Seven Percent Critical Experiment (7uPCX) at the Sandia Pulsed Reactor Facility

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Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company,
for the United States Department of Energy's National Nuclear Security Administration
under contract DE-AC04-94AL85000.

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Agenda

- Critical Experiments
- Codes
- Seven Percent Critical Experiment
- Uncertainty Analysis
- Conclusions To Now

Critical Experiments

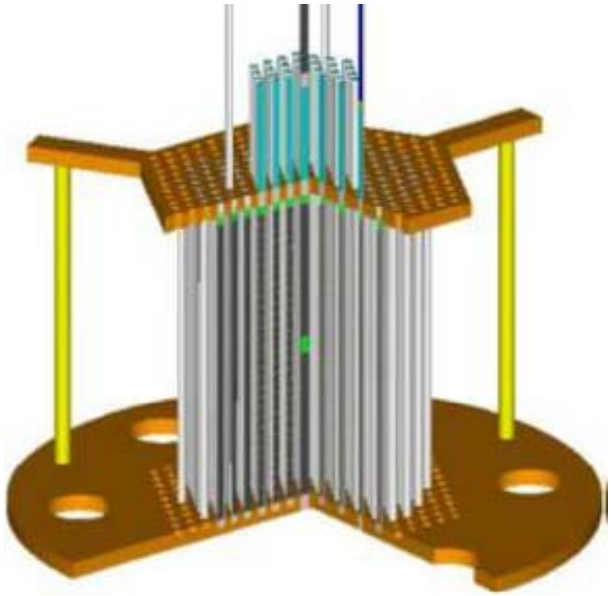
- International Handbook of Evaluated Criticality Safety Benchmark Experiments
  - Project at INL
- 464 Experiments
  - 4,092 critical, near critical or subcritical configurations
    - Fast, Intermediate, Thermal
    - Composition, Solution, Metal
    - HEU, LEU, Pu, Mixed, ^{233}U
  - Criticality Alarm Experiments

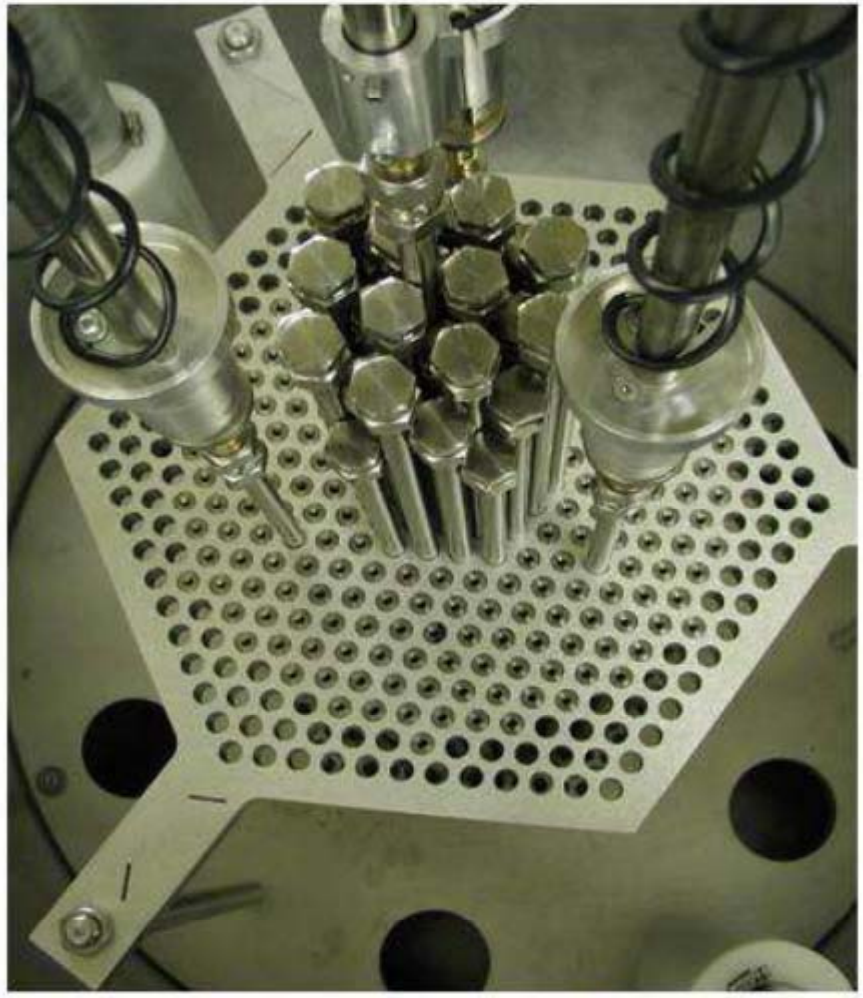
Codes

- MCNP (LANL)
  - Monte Carlo Neutron Production
- SCALE (ORNL)
  - Standardized Computer Analyses for Licensing Evaluation

Burn Up Credit Critical Experiment (BUCCX)

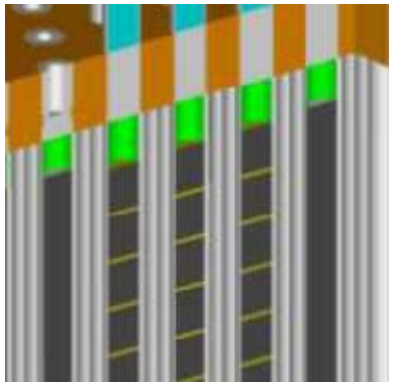
- 4.31 wt% ^{235}U
- Fission Product Effects

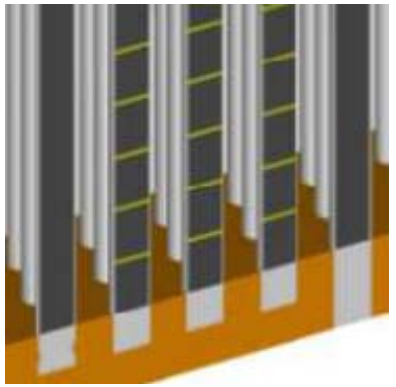




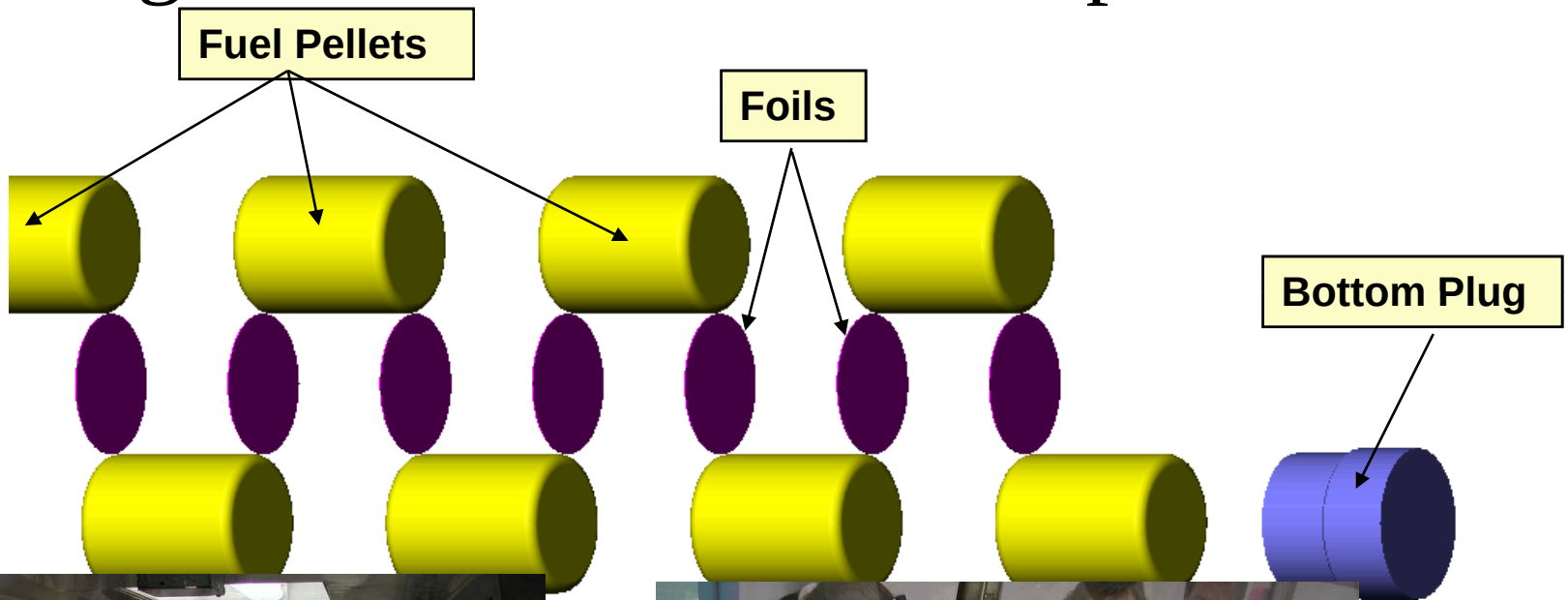
In 2002, SPRF performed some critical experiments with rhodium

- The Burnup Credit Critical Experiment (BUCCX) was funded by the Nuclear Energy Research Initiative (NERI)
- Built a critical assembly in which could insert fission product materials to measure reactivity effects
- The NERI funding was used to bring the experiment capability up and perform the first set of experiments
- Completed a set of experiments with rhodium
- The experiment is documented as LEU-COMP-THERM-079 in the International Handbook of Evaluated Criticality Safety Benchmark Experiments





We built special experiment fuel rods that give us access to the fuel pellets



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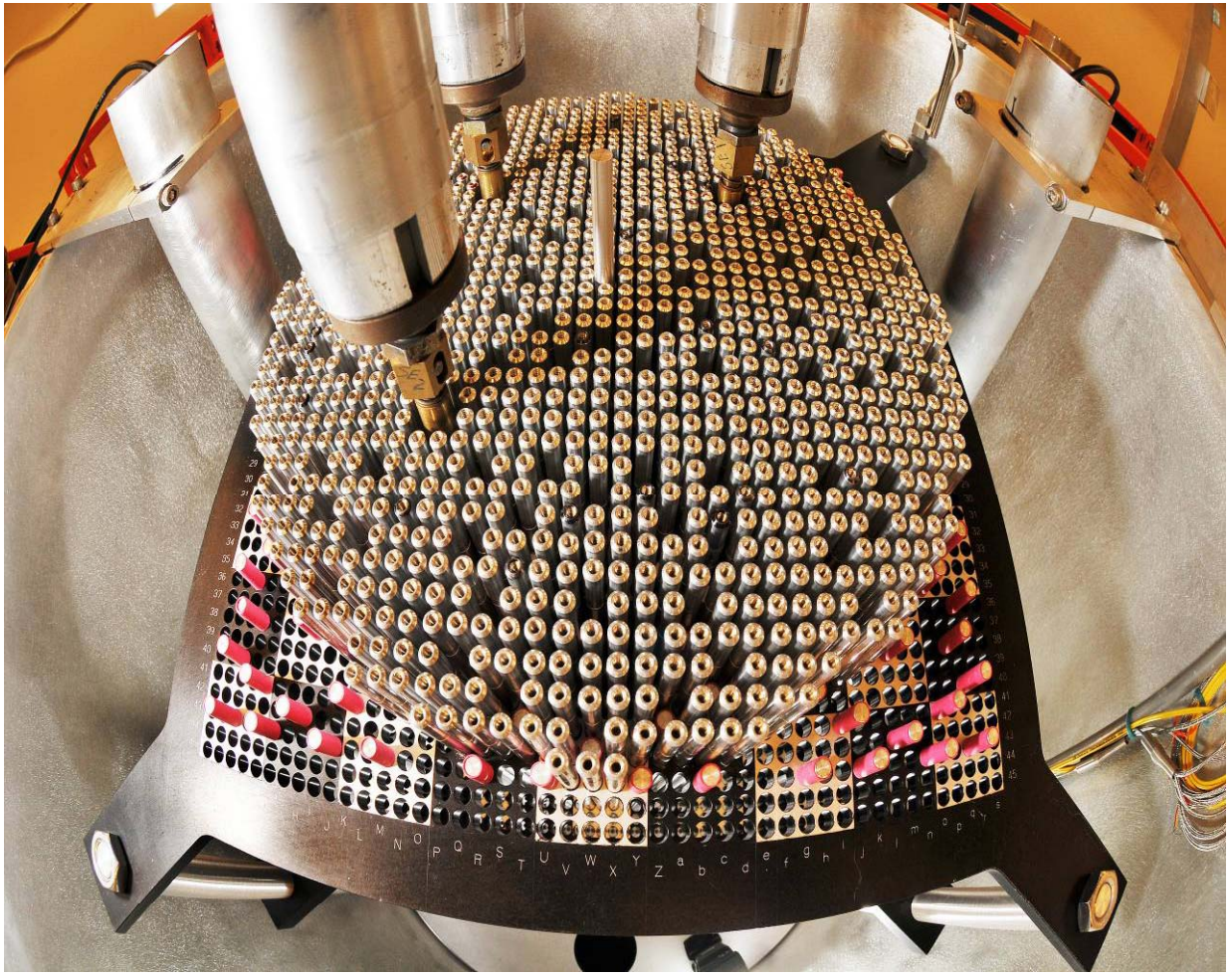
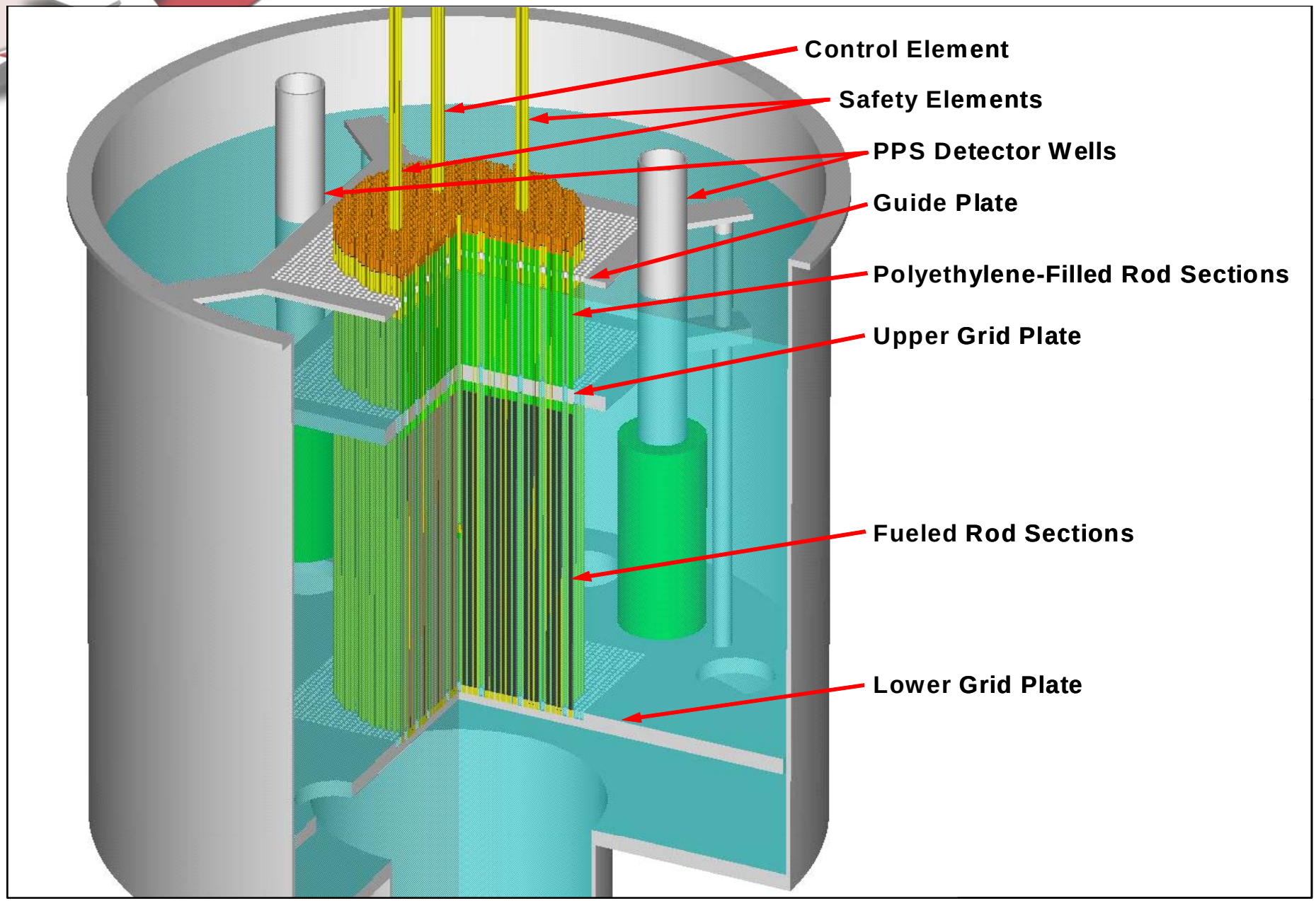
Seven Percent Critical Experiment

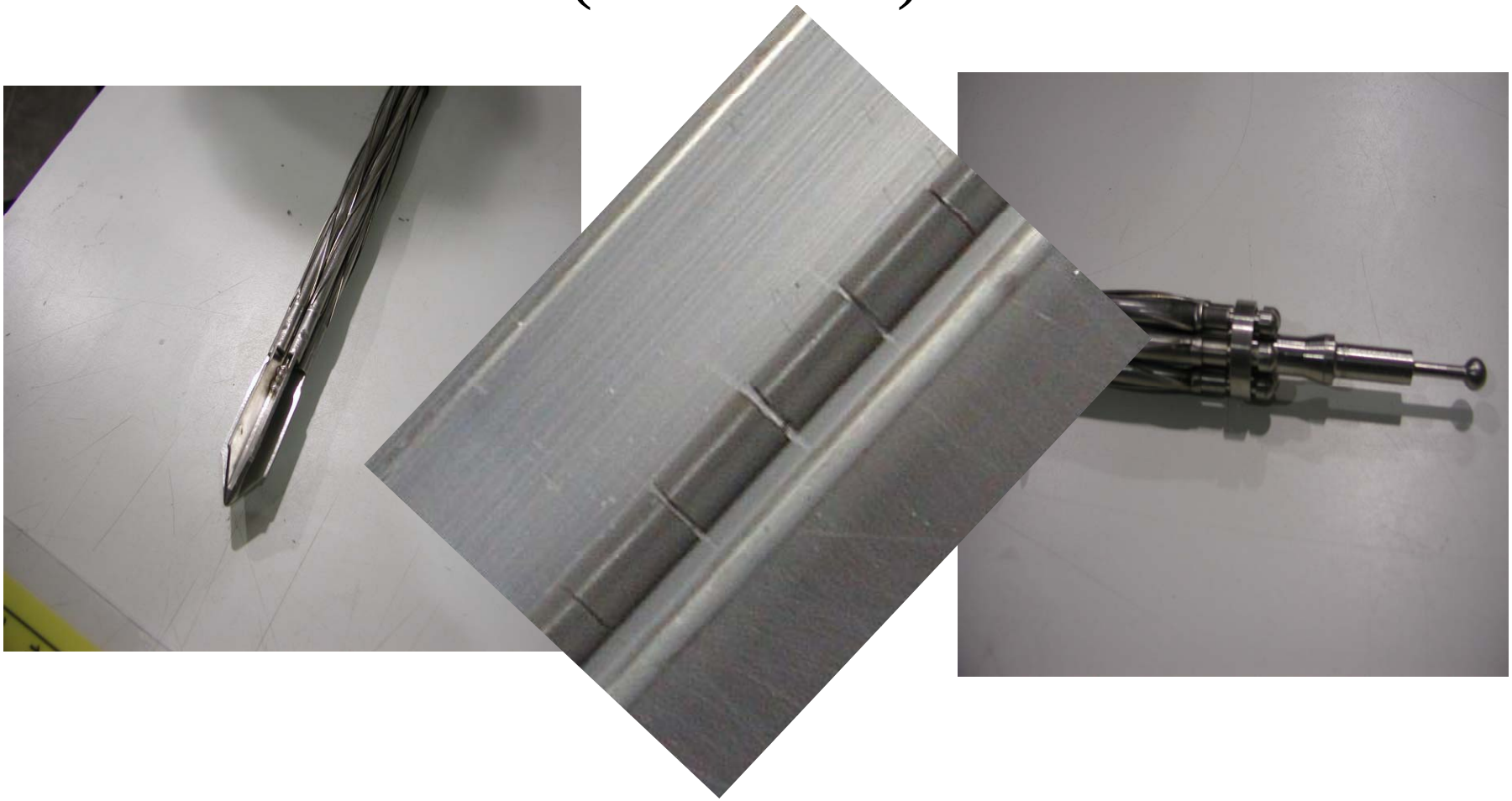
- Square Pitched
- Water Moderator
- 7 wt. % ^{235}U
- Aluminum Cladding
- Very Simple System




Control Element
Safety Elements
PPS Detector Wells
Guide Plate
Polyethylene-Filled Rod Sections
Upper Grid Plate
Fueled Rod Sections
Lower Grid Plate

Fuel Rods

- Pathfinder Fuel (Penn State)



The 7uPCX fuel pellets were taken from Pathfinder fuel elements

Pathfinder Fuel Element

- Remove the bottom fixture
- Loosen the spacer wires
- Strip the spacer wires
- Remove the end plug
- Extract the fuel pellets

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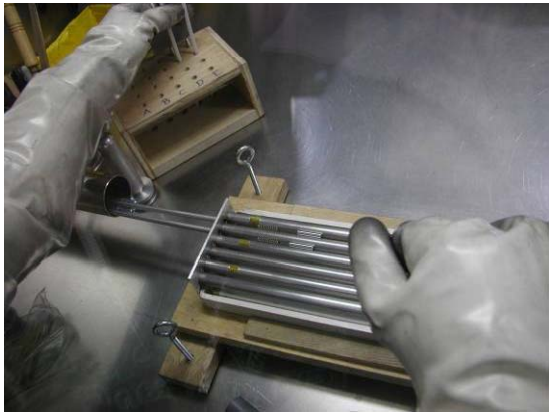
We built 2199 7uPCX fuel elements

Sort the fuel pellets



Align fuel pellets and hardware

Insert fuel and crimp end plug

1. GENERAL REQUIREMENTS AND DRAWING INTERPRETATION PER 9900000.

2. MARK UNIT NUMBER, PER 9919100 CLASS 4-1. TEXT DEPTH TO BE .005 MAX. TEXT HEIGHT TO BE APPROX. .075. LOCATE APPROX. AS SHOWN.

3. LASER WELD AND INSPECT

4. THIS MATERIAL SUPPLIED BY "SANDIA NATIONAL LABORATORIES", ALBUQUERQUE, NM.

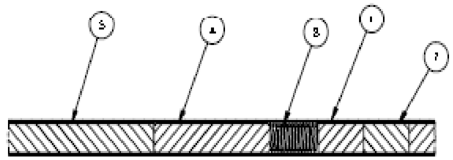
5. CERTIFICATE OF CONFORMANCE OR CERTIFICATION OF MANUFACTURERS TEST REPORTS (CMTRS) REQUIRED.

6. MAY BE OBTAINED FROM "LEE SPRING COMPANY" 1235 NORTH HOBSON STREET GILBERT, AZ 85233.

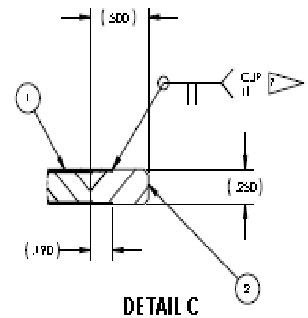
7. THE COMPLETED ITEM 1 TO ITEM 2 WELDMENT SHALL HAVE NO DETECTABLE LEAKS WHEN TESTED WITH A MASS SPECTROMETER TYPE HELIUM LEAK DETECTOR WITH A MINIMUM SENSITIVITY OF 1.0 - 5 STD CC/SEC He. THE LEAK TEST SHALL BE CONDUCTED WITH A DIFFERENTIAL PRESSURE OF 1 ATM.

	REV	ZONE	REVISED BY / DESCRIPTION	DATE	CHK	APVD
97DAAS-000	A		D. SAMUEL 2992/ P.H. HELMICK 6423	5/24/2004		PHH
	B		D. SAMUEL 2992/ P.H. HELMICK 6871	6/03/2004		PHH
		2D1	REMOVED DIM: 2X .200 DIA. & FEATURE			
		2D4	REMOVED TABULATION "A" & FEATURE CHANGED DIM: .2235/.2230 WAS .2240/.2235 CHANGED DIM: .040 WAS .030 ADDED R.004 MAX UNDER CUT			
		2D4	ADDED DETAIL C & ASSOCIATED FEATURES ADDED DIM: 8.14			
		2C3	CHANGED DIM TOL: .02 WAS .010 ADDED PART NOTE TO ITEM 5 DETAIL REMOVED DIM: 2X .020 & FEATURE			
		1C2	UPDATED AND REPOSITIONED DETAIL C			
		1C3	REPOSITIONED DETAIL B			
		1C4	UPDATED AND REPOSITIONED DETAIL D			
	C		D. SAMUEL 2992/ P.H. HELMICK 6871	6/7/2004		PHH
		1A1	CHANGED ITEM 1 DESCRIPTION: ALUMINUM WAS ZIRCONIUM ALLOY			
		2D4	CHANGED DIM: .200 WAS .100 .140 WAS .040			
		2D3	CHANGED DIM: 7.14 WAS 8.14			
		2C3	CHANGED DIM: 8.38 WAS 8.50			
	D		D. SAMUEL 2992/ P.H. HELMICK 6871	6/23/2004		PHH
		1D3	ADDED NOTE 8			
		1A1	CHANGED TITLE			
		1D3	CHANGED NOTE 6 (SUPPLIER)			
		1B2	CHANGED ITEM 6 PART NUMBER REMOVED NOTE 8			
	E		D. SAMUEL 2992/ P.H. HELMICK 6871 CHANGED NOTE 5 (CMTRS)	10/11/2004		PHH

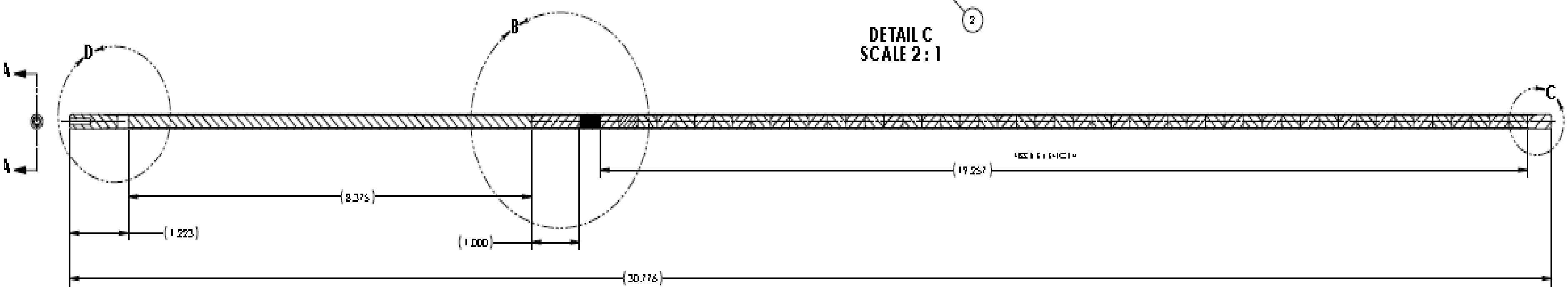
DETAIL D
SCALE 2 : 1



DETAIL B
SCALE 2 : 1



DETAIL C
SCALE 2 : 1



SECTION A-A

QTY.	PART NO.	DESCRIPTION	NOTE	ZONE	ITEM
1	LC-018B-10-S	SPRING COMP, CRES .180 OD .138 ID .875 LG	6		8
49		FUEL PELLET			7
1	97DAAS-500	UPPER POLYETHYLENE PLUG			5
1	97DAAS-400	UPPER ALUMINUM PLUG			4
1	97DAAS-300	TOP END CAP			3
1	97DAAS-200	BOTTOM END CAP	2		2
1	97DAAS-100	CLADDING ALUMINUM			1
NA	9919100	MARKING GENERAL METHODS			
NA	9900000	GENERAL REQUIREMENTS AND DRAWING INTERPRETATION			

SHEET	1	2	3	4	5	6
ISSUE	E	E				

FUEL ROD, 7uPCX

UNCLASSIFIED

UNCLASSIFIED

D

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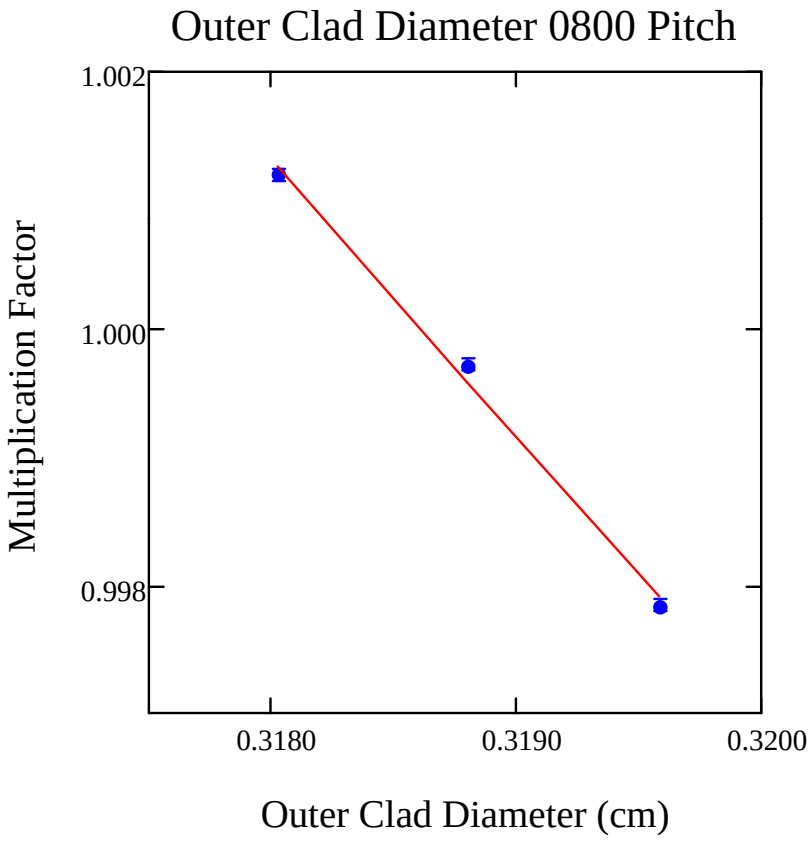
SolidWorks 2004

Direct Uncertainty Analysis

- Determine Uncertainty in Parameter
  - Type A or Type B
- Perturb Experimental Model by Uncertainty
- Relate change in k_{eff} to change in parameter



TSUNAMI-3D

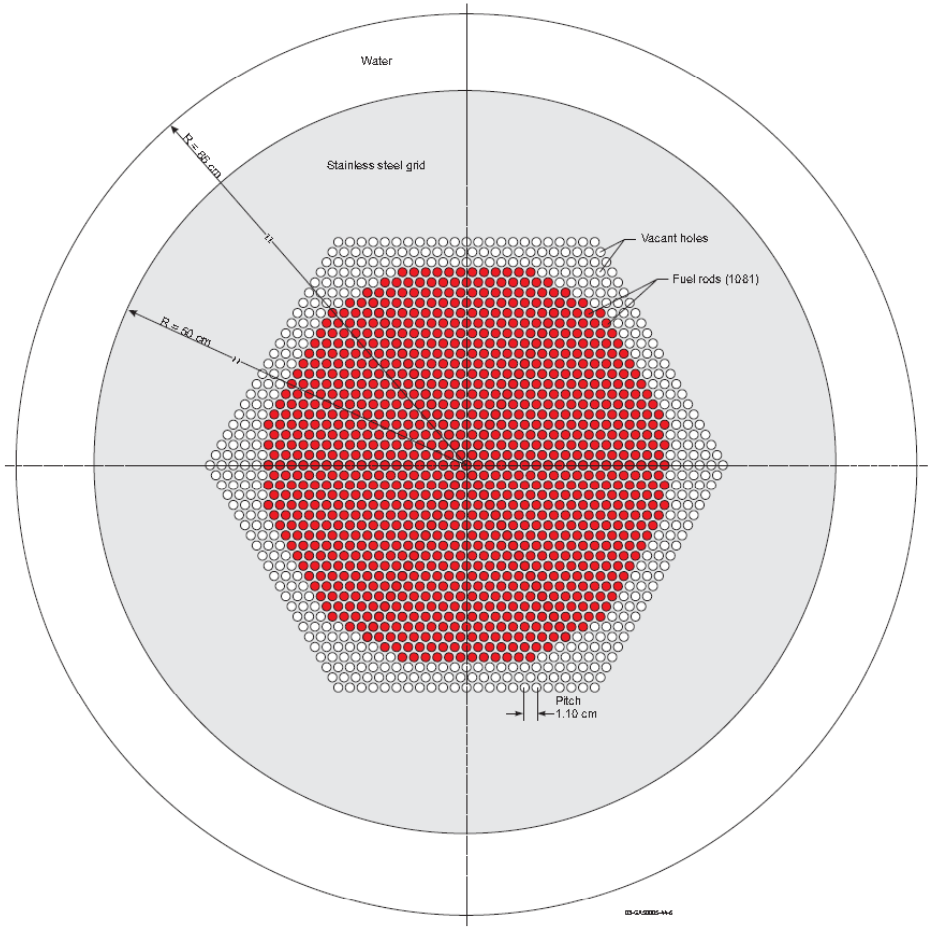
- SCALE 5.1 KENO V.a
- Sensitivity and Uncertainty Analysis Tool
- First Order Linear Perturbation Theory
- FUN Equations
- Covariance Matrices
- 10,000 generations with 40,000 neutrons per generation

Parameters 7uPCX

- ^{235}U wt. % –Fuel Composition
- Temperature – Water
- Pitch – Water
- Fuel Diameter – Fuel Composition
- Clad Thickness – Clad Composition
- Clad Outer Diameter – Water
- Grid Plate Material Composition
- Source Capsule Composition
- Cladding Composition
- Water Composition
- Water Level

LCT070

- 6.5 wt% ^{235}U
- Critical Water Height
- 12 Different Configurations
- Hex Pitch (1.1 cm)



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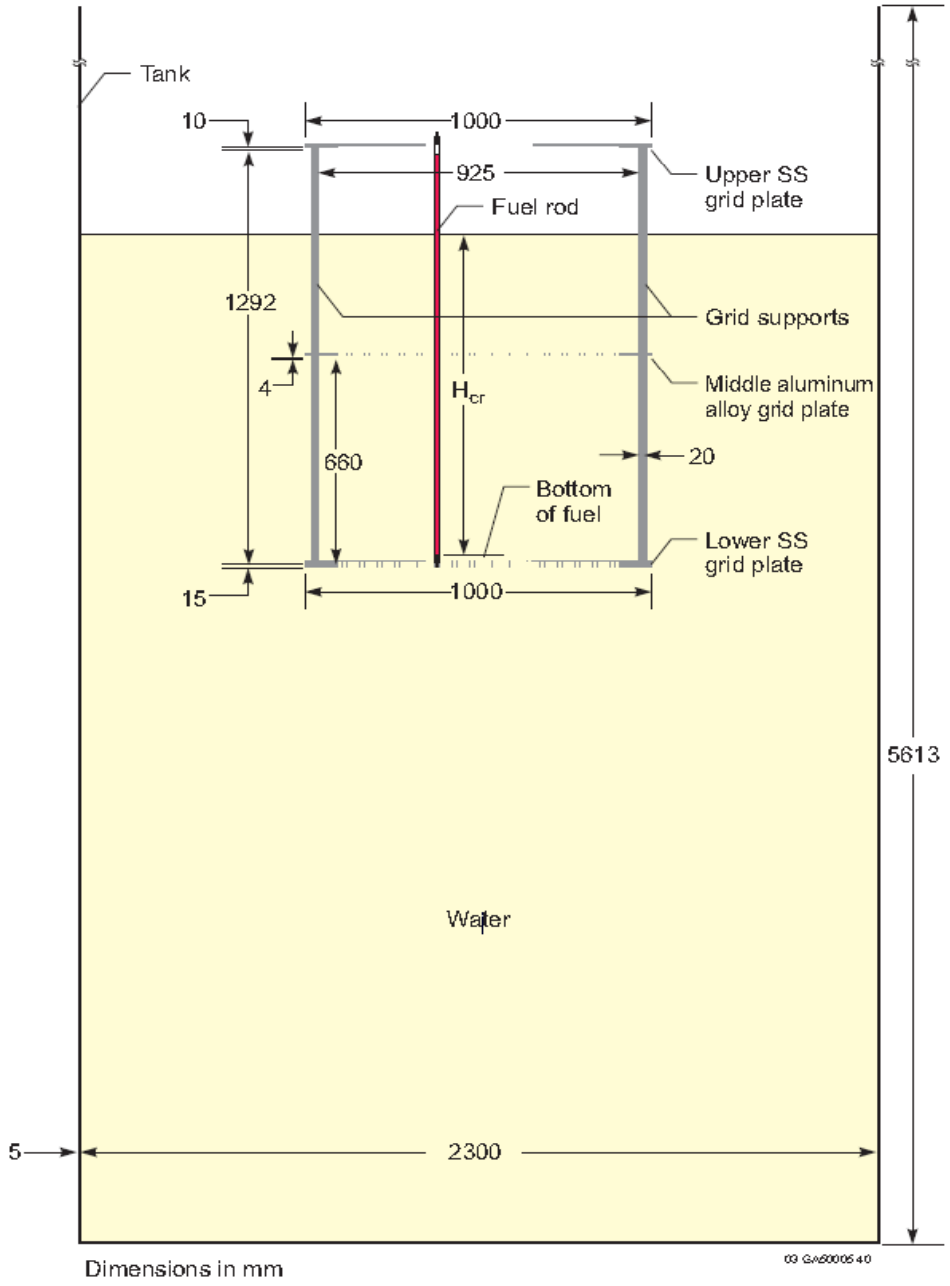

Figure 1. Scheme of the Core Structure.

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Clad Outer Diameter

$$\sigma_{keff,i} = I_i \sigma_{pi}$$

$$w = \left[\frac{\sqrt{3}}{2} p^2 - \pi \left(\frac{d}{2} \right)^2 \right] h\rho$$

$$\frac{\frac{\delta k}{k}}{\frac{\delta d}{d}} = \frac{\frac{\delta k}{k}}{\frac{\delta \rho_{H_2O}}{\rho_{H_2O}} \left[\frac{-\pi}{\sqrt{3}\left(\frac{P}{2} \right)^2 - \frac{\pi}{2}} \right]}$$

$$\frac{\frac{\delta k}{k}}{\frac{\delta \rho_{H_2O}}{\rho_{H_2O}}} = S_{\rho_{H_2O}}$$

- Uncertainty in keff
- Mass of Water in Unit Cell
- Sensitivity of pitch on system
- Sensitivity from TSUNAMI-3D

Results

	TSUNAMI/Analysis		Benchmark		Direct Uncertainty Analysis	
Parameter	Uncertainty in keff	Sensitivity	Uncertainty in keff	Sensitivity	Uncertainty in keff	Sensitivity
Clad Outer Diameter	6.775E-05	-1.114E+00	7.000E-05	1.151E+00	7.011E-05	-1.153E+00
Temperature	2.269E-03	-1.965E-03	1.300E-04	1.126E-04	1.397E-04	1.210E-04
Enrichment	1.007E-03	1.745E-02	1.000E-03	1.732E-02	1.005E-03	1.740E-02
Pitch	1.766E-03	1.814E+00	1.250E-03	1.284E+00	1.246E-03	1.280E+00

- Finish Thesis
- Publish Results
- Hopefully is Widely Used in Benchmark Evaluation

SEERI Summer 2009
Presentation

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