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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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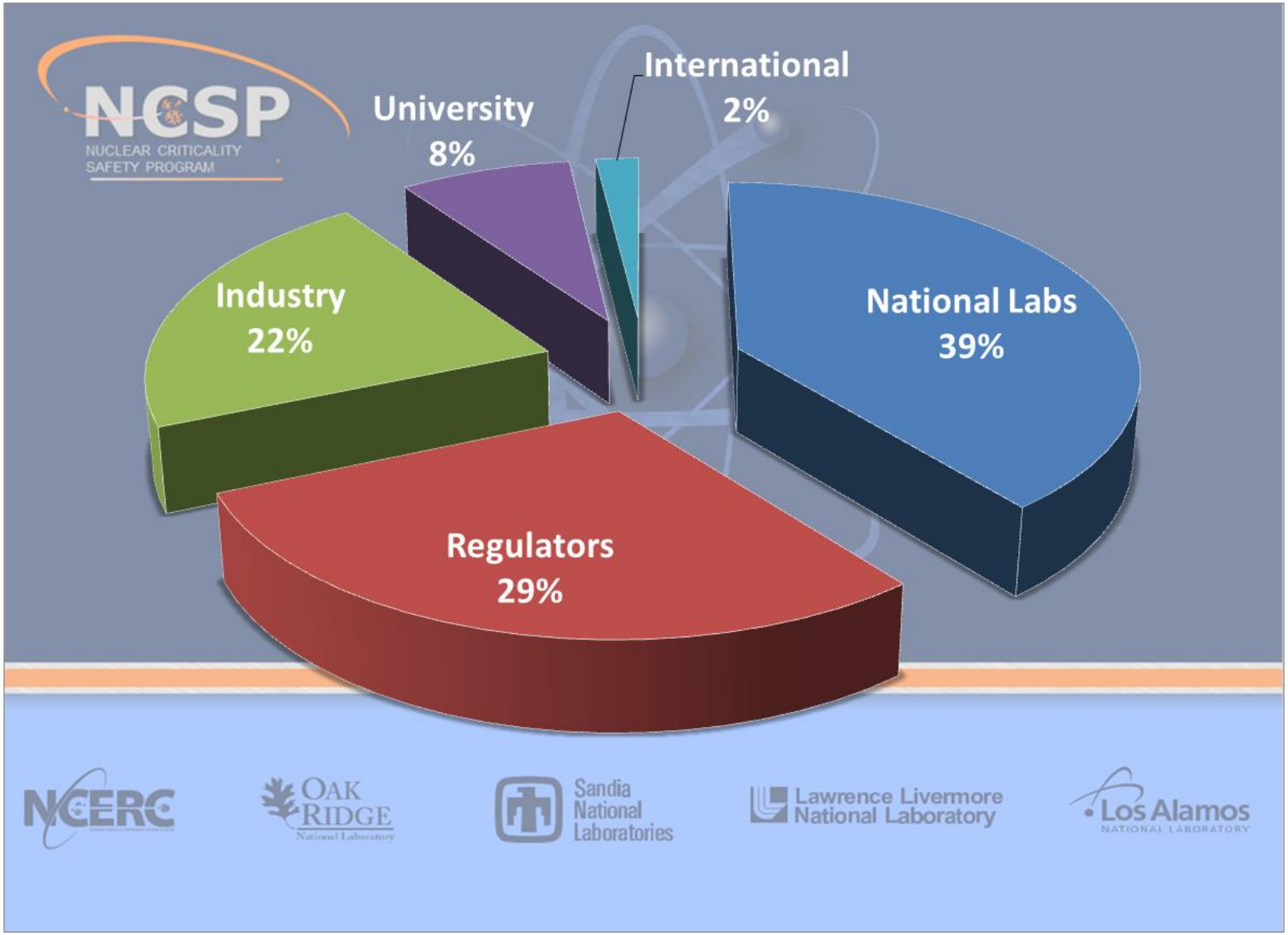
SNL Hands on Criticality Safety Training Course

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

Course Attendance

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	

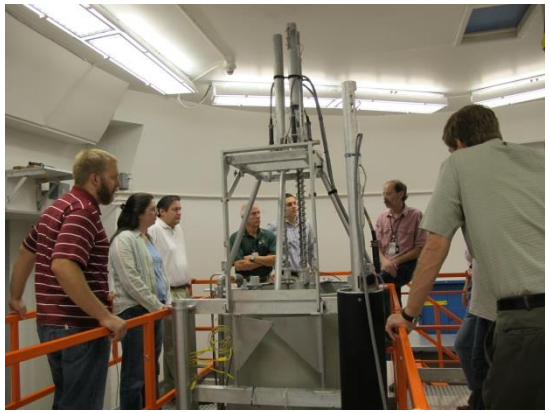

NCSP
NUCLEAR CRITICALITY SAFETY PROGRAM
University
8%
International
2%
Industry
22%
National Labs
39%
Regulators
29%
NCERC
OAK RIDGE National Laboratory
Sandia National Laboratories
Lawrence Livermore National Laboratory
Los Alamos NATIONAL LABORATORY

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

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

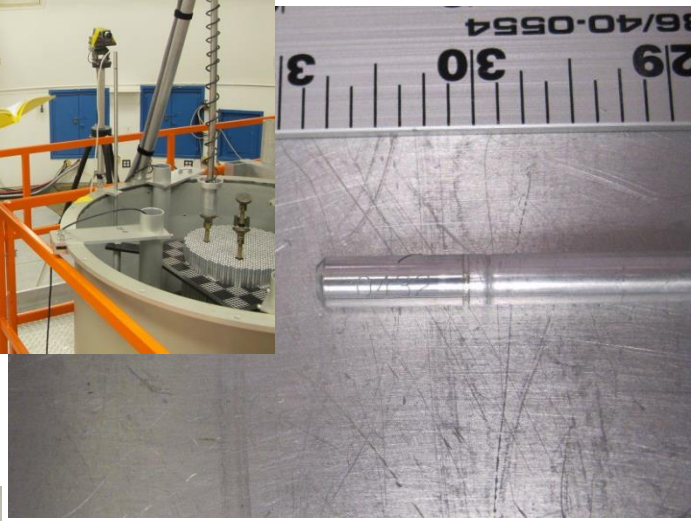
Classroom discussions are interspersed through the experiments

- 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

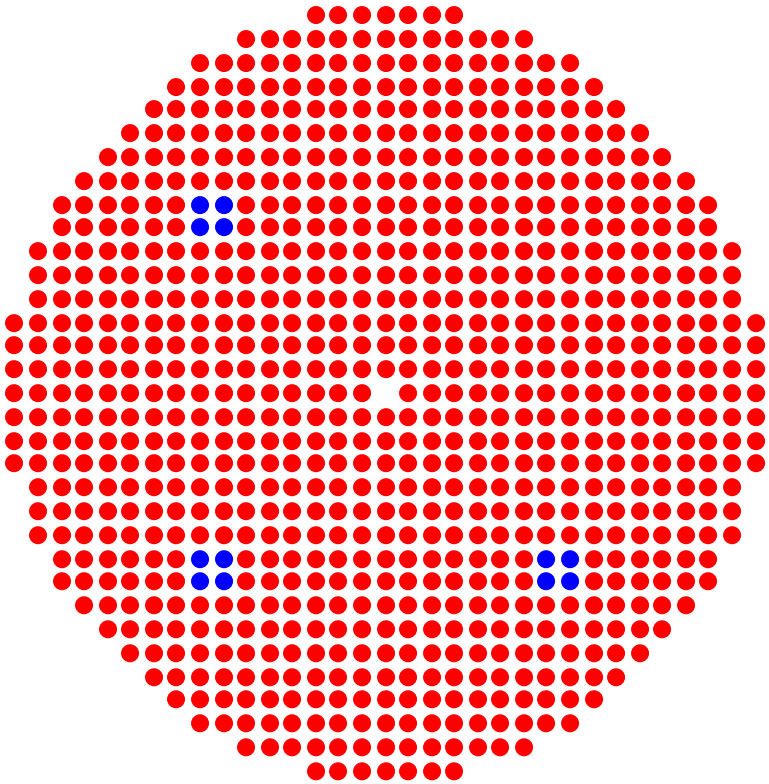


Experiment 1 Overview

- 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?

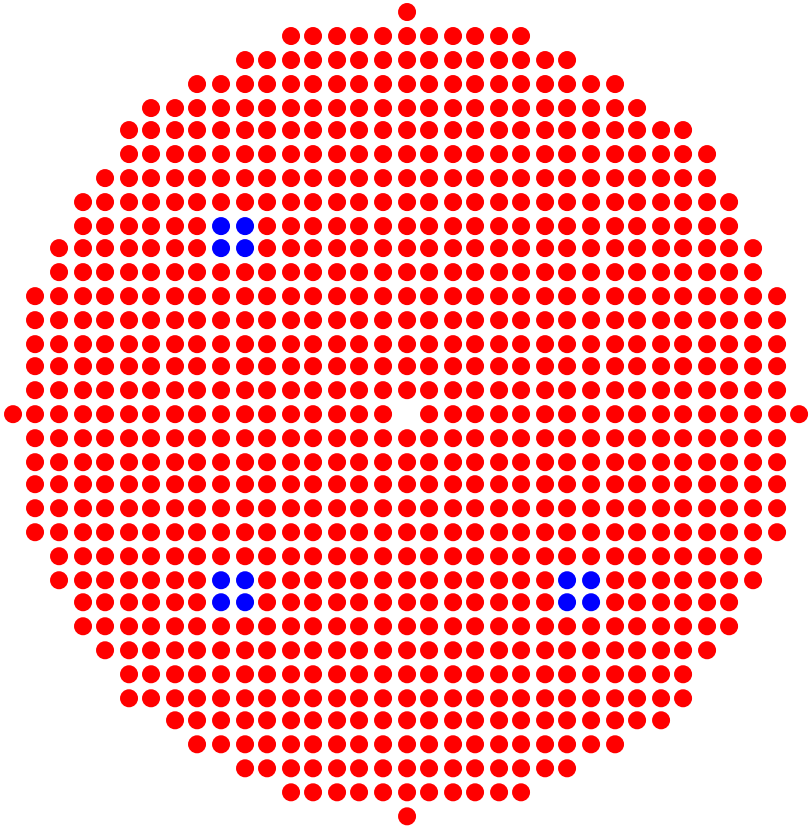
Core Loading Experiment Configuration 1



Fuel Rods: 836

k ~ 0.95

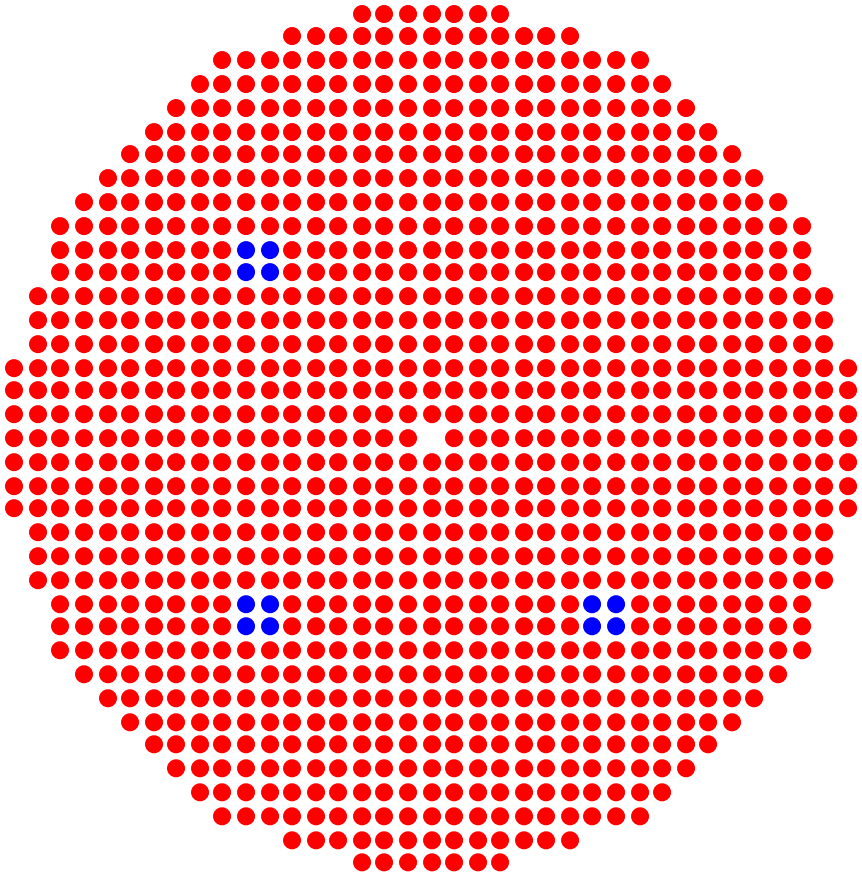
Core Loading Experiment Configuration 2



Fuel Rods: 895

k ~ 0.97

~Critical Core Loading



Fuel Rods: 1060

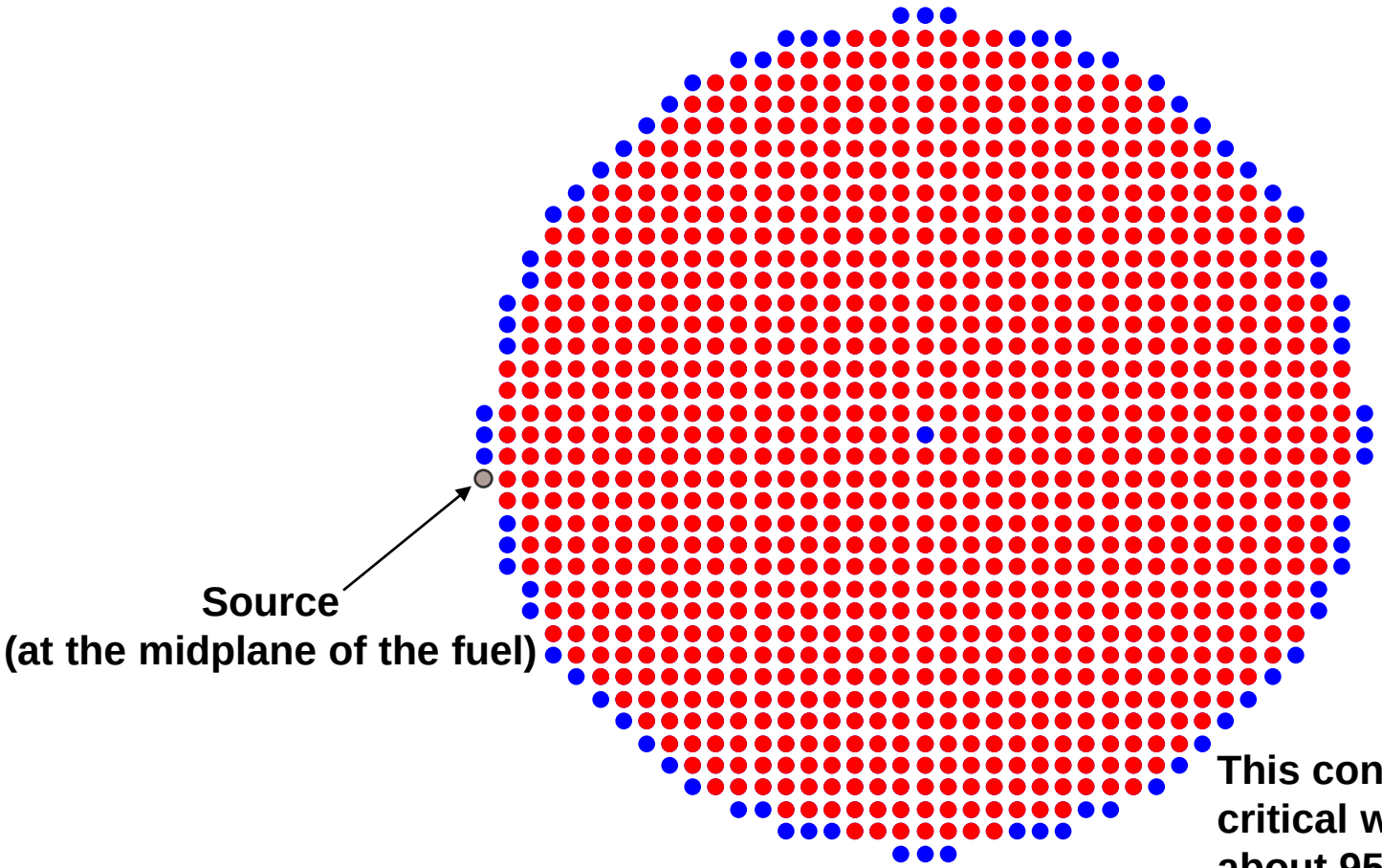
k ~ 1.00 (at 1059.6 rods)

Experiment 2 Overview

- 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

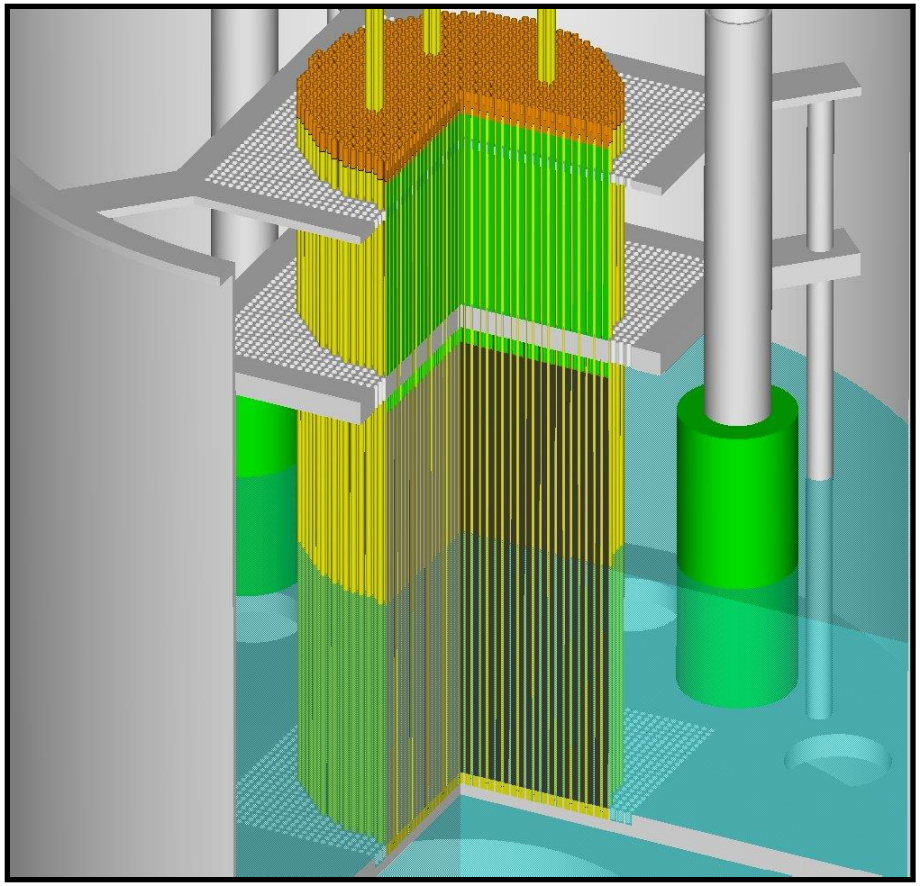


This configuration goes critical with the moderator at about 95% of the fuel height

1137 fuel rods

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

Moderator Height Experiment Configuration 1

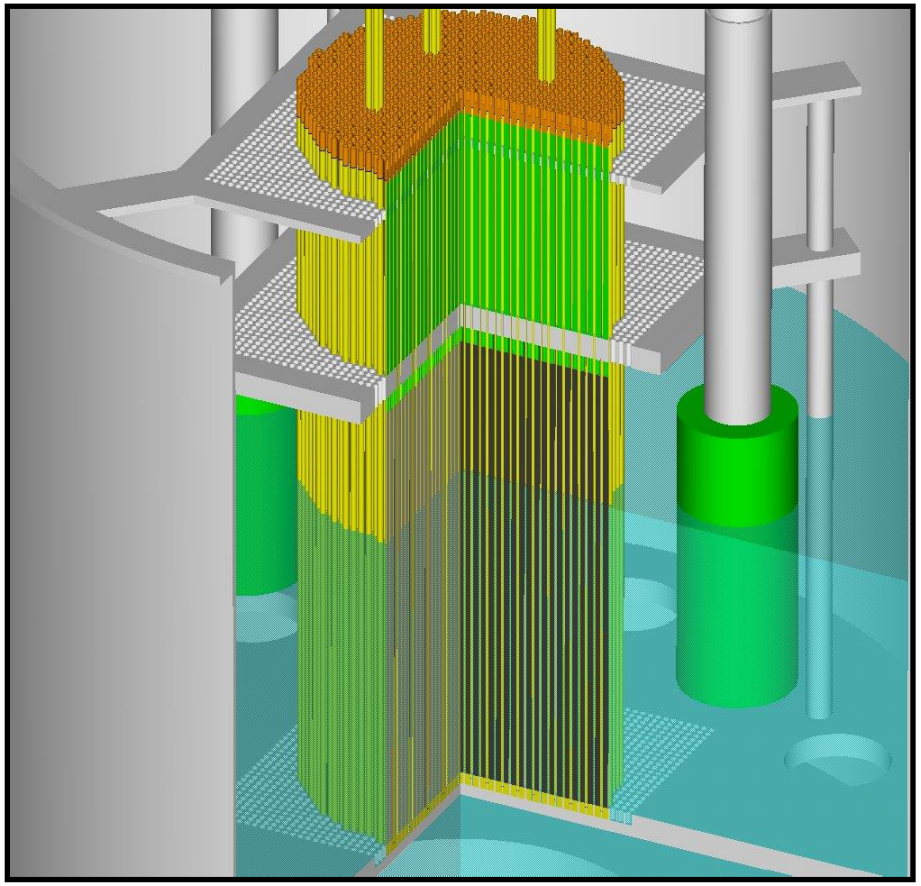


Fuel Rods: 1137

k_{eff}: ~0.90

Water Depth: 271.6 mm

Moderator Height Experiment Configuration 2

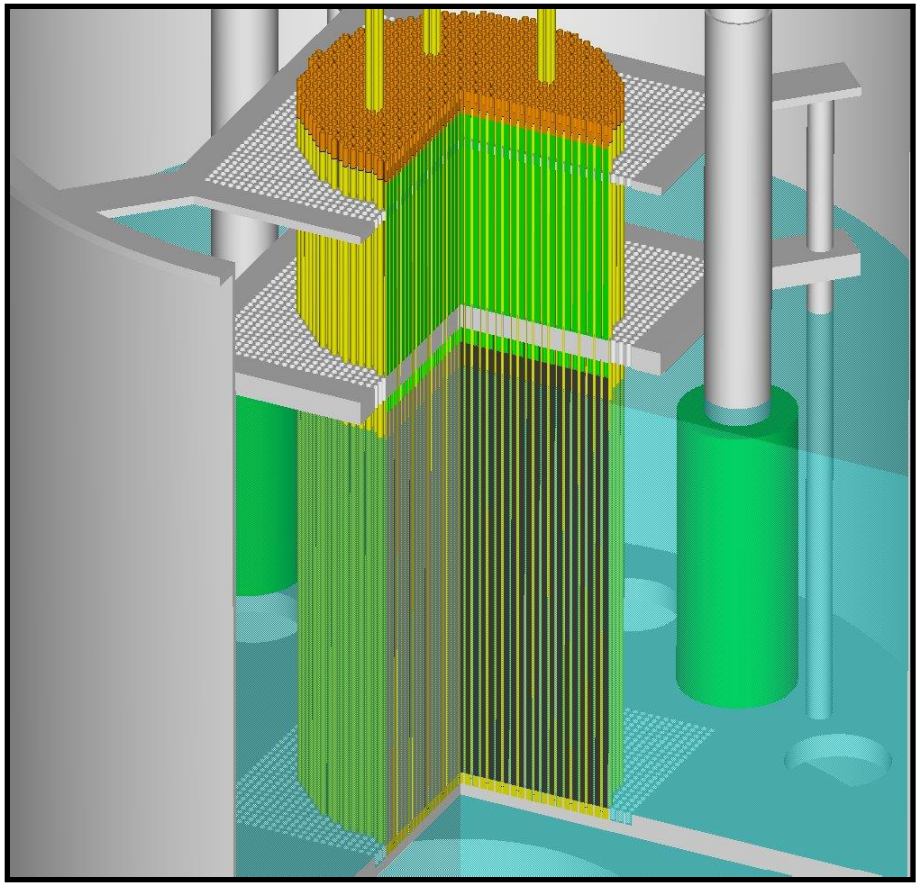


Fuel Rods: 1137

k_{eff}: ~0.95

Water Depth: 341.3 mm

Moderator Height Experiment at DC



Fuel Rods: 1137

k_{eff}: ~1.0

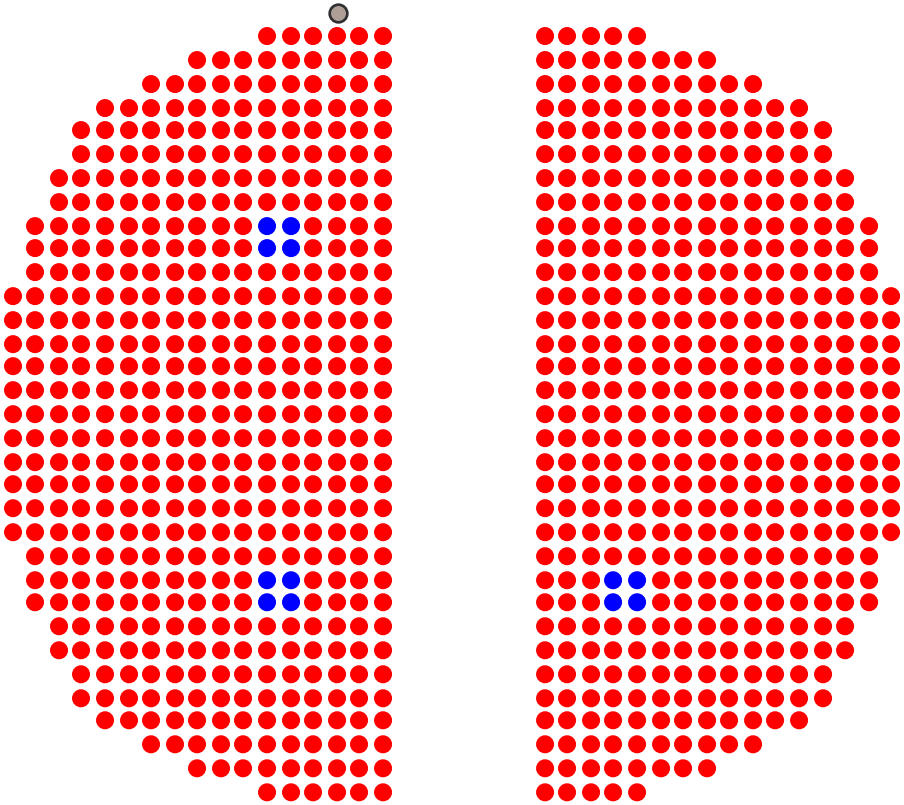
Water Depth: 461 mm

Experiment 3 Overview

- 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.

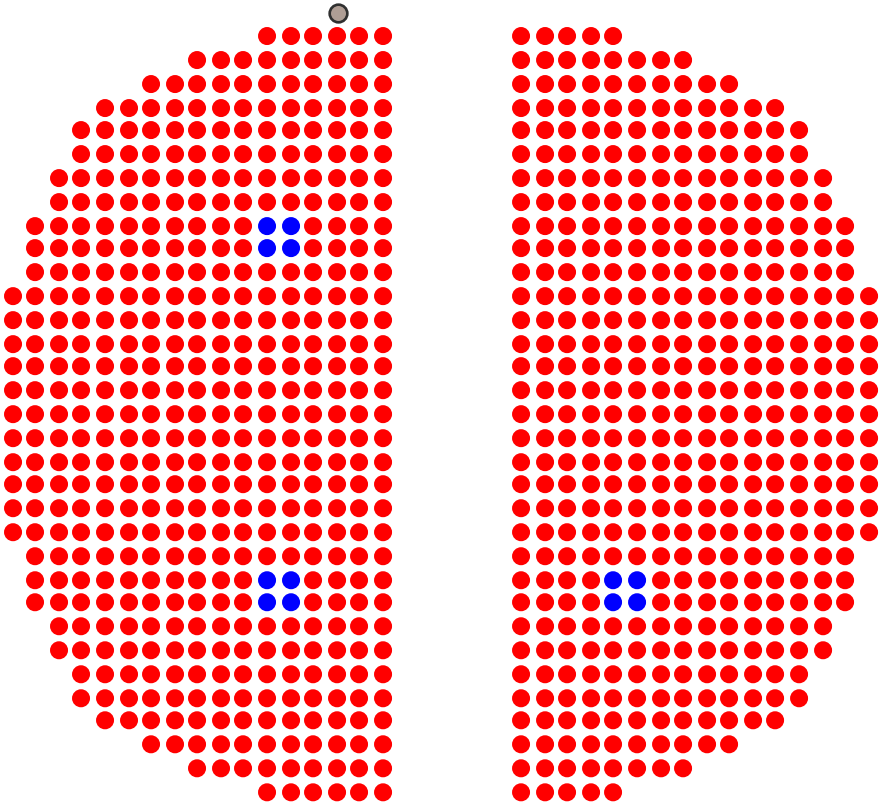
Core Separation Experiment Configurations



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

Separation: 5.130 cm

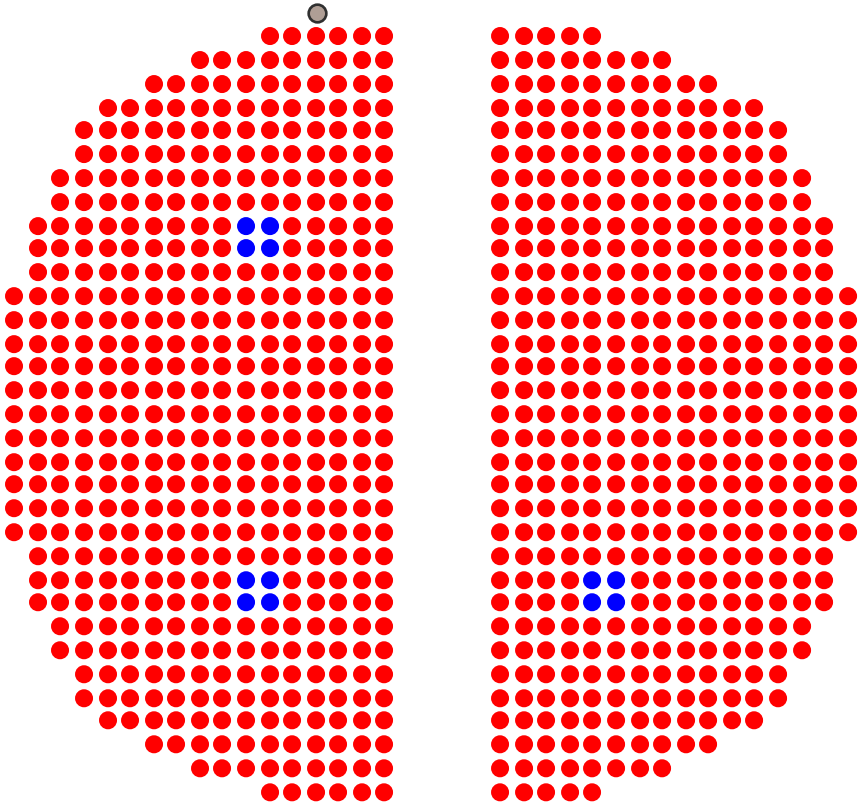
Core Separation Experiment Configurations



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

Separation: 4.275 cm

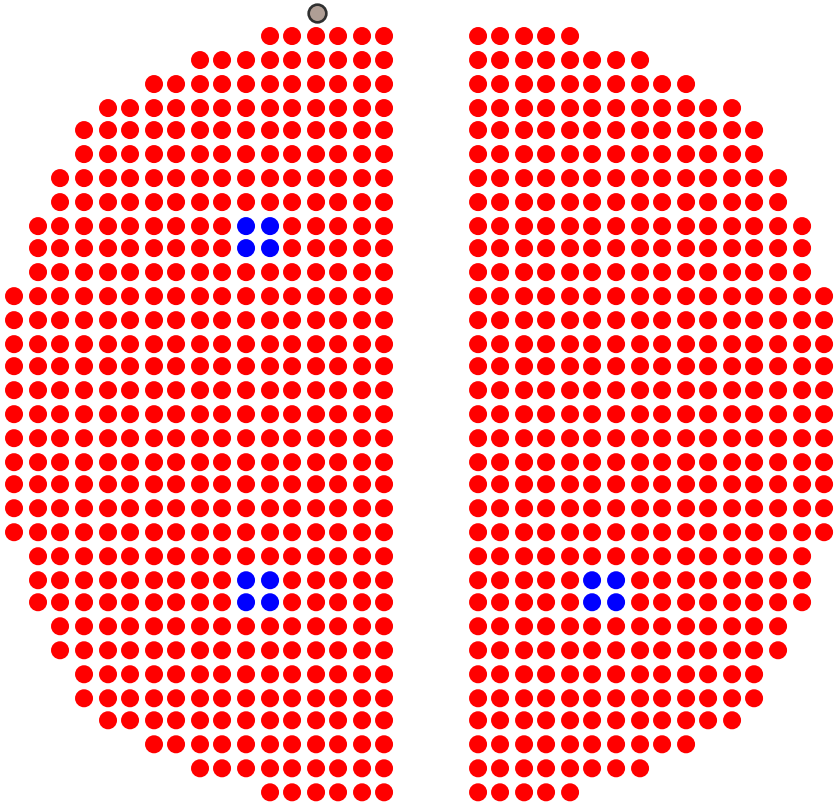
Core Separation Experiment Configurations



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

Separation: 3.420 cm

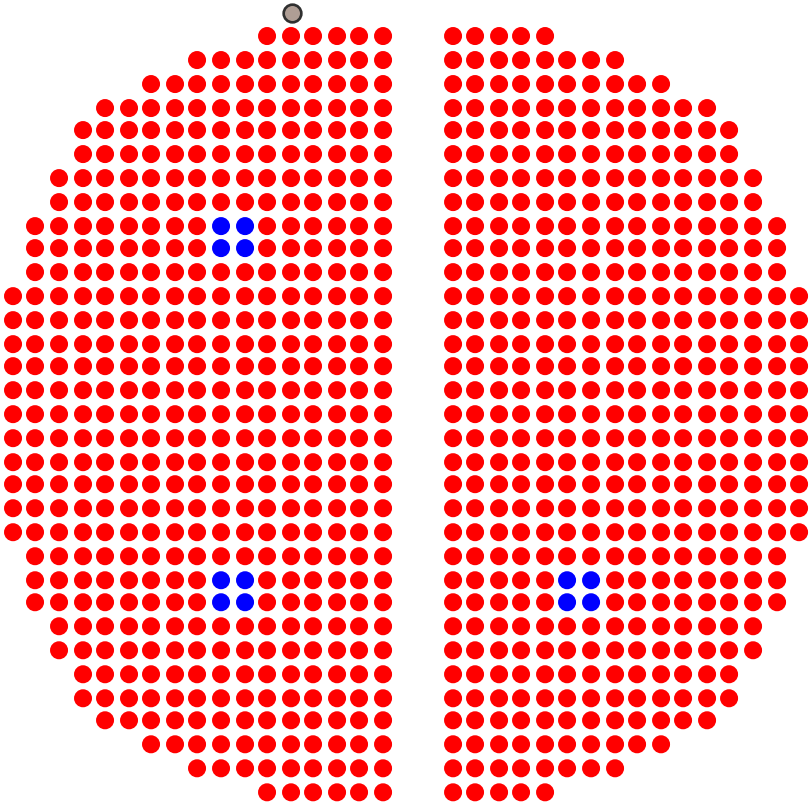
Core Separation Experiment Configurations



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

Separation: 2.565 cm

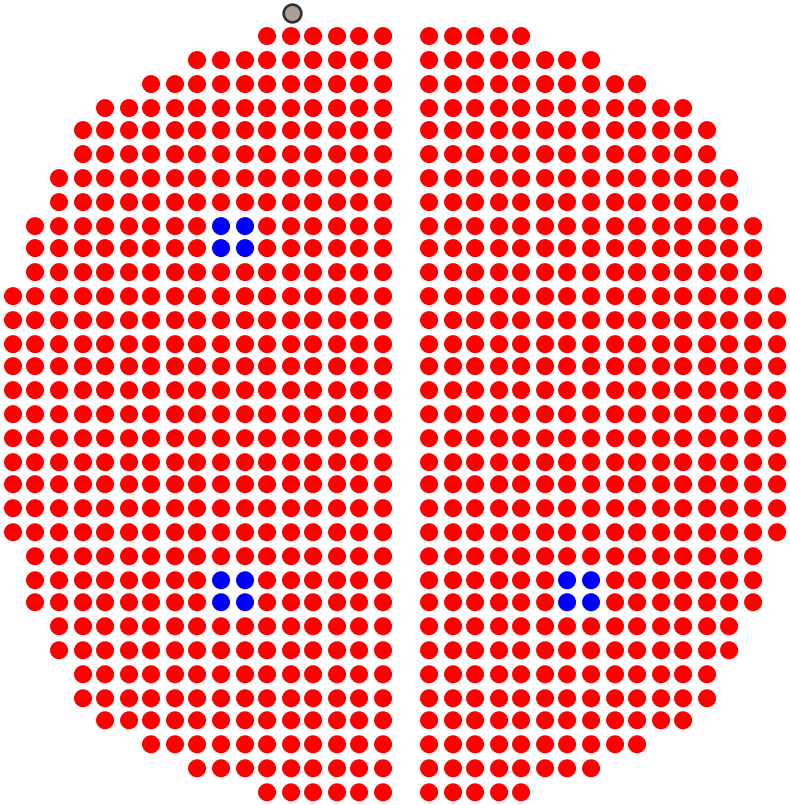
Core Separation Experiment Configurations



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

Separation: 1.710 cm

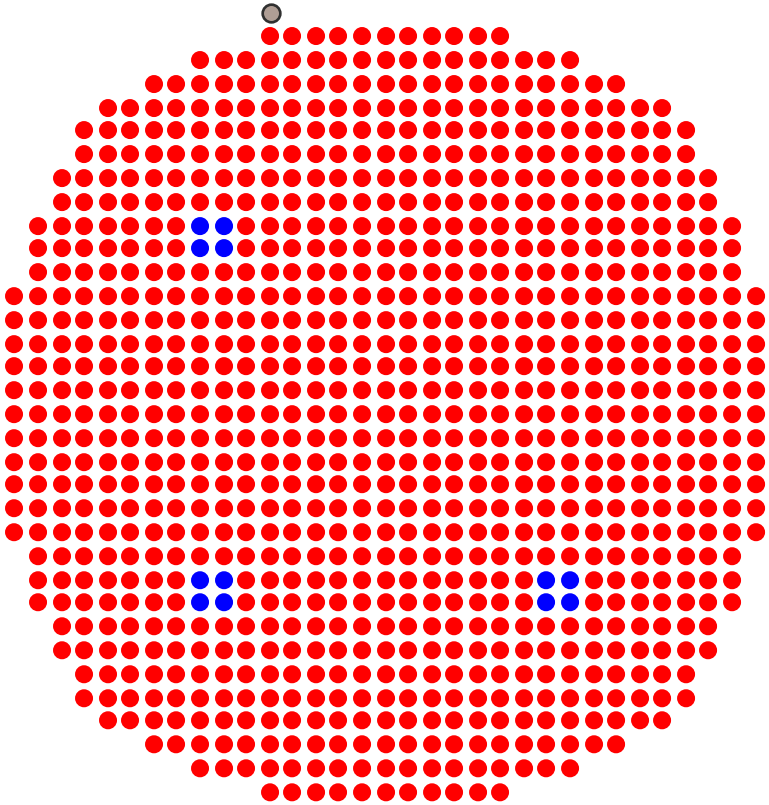
Core Separation Experiment Configurations



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

Separation: 0.855 cm

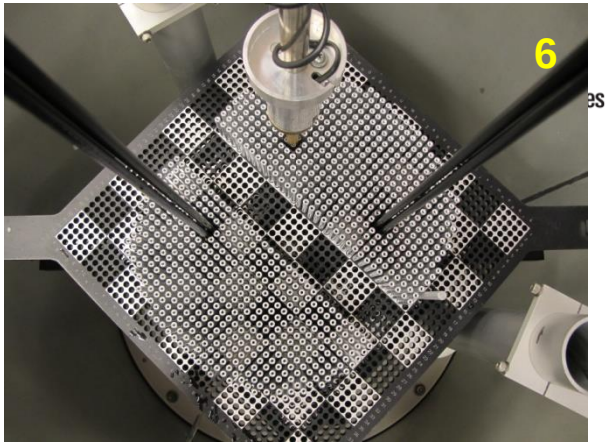
Core Separation Experiment Configurations

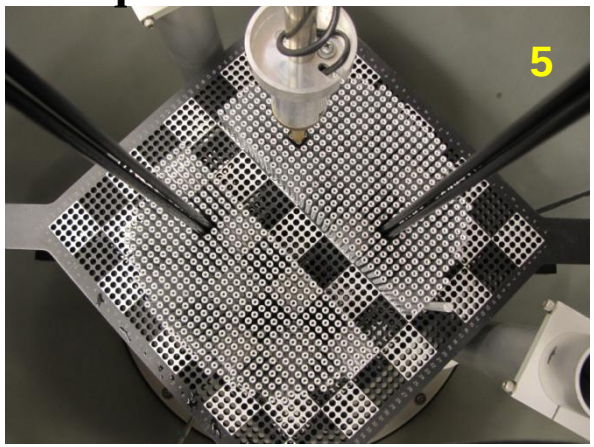


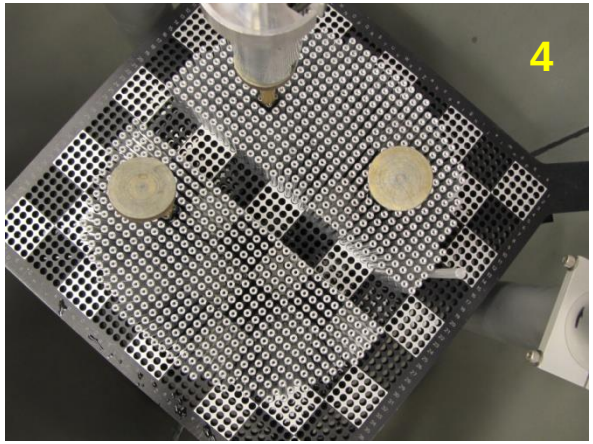
Fuel Rods: 921

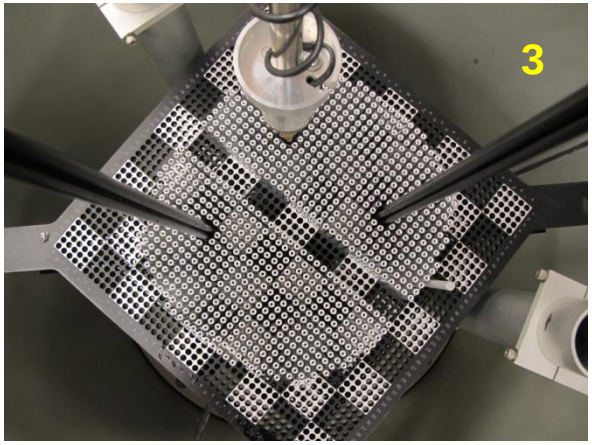
Fuel Separation Experiment

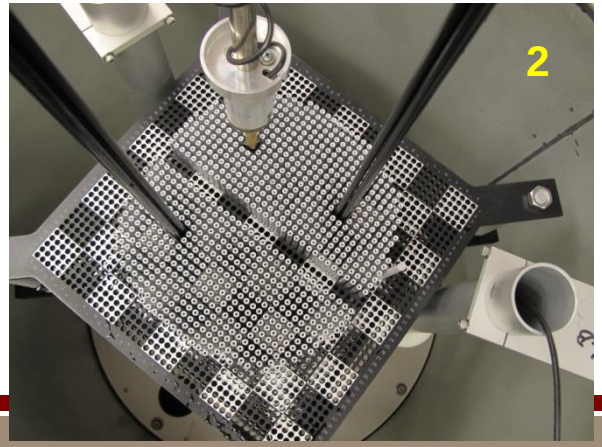
This experiment demonstrates the trade-off between increasing interaction between the core halves as they come together and decreasing moderation as the water is squeezed from between the core halves.

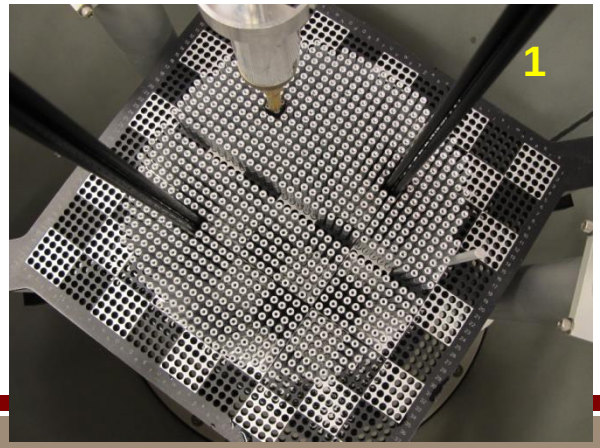


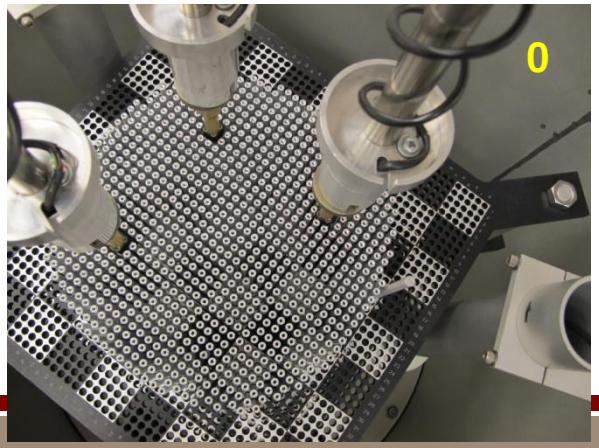










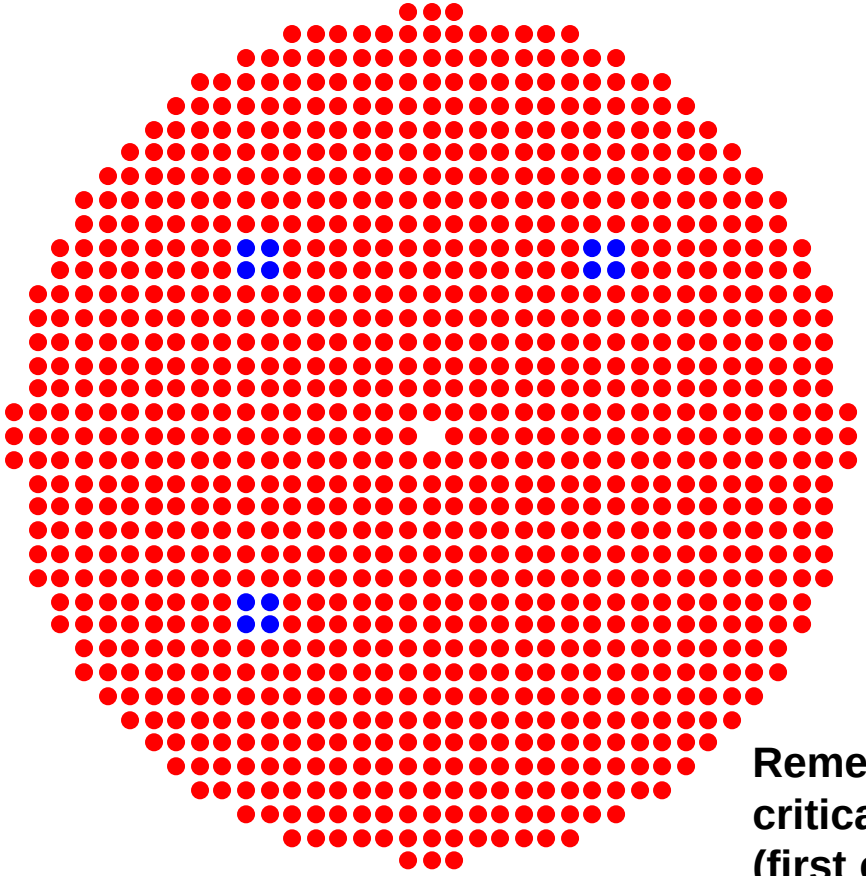


Experiment 4 Overview

- 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

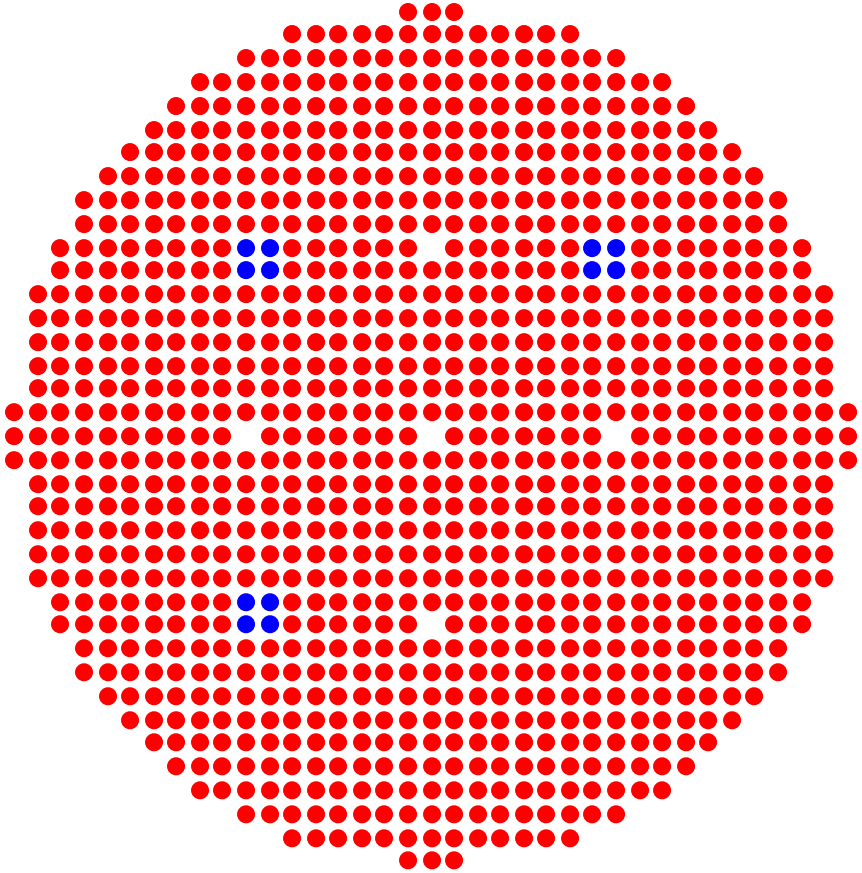


Remember that this core is critical with about 1060 rods (first experiment)

1032 Fuel Rods

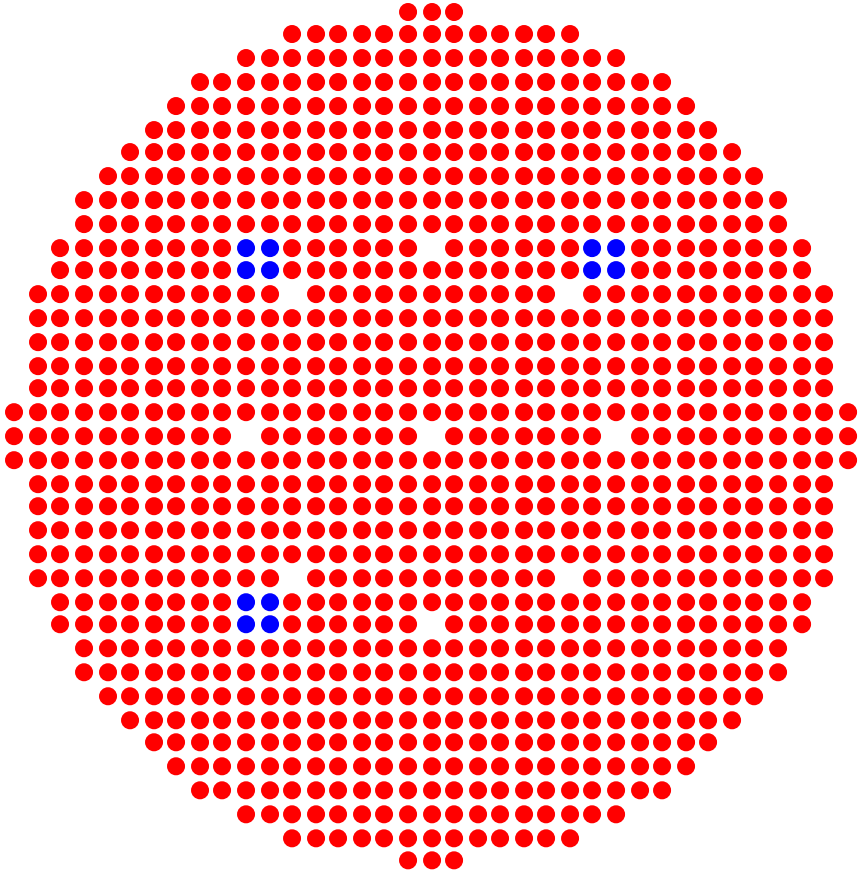
0 Water Holes (the source doesn't count)

Fuel Replacement with Water Configuration 1



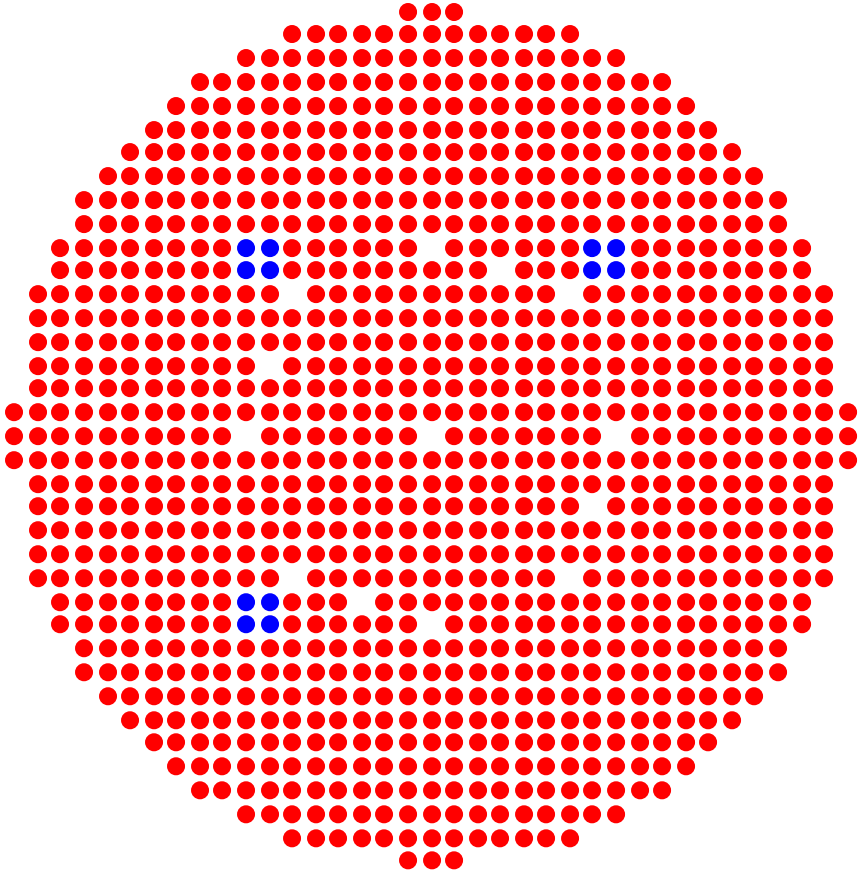
1028 Fuel Rods
4 Water Holes

Fuel Replacement with Water Configuration 2



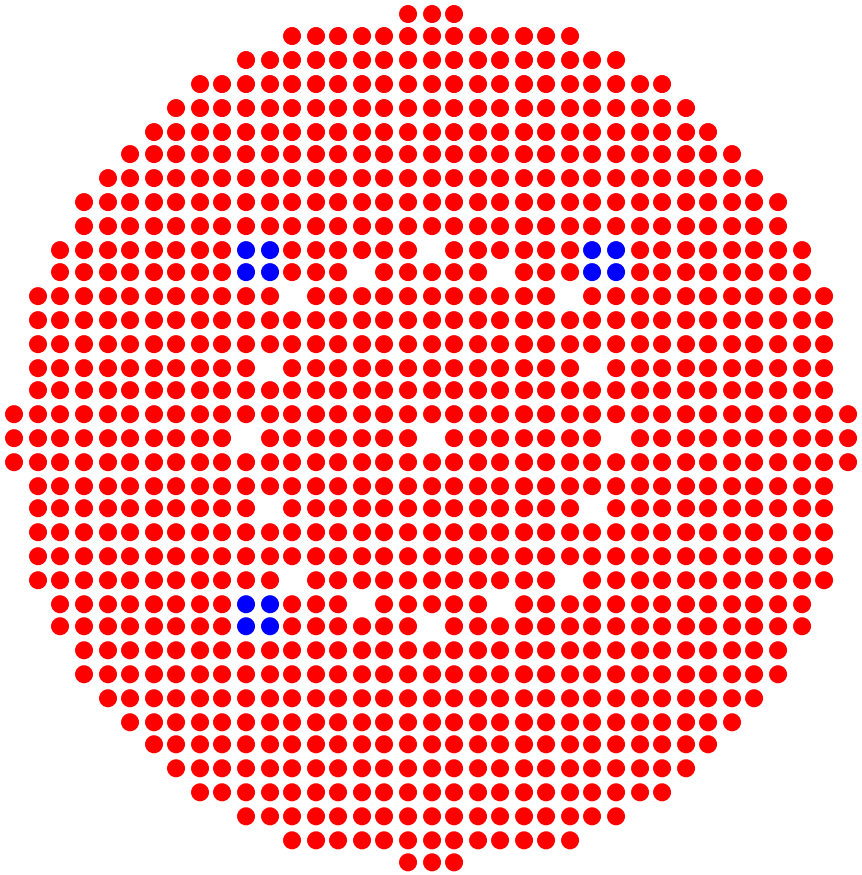
1024 Fuel Rods
8 Water Holes

Fuel Replacement with Water Configuration 3



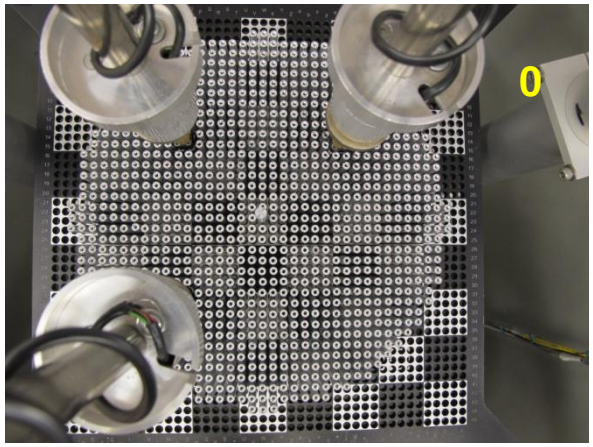
1020 Fuel Rods
12 Water Holes

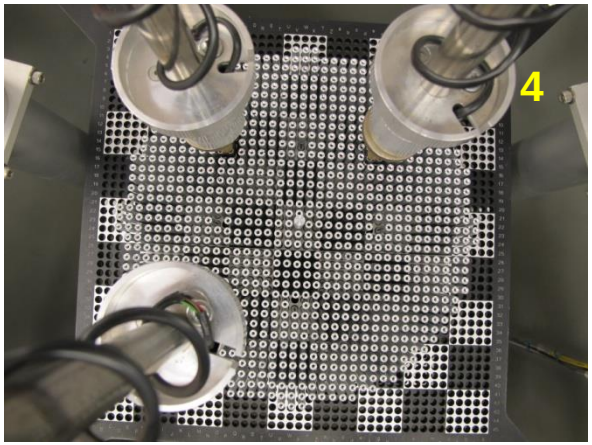
Fuel Replacement with Water Configuration 4

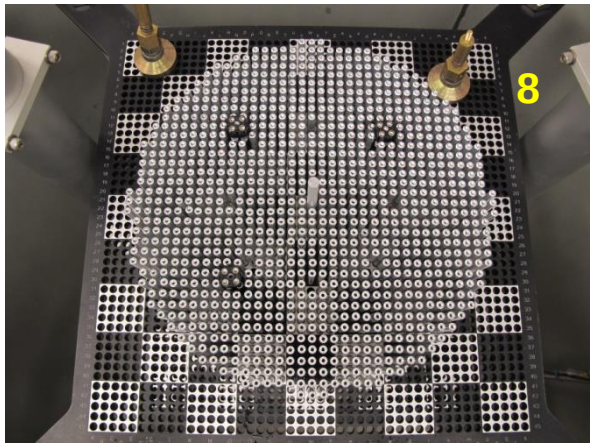


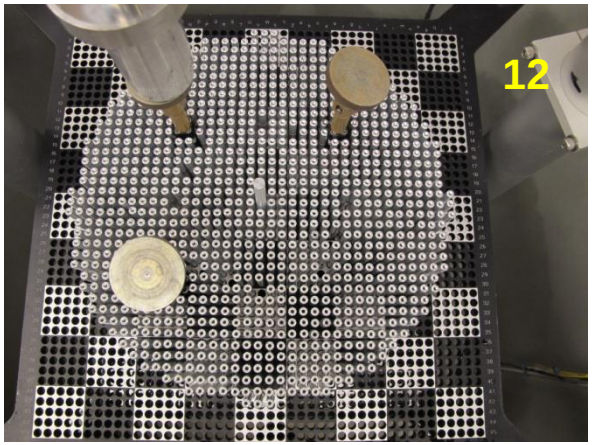
1016 Fuel Rods
16 Water Holes

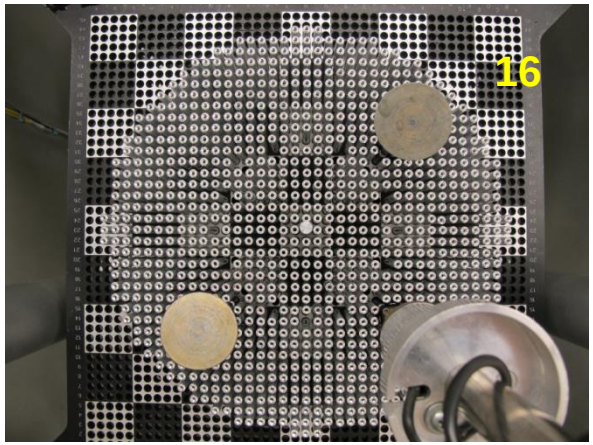
Approach on Water Holes











Concluding Remarks

- 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