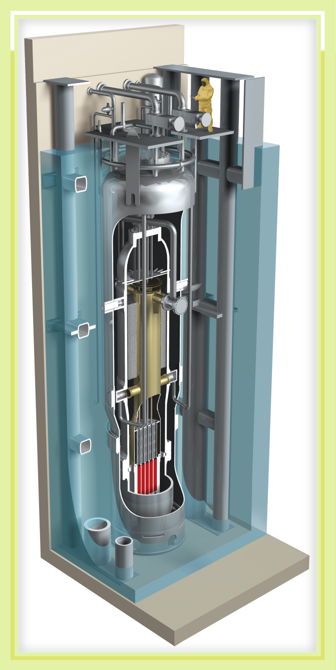
NUSCALE CHF & RELAP5

IRUG 2013



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9/13/13

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NuScale System

[redacted]

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Outline

- NuScale Reactor
- CHF Testing at STERN Labs
- What I can talk about and what I cannot
- Code Implementation
- Comparison to data
- Other Code Issues
- Mass Error – Big Ones
- Left-to-Right short-circuit processing in Compilers (or why Dr. Fortran at Intel should be given a new surname like Dumasse in relation to CVF)
- Future Plans

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NuScale Reactor

- Natural Circulation
- Core heats the water
- Rises through a central hot leg
- Turns in an upper plenum and heat is exchanged to the helical coil steam generator.
- The lower temperature water then flows down the cold leg down comer.
- Reaches the inlet of the core to complete the water flow circuit.

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Containment and Cooling Pool

- RPV inside a steel containment.
- Containment within a submerged reactor building cooling pool.
- The containment serves as a radiation barrier and a coolant flow path in the event of a small-break loss-of-coolant accident (SBLOCA), since large piping is not present in the NuScale design.
- Water enters the lower pressure containment, flashes to steam. Steam condenses on the cool containment shell. Heat transferred to the reactor building pool by conduction through the containment shell.
- The water level in the containment will rise as the RPV blows down into the containment.

STERN LABS

- Stern Laboratories critical power experiments performed using a five-by-five fuel assembly array.
- Installed in a vertical fuel channel representative of the NuScale small reactor design.
- Designed to perform critical power tests for uniform/ center peaked cosine.
- To provide experimental data which is used to develop CHF correlations that cover the NuScale reactor operating envelope.

What I Can and Cannot Talk About

- Can Talk about Ratios to Maximum Values
- Maybe some "General Ranges"
- General References for the CHF Correlation
- CHF General Procedure during Experiment
- CHF Correlation Based on "Layer Theory"

A MECHANISTIC CRITICAL HEAT FLUX MODEL FOR SUBCOOLED FLOW BOILING BASED ON LOCAL BULK FLOW CONDITIONS, *C. H. LEE and I. MUDAWWAR,* Boiling and Two-phase Flow Laboratory, School of Mechanical Engineering, Purdue University, West Lafayette, IN 47907, U.S.A., *Int. J. Multiphase Flow Vol. 14, No. 6, pp. 711-728, 1988.*

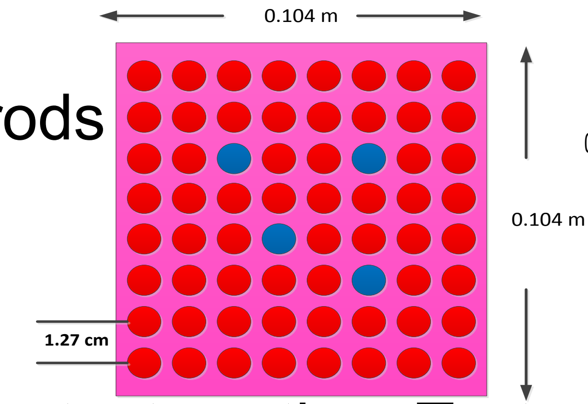
Code Implementation

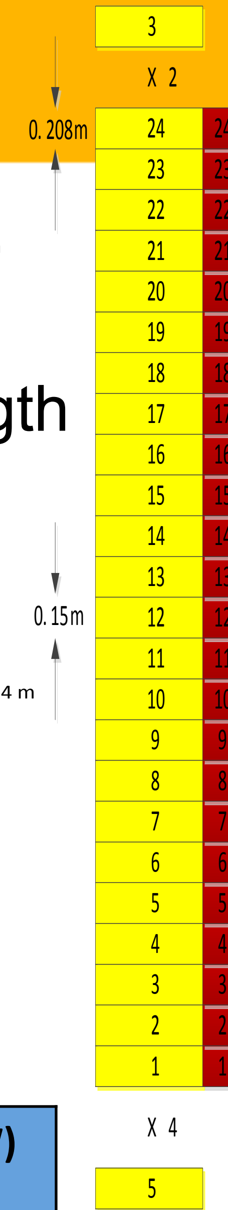
- Develop Model ORNL THTF Tests 3.07.9B, 3.07.9N, 3.07.9W
- Sixty-four rods -> eight- by-eight bundle, heated length 3.66 m.
- Sixty heated and four unheated rods
- Inlet flow established,

  Power increased to dryout point,

  reached a desired elevation in the test section. Test

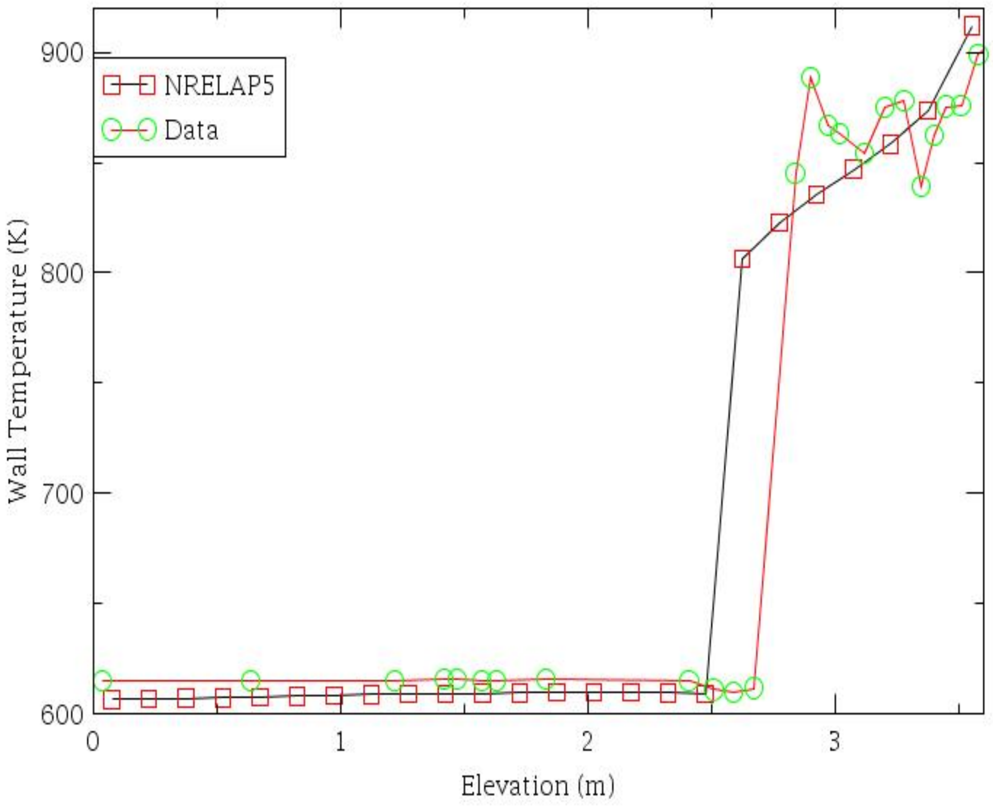
  run until the operating pressure and rod surface temperatures stabilized.





Test	Pressure (MPa)	Inlet Temperature (K)	Mass Flow (Kg/s)	Power (kW)
3.07.9W	12.0	567.0	1.58	2490.5

Results



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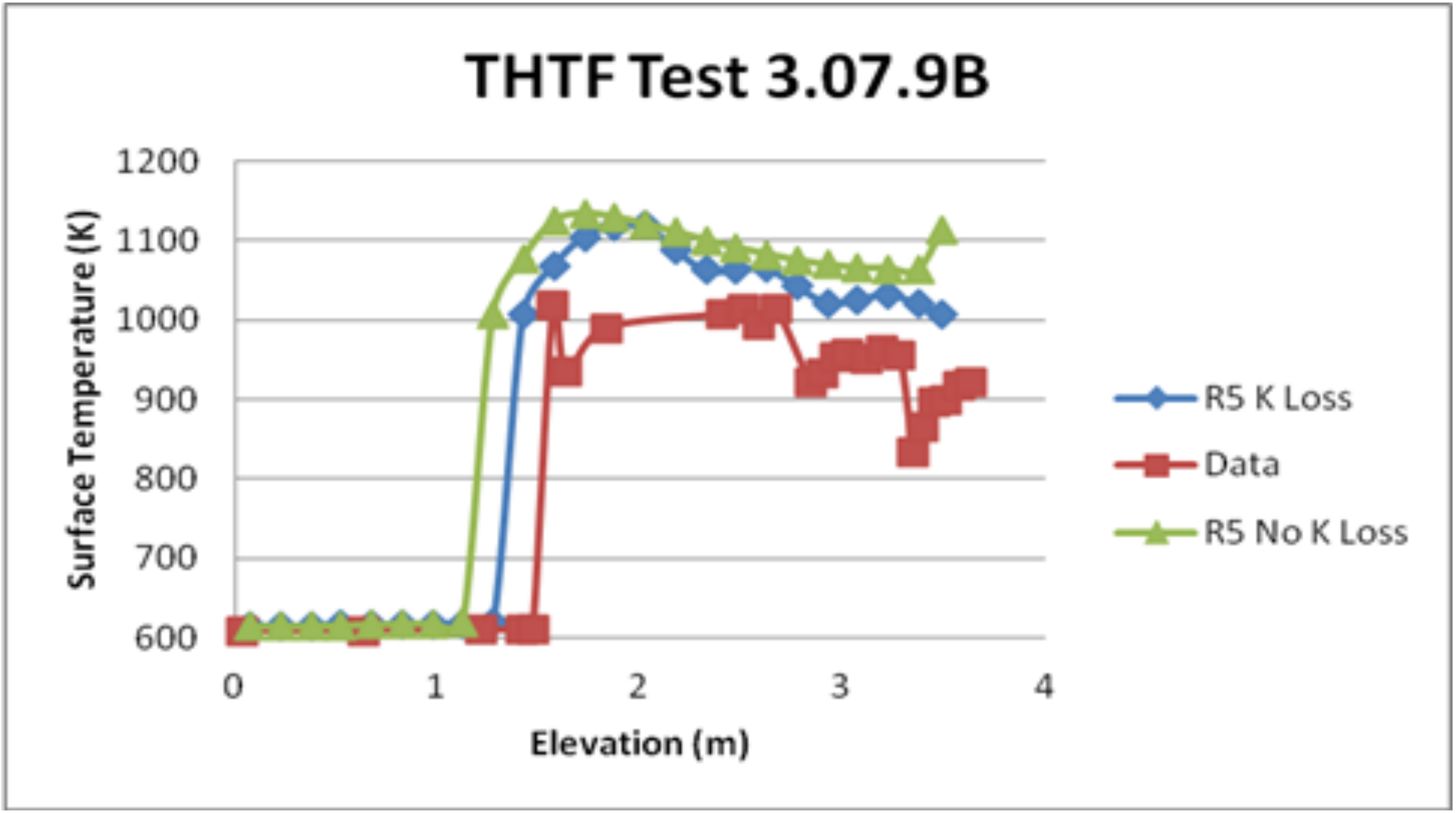
Grid Spacers on Different Test



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Steps

- Fortran into Three and Six Equation Test Codes with Boiling Curves, Thermo Props for Testing

  "Teaching Thermal Hydraulics & Numerical Methods" , An Introductory Control Volume Primer © D. Scott Lucas, Ph.D., or at www.microfusionlab.com

- Compared to SNAP Thermo Props
- Followed the Advice of the RELAP5 Philosopher Dr. Rich Riemke " Take Baby Steps" , Nolan Says, Don't Muck it Up
- Copied SRL CHF Correlation
- Put Option under RCHNG Subroutine
- Put Under CHFCAL as Stand Alone
- Run it through Debugger in R5 and Compare Line by Line to Implementation in Codes Above
- Connect to MAJOUT, Input and Test

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Correlation

Case	374	379	389	252	150	375	140	435
Pi/PiMax	.13	.13	.13	1.0	.63	.13	.62	.25
Ti/TiMax	.59	.59	.53	.94	.89	.59	.89	.64
Wi/WiMax	.34	.59	.34	.45	.25	.44	.25	.27
Pwr/PwrMax	.43	.74	.45	.32	.32	.49	.30	.36
CHF/CHFMax	.44	.74	.46	.32	.33	.50	.32	.36
NR5 % Error	13.	13.	12.	5.	7.	12.	18.	33.

Other Code Issues

- Appendix K Models under Option 22
- Allows User to Compare with Best Estimate
- 1.02 Power Multiplier
- Baker Just V&V Analytical Solution
- 1971 ANS DECAY Heat with Spread Sheet and Point Kinetics via D. Prelewicz (ISL)
- Appendix K CHF Correlations
- STERN CHF CORRELATION – Additional Work NRELAP5 & SCANR (Sub Channel Code)
- Approved Transition Boiling Model
- No Return to Nucleate after CHF
- The logic to prevent return to transition boiling.
- A calculated core flow smoothing model.
- Fauske + Moody Critical Flow (Moody for 2 Phase, Fauske for Single + Transition)
- Schultz, R., Davis, C., "Recommended Models and Correlations and Code Assessment Matrix for Creating a 10 CFR 50.46 Licensing Version of Relap5-3D© for Pressurized Water Reactors," INEEL/EXT-98-01257-Revision 2.

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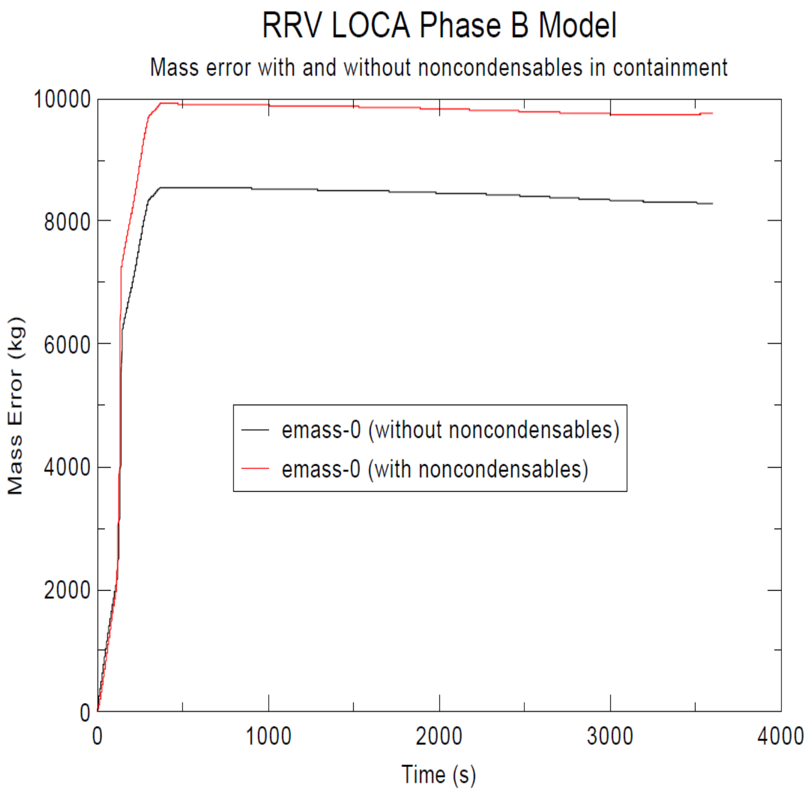
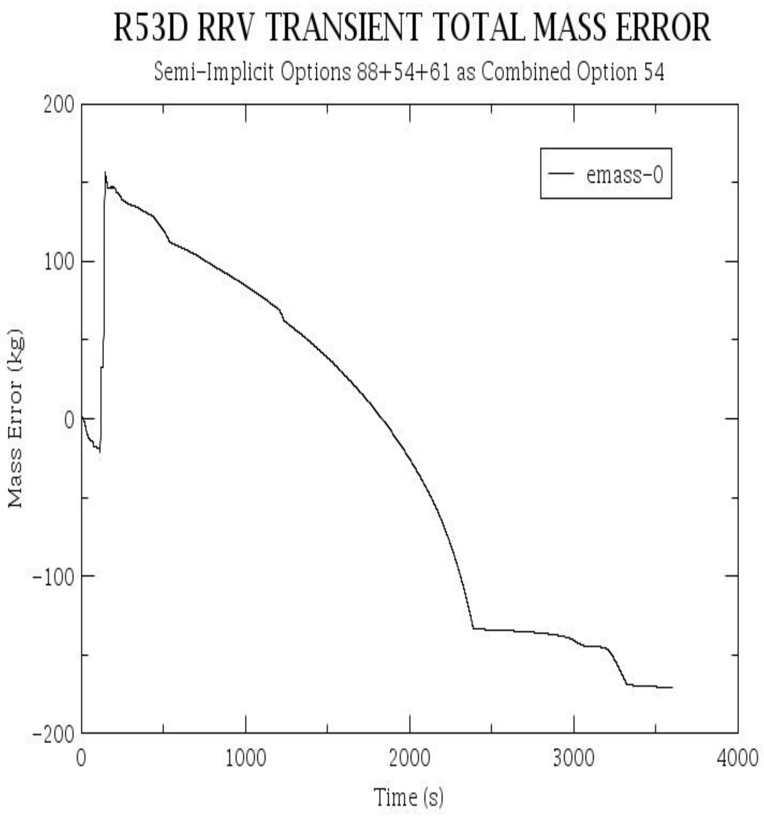
Mass Errors – NuScale Disclaimer





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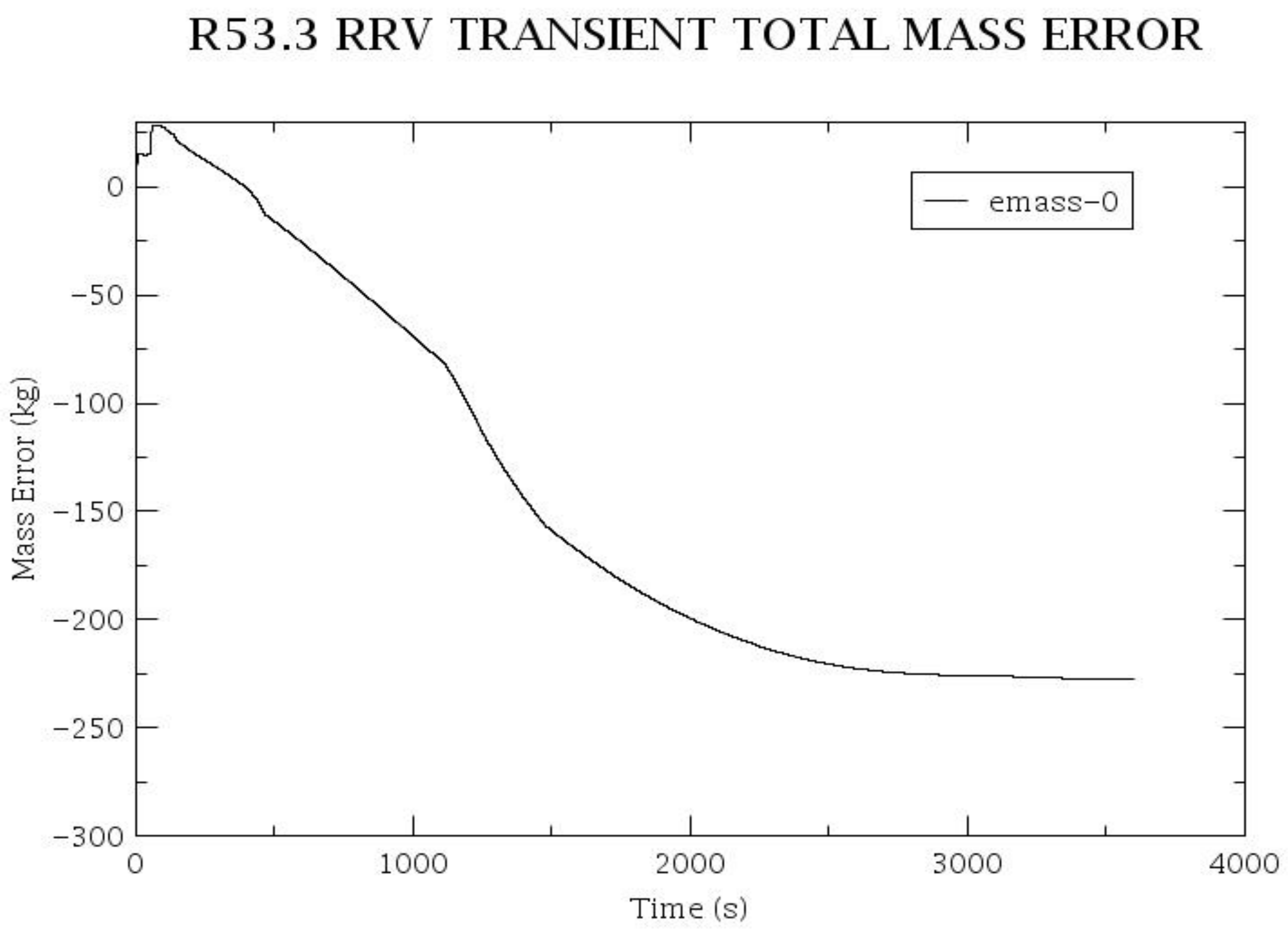
R53.3 Mass Error



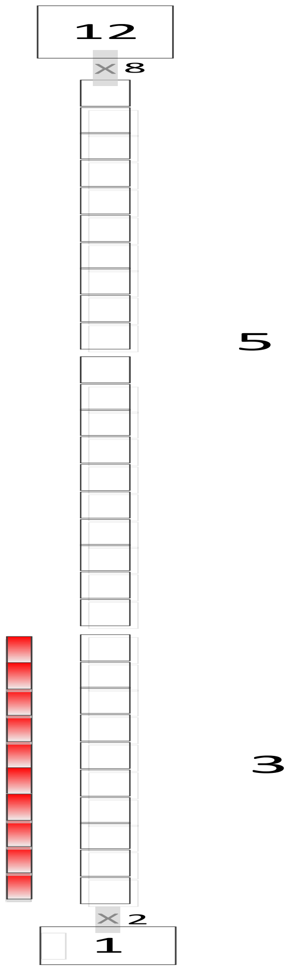
Compiler Short Circuit

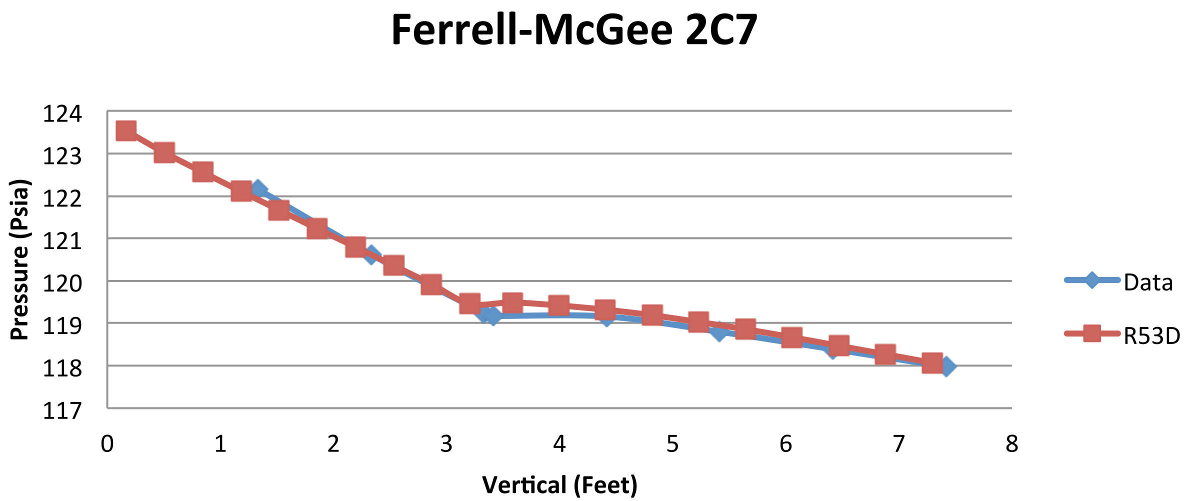
- We have had a number of software anomaly and defect issues associated with FORTRAN coding and modern compilers such as the current Intel Visual Compiler (IVC) currently used at NuScale. Much of this coding was developed using the Compaq Visual Fortran (CVF) 6.x era compiler:
- In January of this year Scott Lucas and I identified errors associated with left-to-right short-circuit processing assumptions in Fortran coding, which are difficult to fix with IVC.
- In March, INL confirmed and identified errors with respect to compound if-statements with left-to-right operational short-circuit assumptions and has started to fix many of them. The NRC version will most likely never be fixed.
- The old (W) slogan, Good, Fast, Cheap, Pick any Two.
- In April, we spent two weeks attempting to compile Cobra-en with other compilers. Eventually a version of CVF was found, and Cobra-en compiled easily without errors.
- Computer codes such as Cobra, RELAP and Trace were historically developed and compiled using Compaq Visual Fortran.

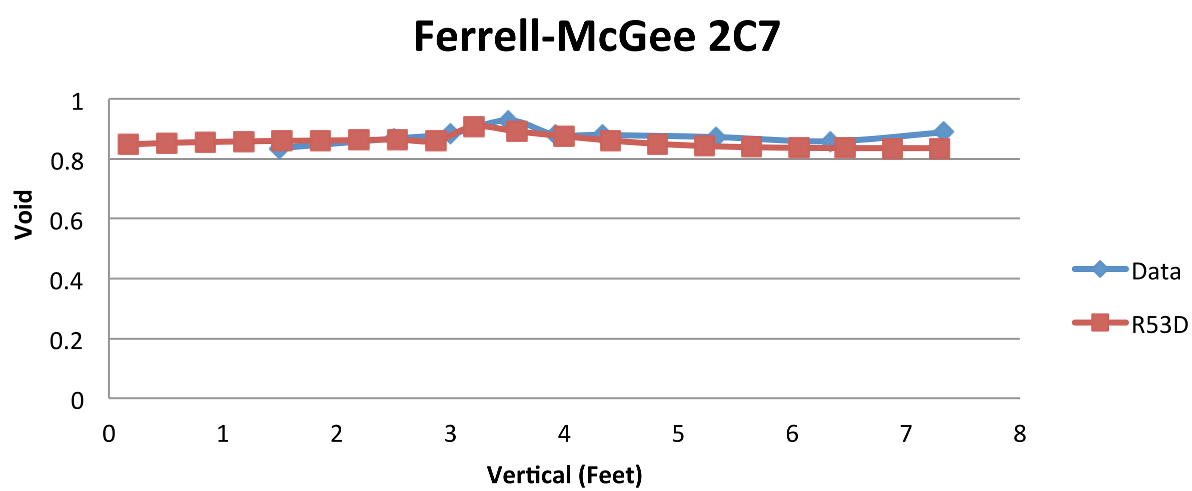
Scott Lucas, not NuScale

- Early 2000's there was a need to Consolidate Mod3.3 and 3D Features
- OvrChk, Courant 1, Courant 2, New Steam Tables, PARCS Full Features, Lowered Mass Errors, Smoothing, Ramps, etc.
- Nixed by an NRC Research Manager whom will go Nameless, Climate has Changed, TRACE is deemed a SUCCESS
- INTEREST BY IRUG???
- Certainly, Interest by Others.

Ferrell McGee







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