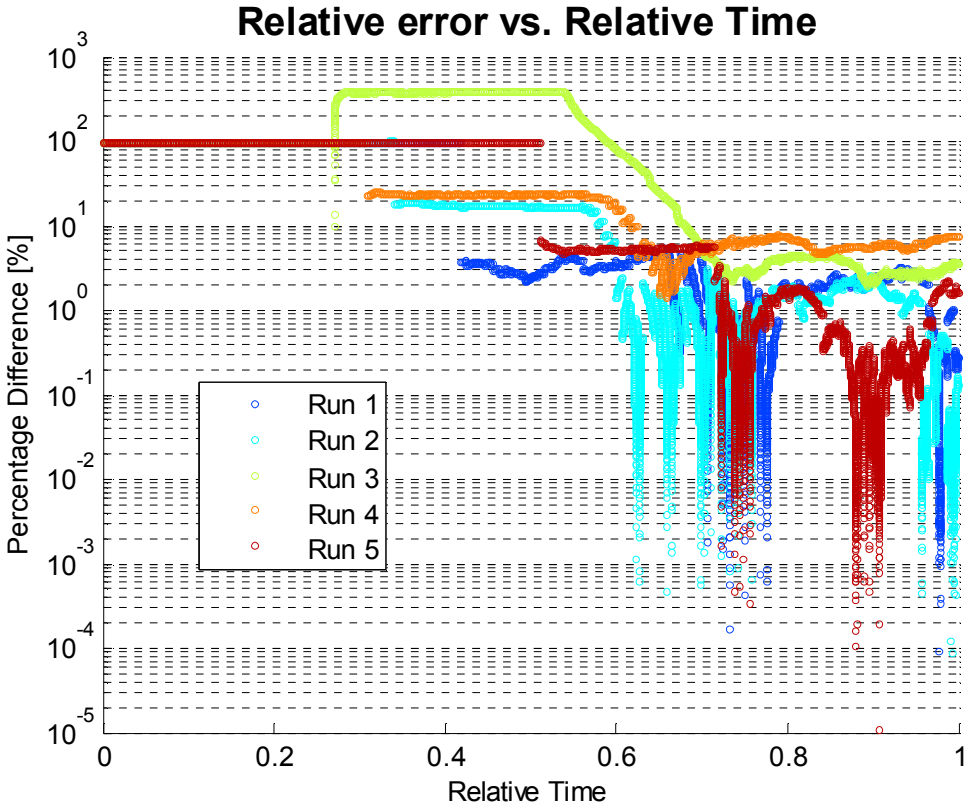




Correlation of RPC-SIM Models Using MSFC Primary Test Circuit Data

Free Piston Stirling Engines



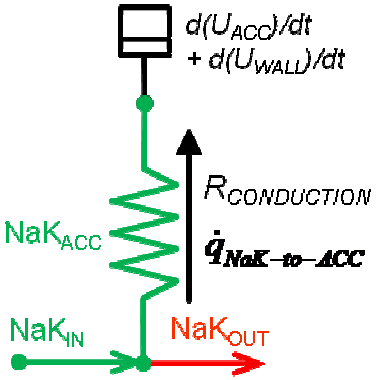


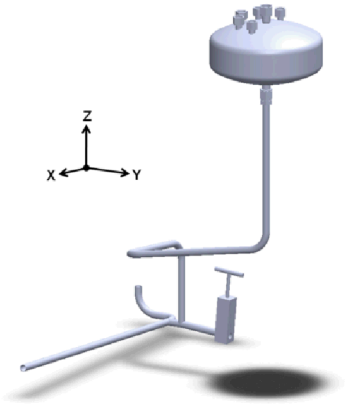
Stirling engine electrical power output vs. time

Correlation of RPC-SIM Models Using MSFC Primary Test Circuit Data

Accumulator

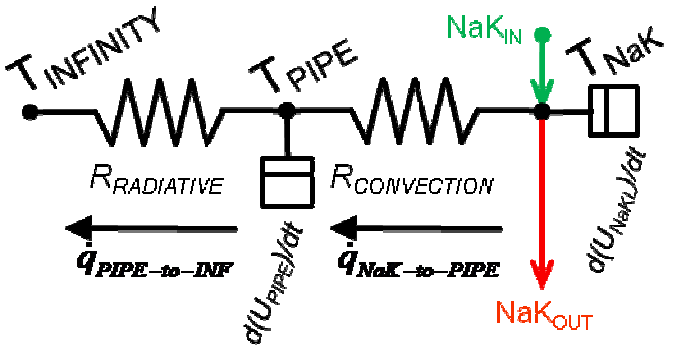
- Inadequate instrumentation for detailed analysis of accumulator, though data indicates that system was not filled enough for liquid to reach beyond the riser, into the accumulator volume.





Correlation of RPC-SIM Models Using MSFC Primary Test Circuit Data

Piping System



- Inadequate instrumentation for detailed analysis of losses through system piping.