SAND2013-4367C

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Sandia National Laboratories

Progress on NCSP Training and Education Programs at Sandia

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Sandia National Laboratories
SAND2013 - XXXX

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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SNL Hands on Criticality Safety Training Course

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- Course Attendance
- Course Content
- Experiments
  - Approach on Fuel
  - Approach on Moderator Height
  - Approach on Separation
  - Approach on Removal of Fuel

Course Attendance

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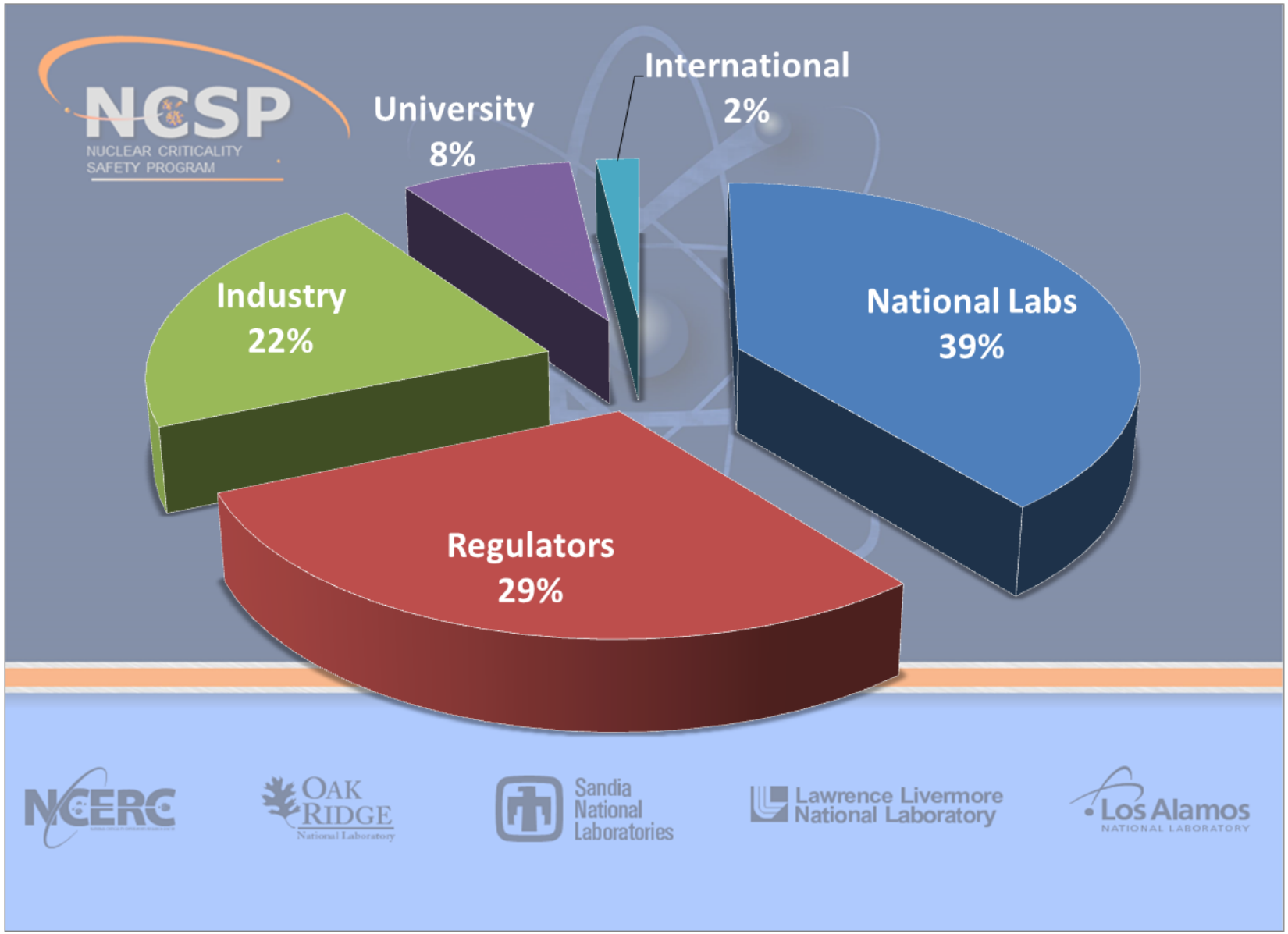
May 2013	Feb 2013	Aug 2012	May 2012	Feb 2012
LANL	Savannah River Site	Washington River Protection Solutions	NSA	NNSA
Savannah River Remediation	NRC	WTP-Bechtel	NNSA	SAIC
Transport Logistics International	University of Florida	WTP-Bechtel	DOE-Richland	NNSA
Global Nuclear Fuels	Hanford	NRC	ORNL	SAIC
Global Nuclear Fuels	US Enrichment Corp.	DOE-ORP	DNFSB	LLNL
INL	SNL	INL	INL	PNNL
Iowa State University		Sellafield Ltd.	NRC	DOE-Idaho
Nuclear Waster Partnership		NNSA	LANL	
SNL		SNL	UNM	
LANL			LANL	
LANL			LANL	
			Columbia Basin College	
			DOE-Richland	


NCSP
NUCLEAR CRITICALITY SAFETY PROGRAM
University 8%
International 2%
Industry 22%
National Labs 39%
Regulators 29%
NCERC
OAK RIDGE National Laboratory
Sandia National Laboratories
Lawrence Livermore National Laboratory
Los Alamos NATIONAL LABORATORY

United States Department of Energy
Nuclear Criticality Safety Program (NCSP)
Hands-On Training
Water-Moderated Critical Experiments
Sandia National Laboratories

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Day	Module	Title
Monday 8:30 AM - 5:00 PM	Module 00	Logistics
	Module 01	Fundamentals of Nuclear Criticality Safety – Criticality Parameters
	Module 02	Experiment Bases for Nuclear Criticality Safety
	Module 03	Critical-Measurement Accident - Chelyabinsk-40 1958
	Module 04	Subcritical Multiplication
	Module 05	Design of SPRF/CX Critical Experiment
	Module 06	Experiment 1 – Approach to Critical on Fuel Loading
Tuesday 8:00 AM - 5:00 PM	Module 07	Conduct of Operations
	Module 08	Nuclear Instrumentation
	Module 09	Critical-Measurement Accident – Kurchatov May 1971
	Module 10	SPRF/CX Reactor Theory
	Module 11	Reactor Kinetics
Wednesday 8:00 AM- 5:00 PM	Module 12	Experiment 2 – Approach to Critical on Moderator Height
	Module 13	Critical-Measurement Accident – Saclay/ALIZE 1960
	Module 14	Nuclear Criticality Safety Data and Limits
	Module 15	The International Criticality Safety Benchmark Evaluation Project
	Module 16	Results from the Sandia Critical Experiments
Thursday 8:00 AM - 5:00 PM	Module 17	Experiment 3 – Approach to Critical on Fuel Separation
	Module 18	Critical-Measurement Accident – Mol/VENUS 1965
	Module 19	Critical-Measurement Accident – Arzamas-16/Sarov 1997
	Module 20	Critical-Measurement Accident – Los Alamos 1945/1946
	Module 21	ANS-1 Section 3.0, 4.0, 5.0
Friday 8:00 AM - 3:00 PM	Module 22	Experiment 4 – Interior Fuel Rod Removal
	Module 23	Light Water Reactor (LWR) Design
	Module 24	Fuel Depletion/Burnup
	Module 25	LWR Fuel Paradigms
	Module 26	Review of the Experiments
	Exam	Closed-Book Exam

Classroom discussions are interspersed through the experiments

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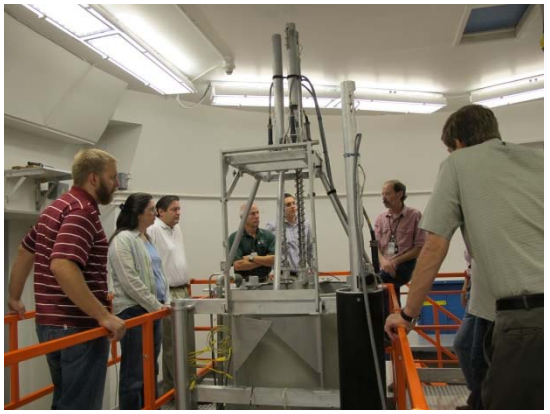
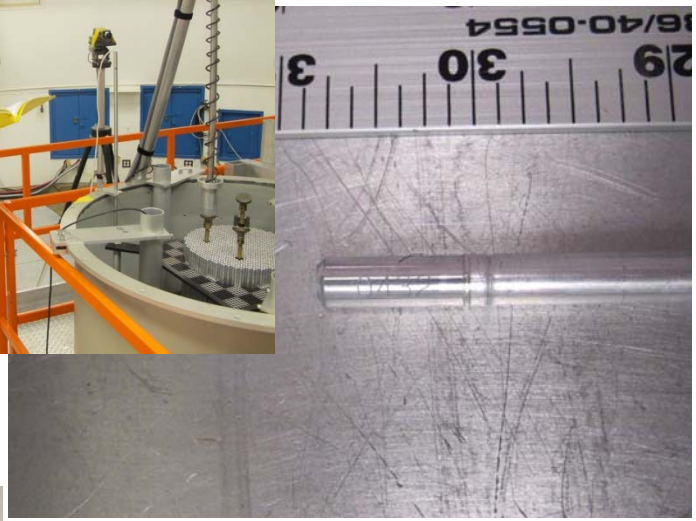
- The basics of criticality safety
- Criticality safety data and limits
- Historic critical experiments
- Subcritical multiplication
- Reactor theory and kinetics
- Description of selected critical mass accidents
- The design and operation of critical experiments at Sandia
- Radiation detection in the experiments
- Results of Sandia critical experiments
- The development and use of critical experiment benchmarks
- Light water reactor concepts as applied to the Sandia experiments



Hands-On Training

- Sort Fuel
- Hand Fuel to Load into Experiment
- Load Fuel into Experiment



Experiment 1 Overview

- Approach-to-critical experiment by loading fuel into the fully-reflected assembly
- Same process that is performed for experiments
- Criticality safety parameters that are in play:
  - Mass
  - Moderation
  - Reflection
  - Absorption

- Application to criticality safety:
  - What happens when the number of fuel lumps in an array increases?

Core Loading Experiment Configuration 1

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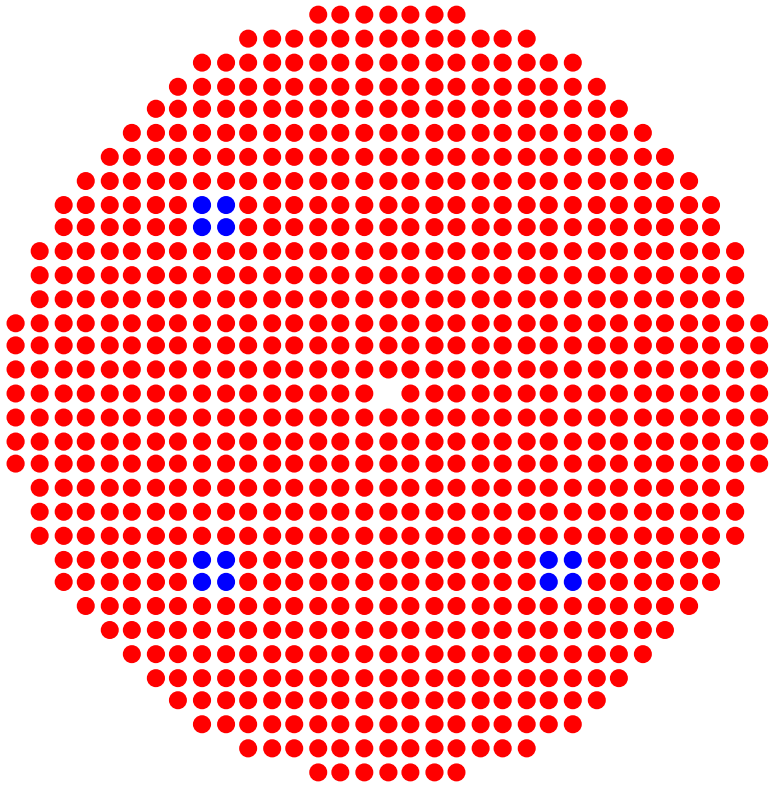

Fuel Rods: 836

k ~ 0.95

Core Loading Experiment Configuration 2

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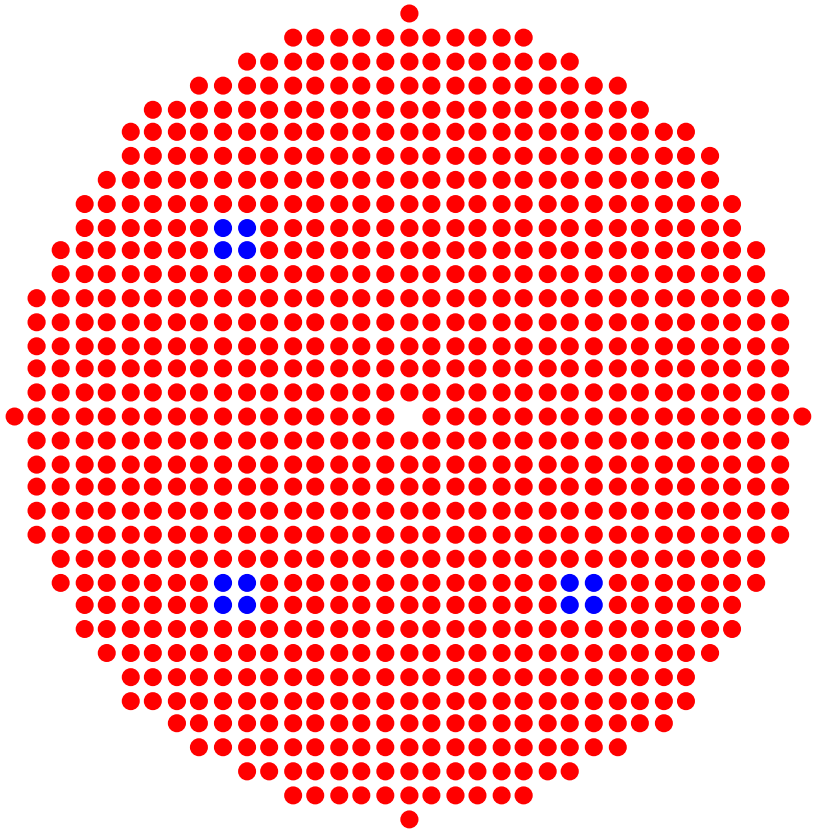

Fuel Rods: 895

k ~ 0.97

~Critical Core Loading

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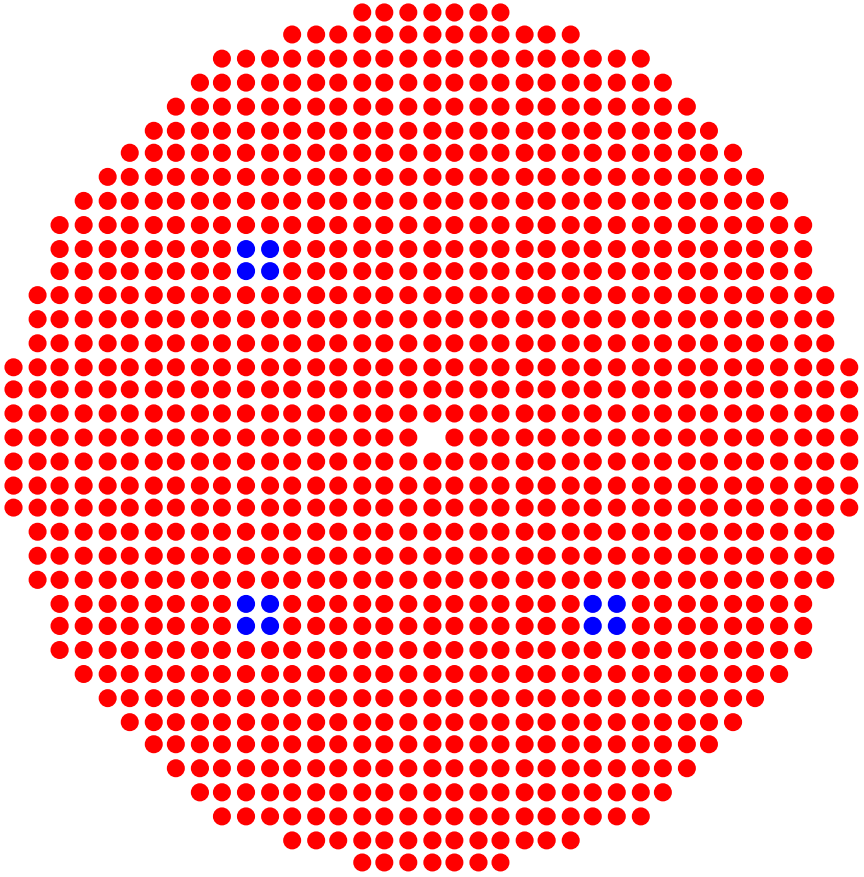

Fuel Rods: 1060

k ~ 1.00 (at 1059.6 rods)

Experiment 2 Overview

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- Approach-to-critical experiment by increasing the moderator height in the assembly with a constant fuel loading
- Criticality safety parameters that are in play:
  - Moderation
  - Geometry
  - Mass
- Application to criticality safety:
  - What happens to an array that becomes flooded?

The Fuel Rod Configuration

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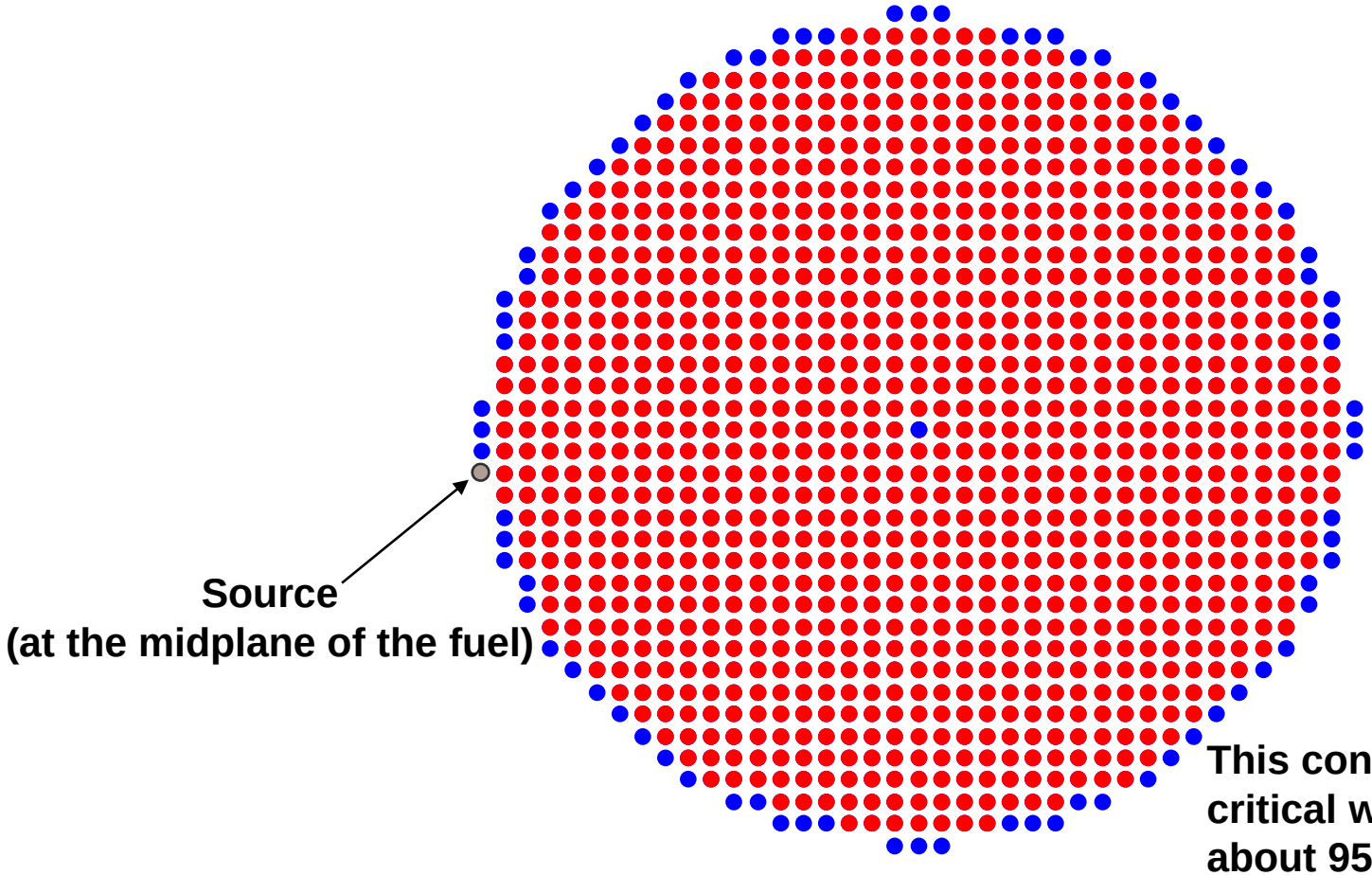
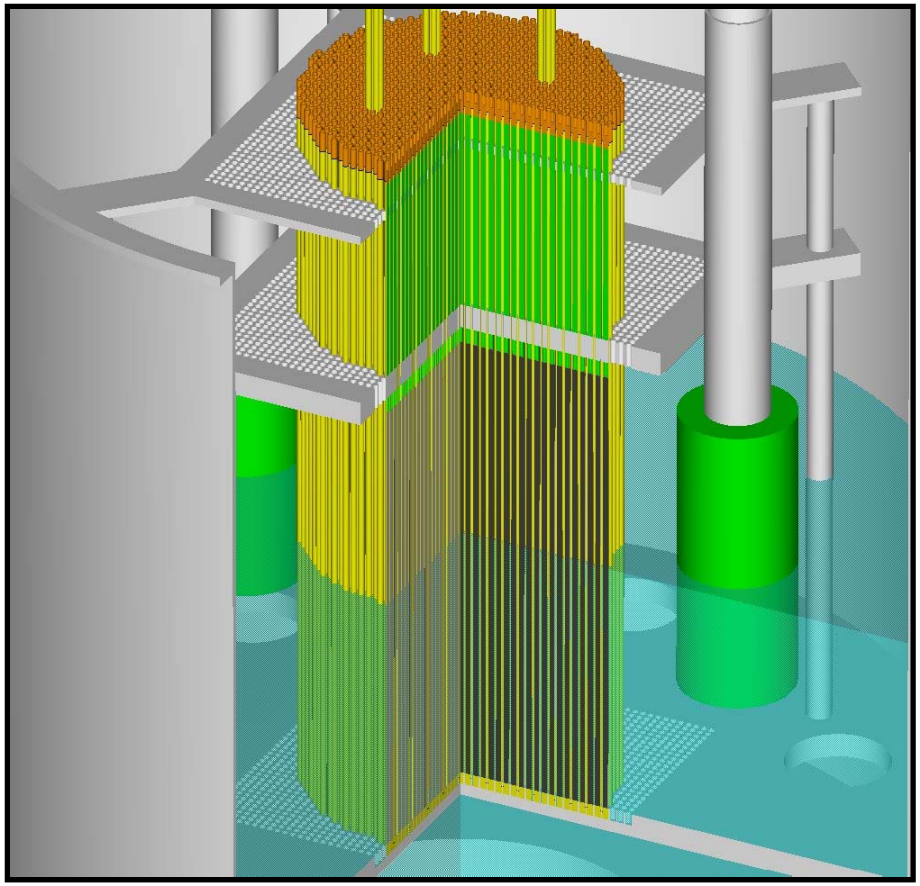


This configuration goes critical with the moderator at about 95% of the fuel height

1137 fuel rods

The blue rods are the difference from the fully-reflected critical array in the first experiment

Moderator Height Experiment Configuration 1

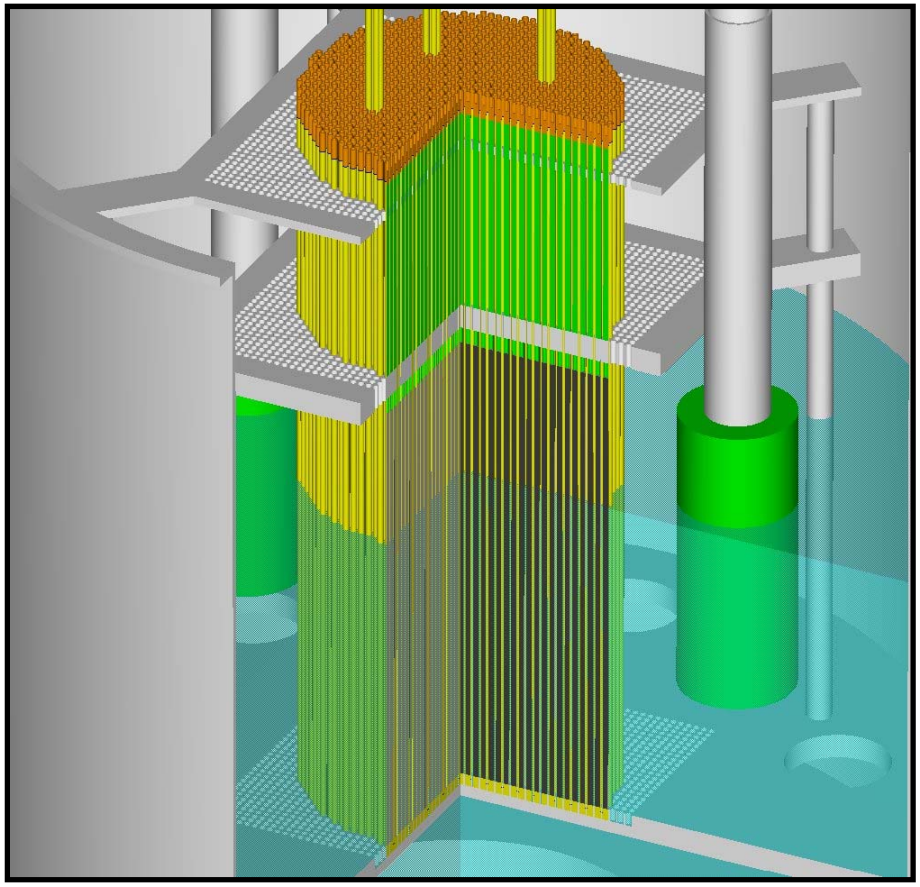


Fuel Rods: 1137

k_{eff}: ~0.90

Water Depth: 271.6 mm

Moderator Height Experiment Configuration 2

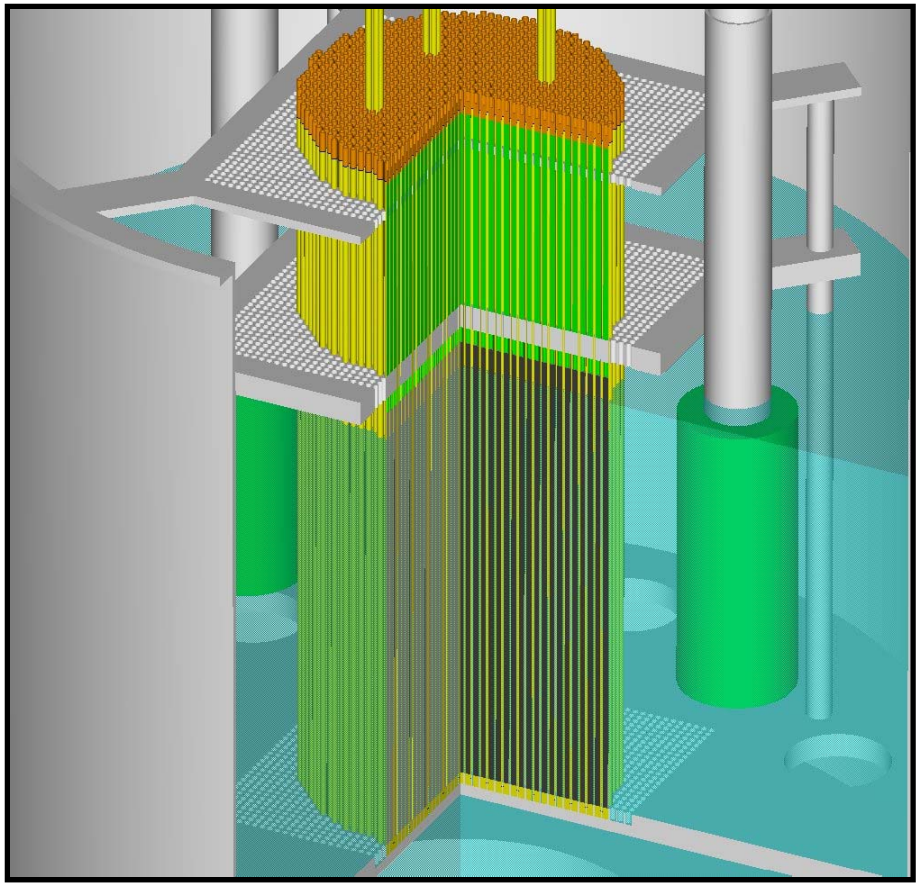


Fuel Rods: 1137

k_{eff}: ~0.95

Water Depth: 341.3 mm

Moderator Height Experiment at DC



Fuel Rods: 1137

k_{eff}: ~1.0

Water Depth: 461 mm

Experiment 3 Overview

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- Approach-to-critical experiment by moving two roughly equal (and unchanging) fuel lumps toward each other
- This simulates experiments done with a horizontal split table machine
- Criticality safety parameters that were in play:
  - Interaction
  - Moderation

- Application to criticality safety:
  - What happens as two fuel masses are moved progressively closer to one another?
  - What happens when two neighboring fuel masses are moved apart?
  - This experiment is applicable to many accident configurations.

Core Separation Experiment Configurations

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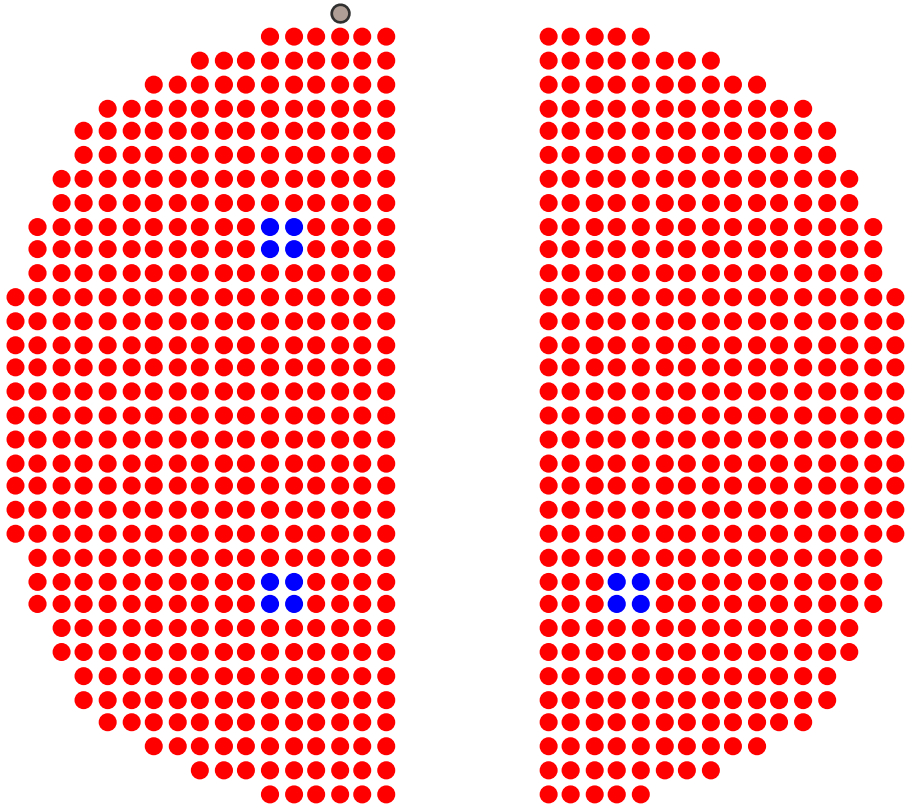

Fuel Rods: 477 (left) + 444 (right) = 921 (total)

Separation: 5.130 cm

Core Separation Experiment Configurations

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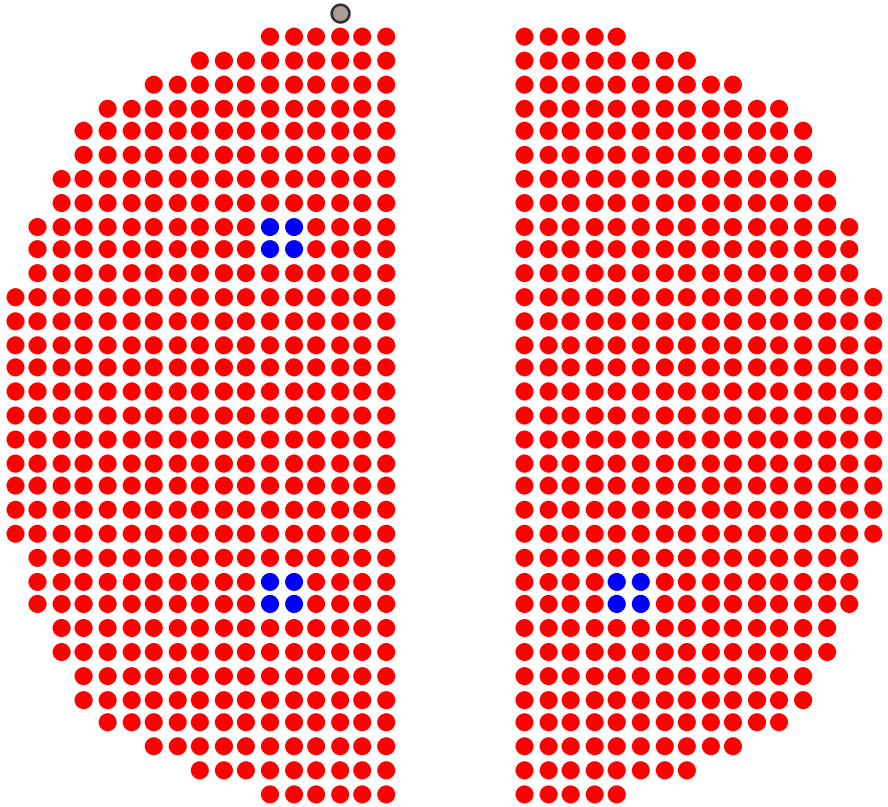
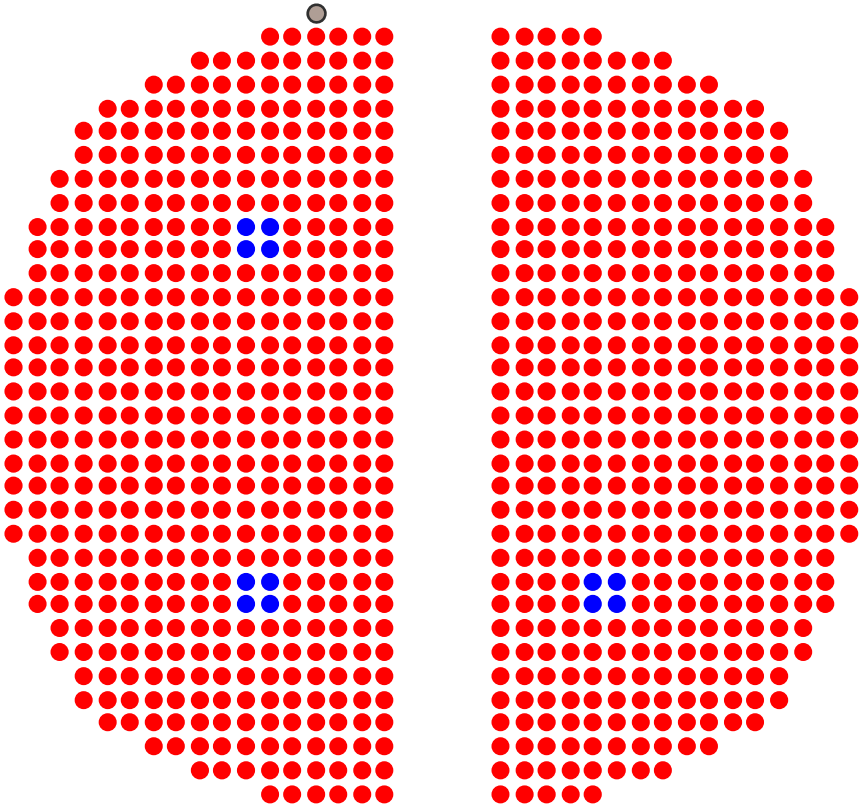


Fuel Rods: 477 (left) + 444 (right) = 921 (total)

Separation: 4.275 cm

Core Separation Experiment Configurations

Sandia National Laboratories

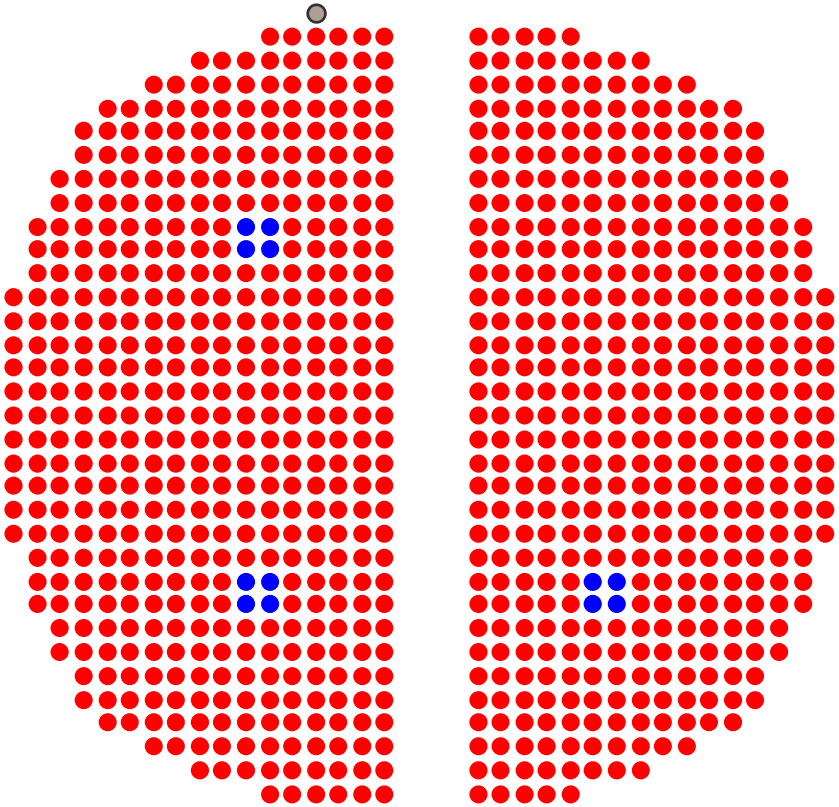


Fuel Rods: 477 (left) + 444 (right) = 921 (total)

Separation: 3.420 cm

Core Separation Experiment Configurations

Sandia National Laboratories

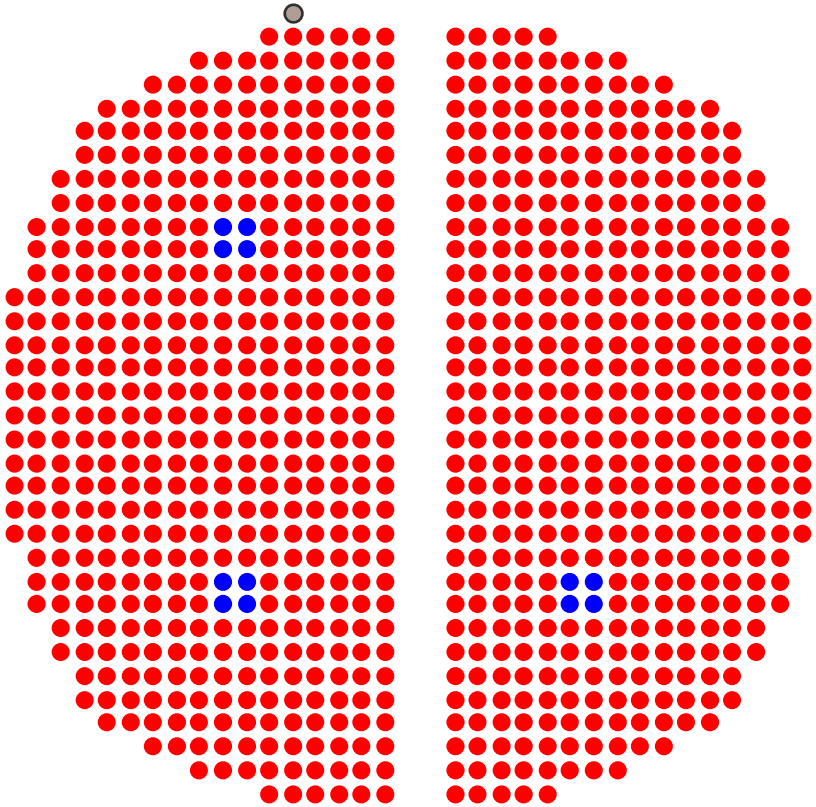


Fuel Rods: 477 (left) + 444 (right) = 921 (total)

Separation: 2.565 cm

Core Separation Experiment Configurations

Sandia National Laboratories



Fuel Rods: 477 (left) + 444 (right) = 921 (total)

Separation: 1.710 cm

Core Separation Experiment Configurations

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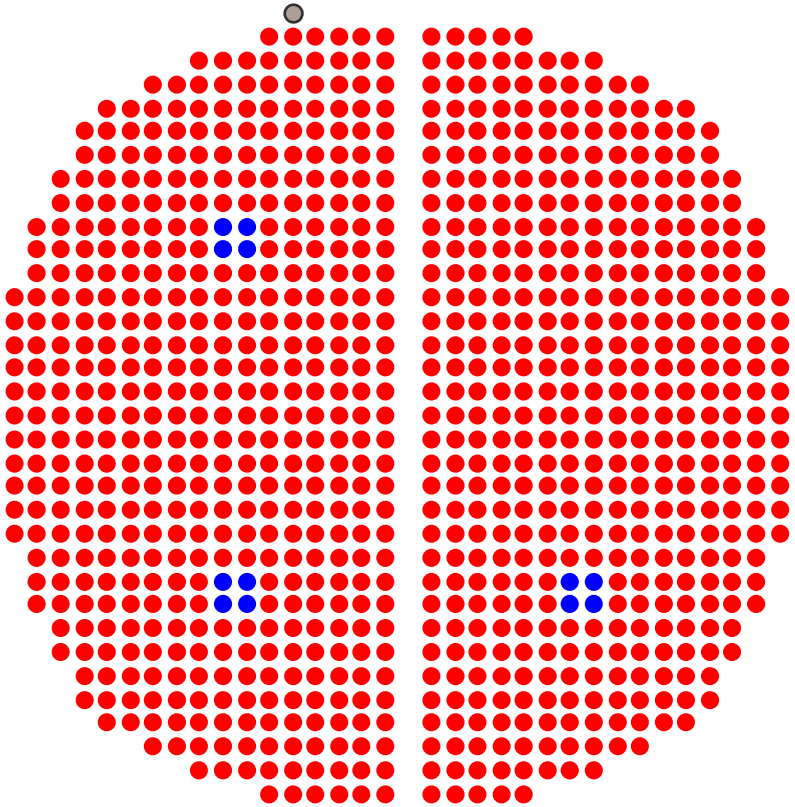
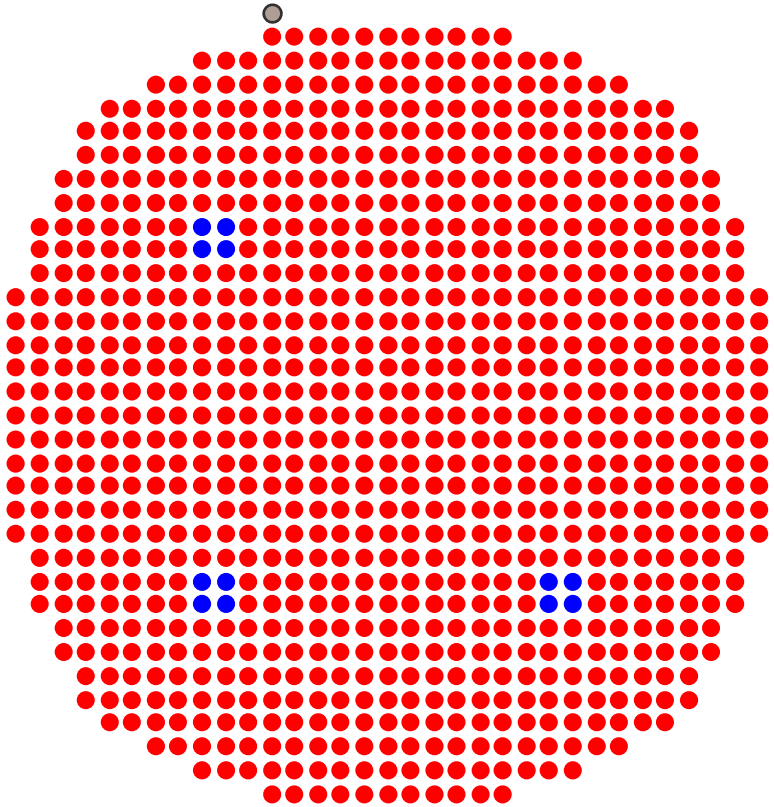


Fuel Rods: 477 (left) + 444 (right) = 921 (total)

Separation: 0.855 cm

Core Separation Experiment Configurations

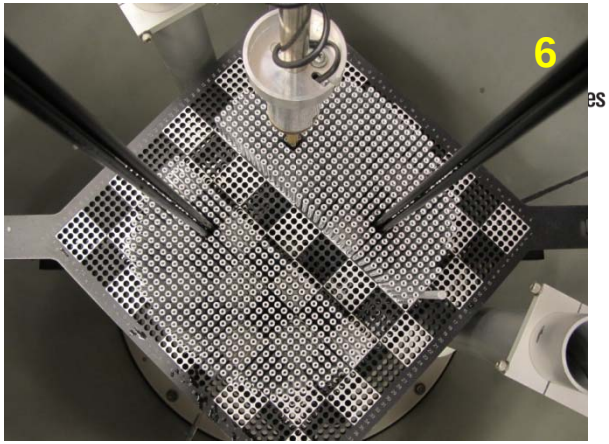
Sandia National Laboratories

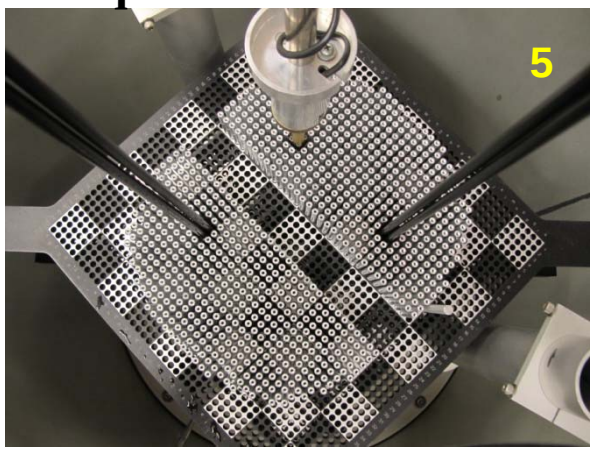


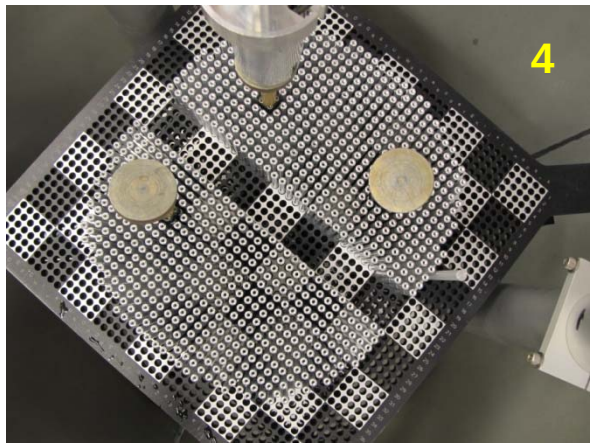
Fuel Rods: 921

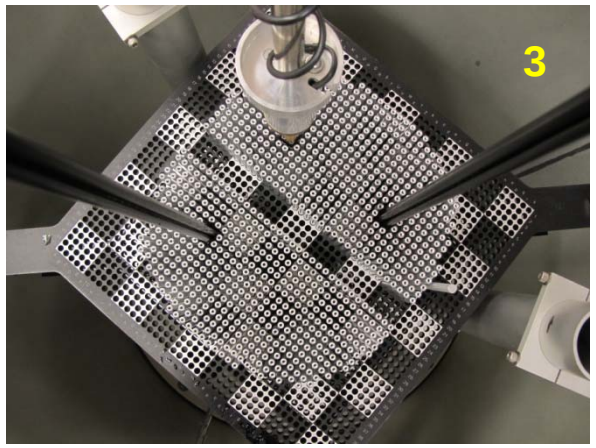
Fuel Separation Experiment

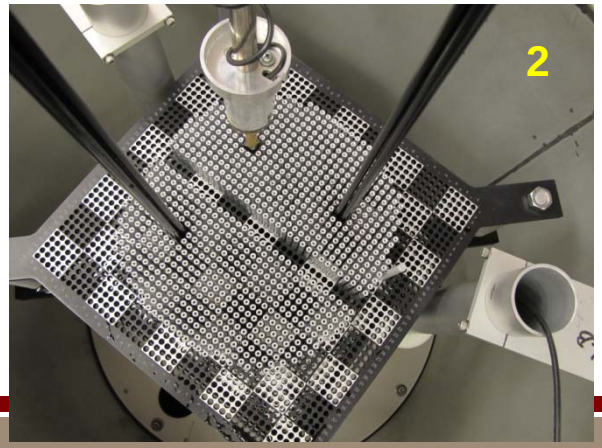
This experiment demonstrates the trade-off between increasing interaction between the core halves as they come together and decreasing moderation as the water is squeezed from between the core halves.

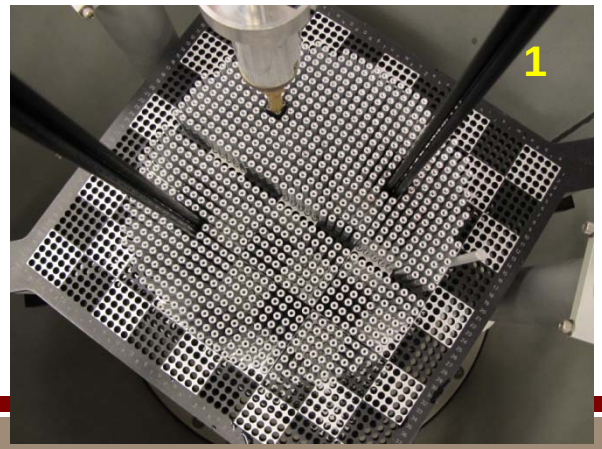


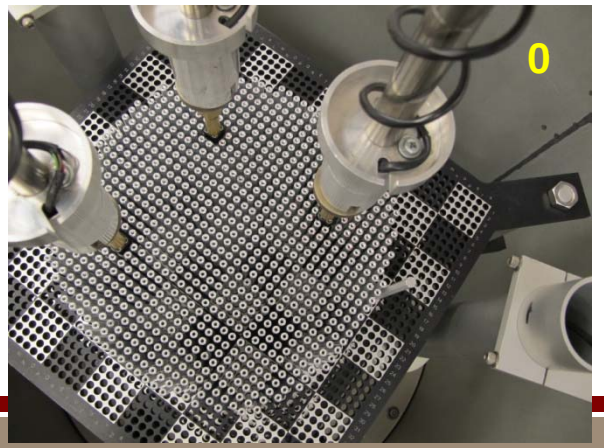










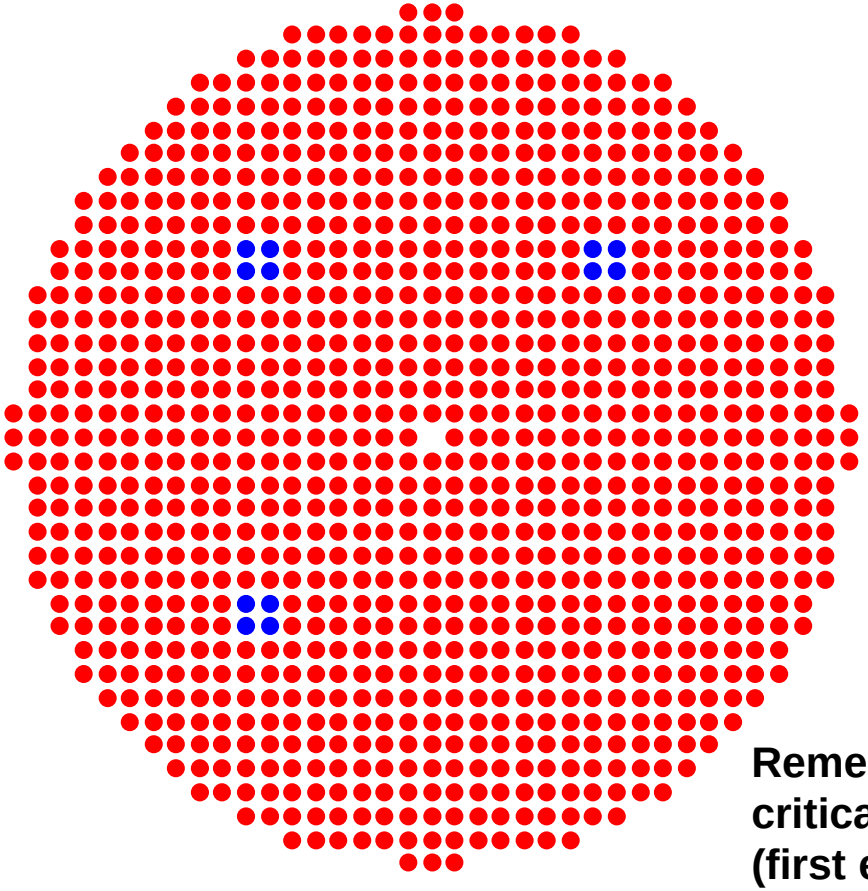


Experiment 4 Overview

- Effect of removing fuel rods from the interior of the fuel array
- Replacing fuel rods with water
- Criticality safety parameters that are in play:
  - Mass
  - Moderation
  - Reflection
  - Absorption

- Application to criticality safety:
  - What happens to a compact array of fuel lumps if the array becomes more spread out?

Fuel Replacement with Water Configuration 0

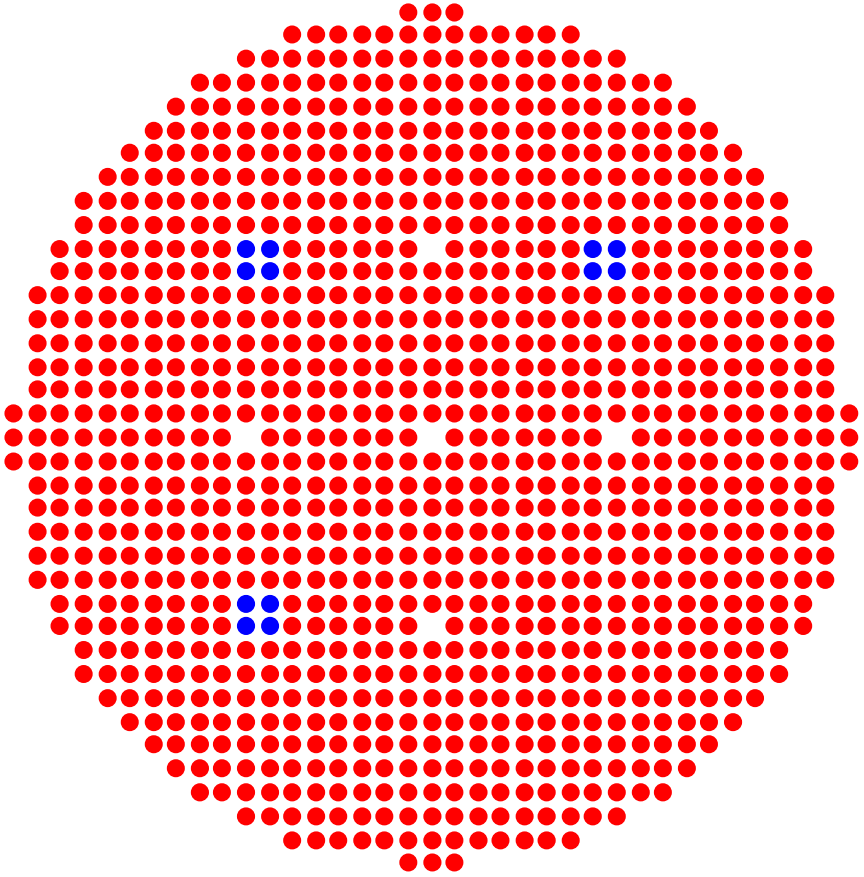


Remember that this core is critical with about 1060 rods (first experiment)

1032 Fuel Rods

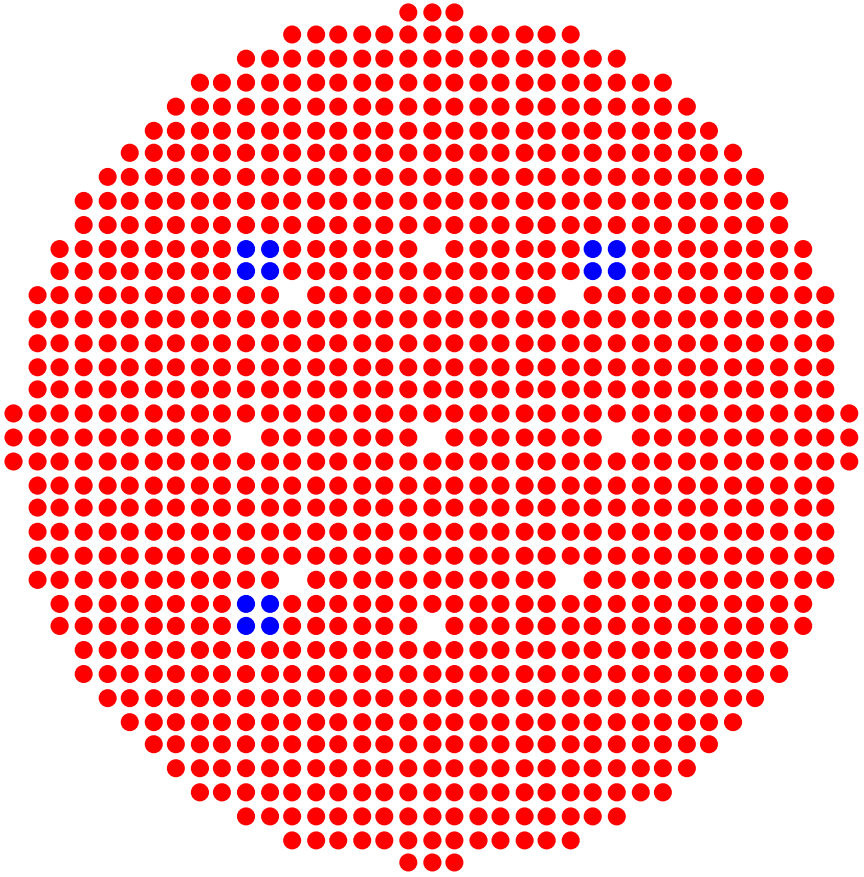
0 Water Holes (the source doesn't count)

Fuel Replacement with Water Configuration 1



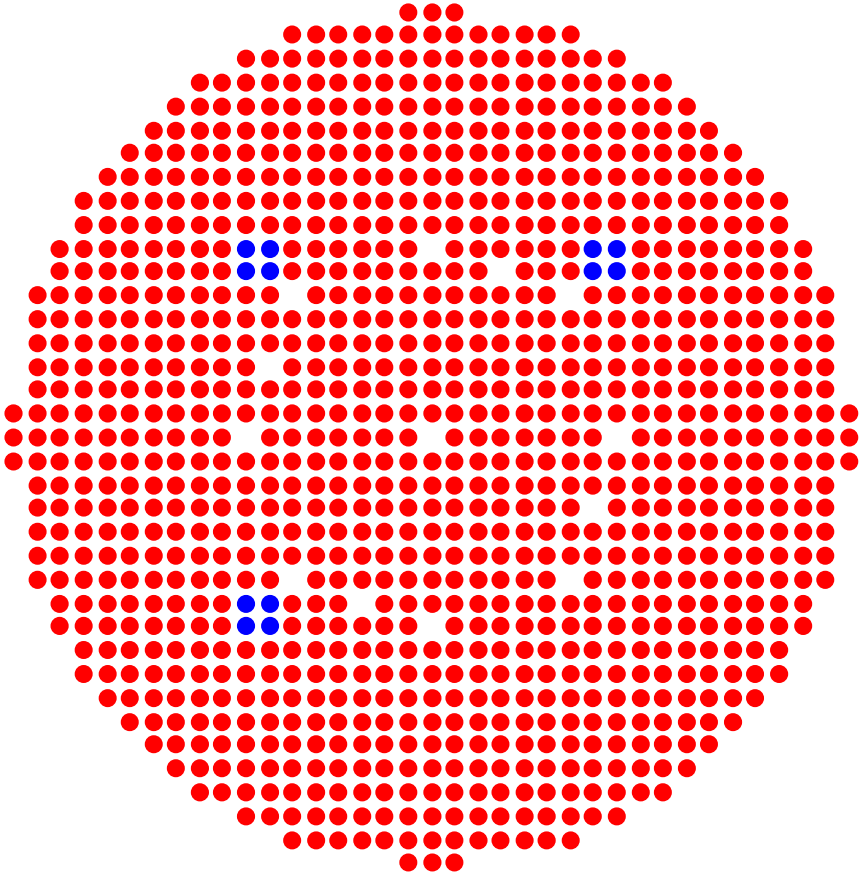
1028 Fuel Rods
4 Water Holes

Fuel Replacement with Water Configuration 2



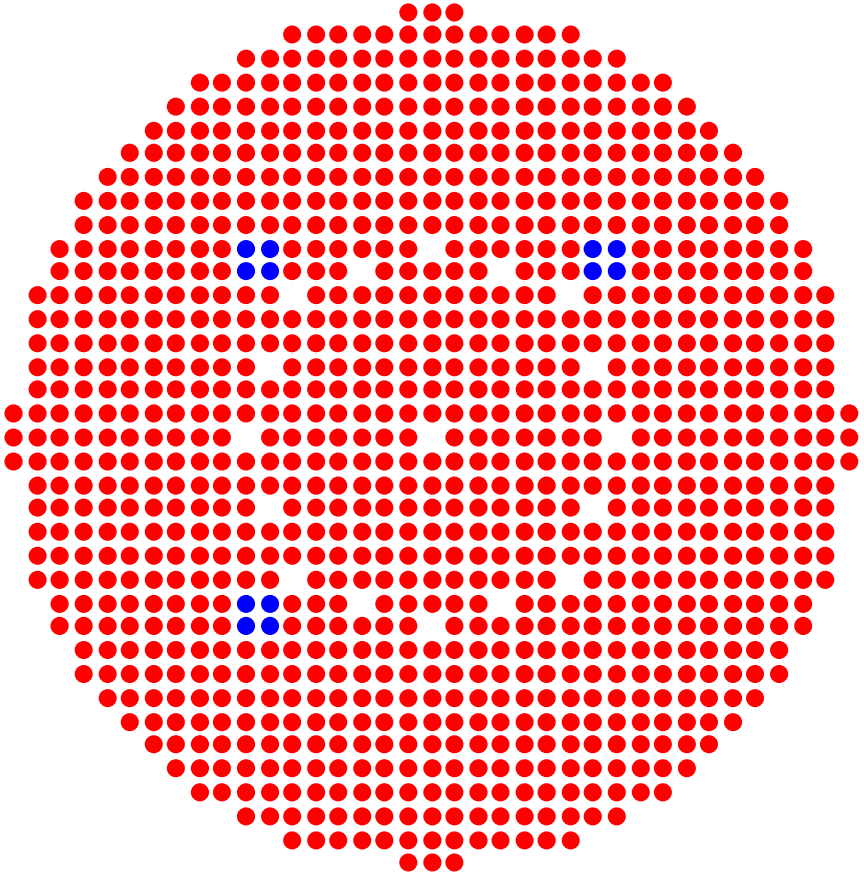
1024 Fuel Rods
8 Water Holes

Fuel Replacement with Water Configuration 3



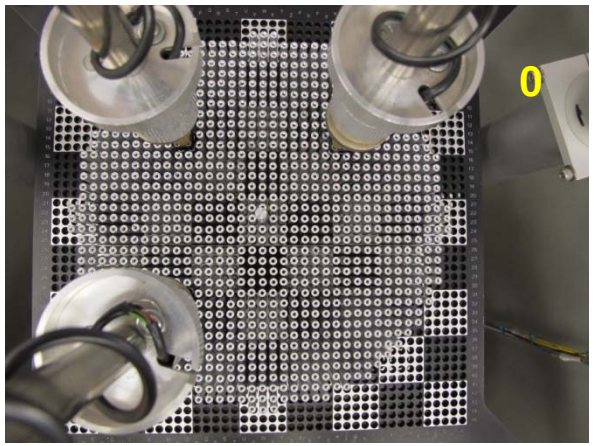
1020 Fuel Rods
12 Water Holes

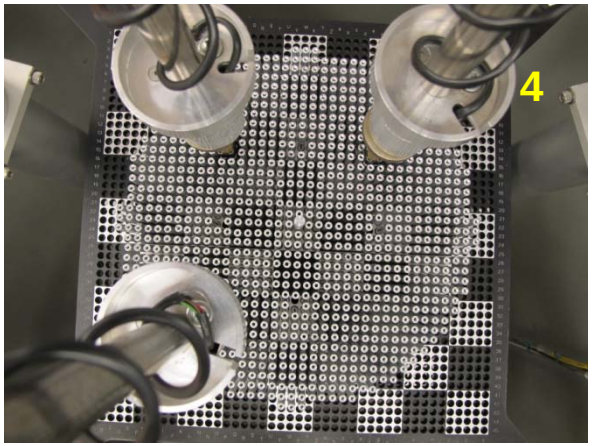
Fuel Replacement with Water Configuration 4

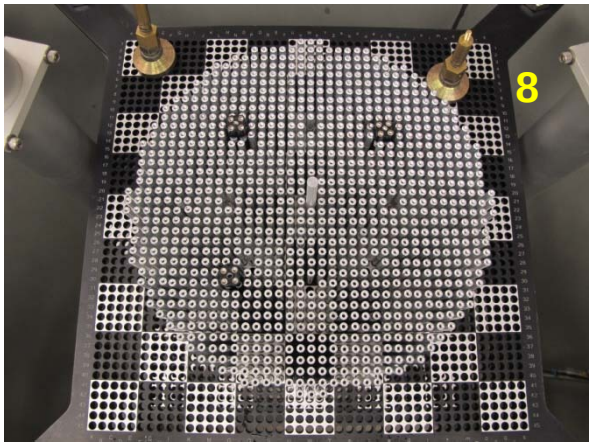


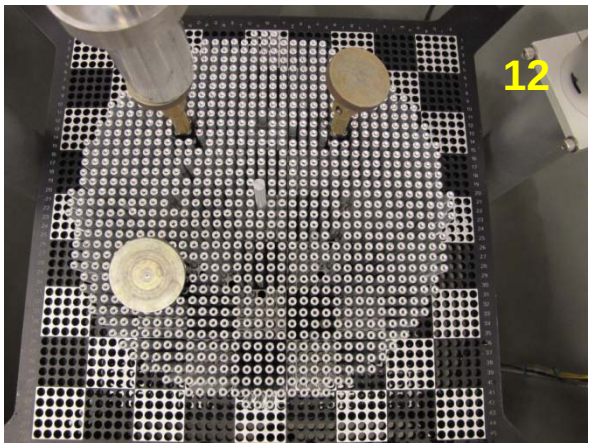
1016 Fuel Rods
16 Water Holes

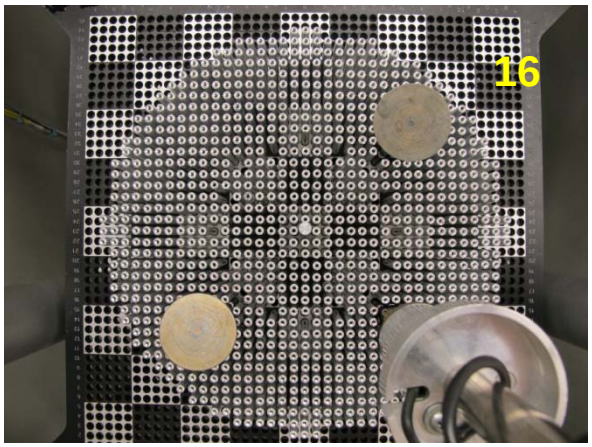
Approach on Water Holes











Concluding Remarks

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- Hands-on criticality experiments class
  - Second week in the NCSP T&EP course for Nuclear Criticality Safety Engineers
  - Conducted Five Classes
- The class consists of four experiments, all using a different approach variable
- The experiments are accompanied by a series of lectures intended to supplement the experiments