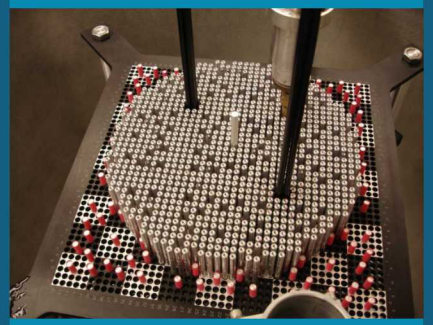
SAND2020-1347PE

Sandia 7uPCX Fuel Pitch Variation Experiments that Decrease the Fuel-to-Water Ratio and Approach Optimum Moderation (IER-230)



PRESENTED BY

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2020 DOE NCSP TPR
Santa Fe, NM

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SAND No

Introduction

- Sandia Critical Experiments Program
  - 7uPCX
  - BUCCX
- Fuel Pitch Variations
  - Strategically Remove Fuel Rods
  - Decrease Fuel-to-Moderator Ratio
- Experimental Method
- Calculational Results
  - Critical Arrays
  - Uncertainty
  - Neutron Spectra
- Conclusions
- Acknowledgements

Sandia Critical Experiments Facility

The Seven Percent Critical Experiment (7uPCX)

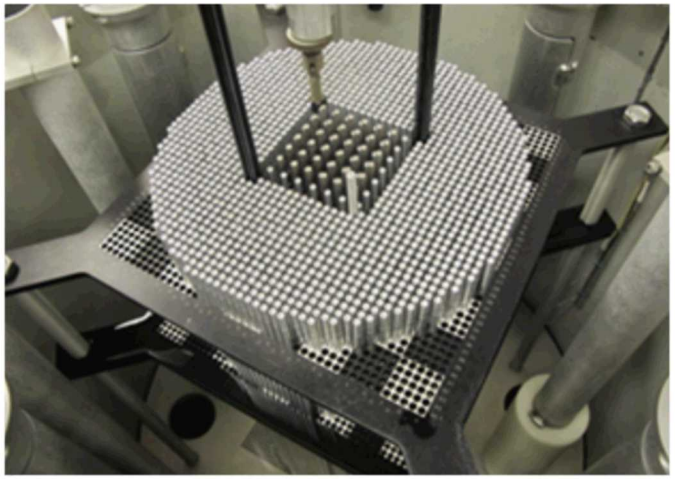
- UO_2 fuel (6.9%)
- 45x45 Square array (pitch 0.315 and 0.337 inch)
- Fuel locations 2025
- Fuel rod diameter 0.25 inch
- Fuel length 19.25 inch
- LCT-078, 080, 096, 097, 101 (experiments completed earlier this year)

The Burnup Credit Critical Experiment (BUCCX)

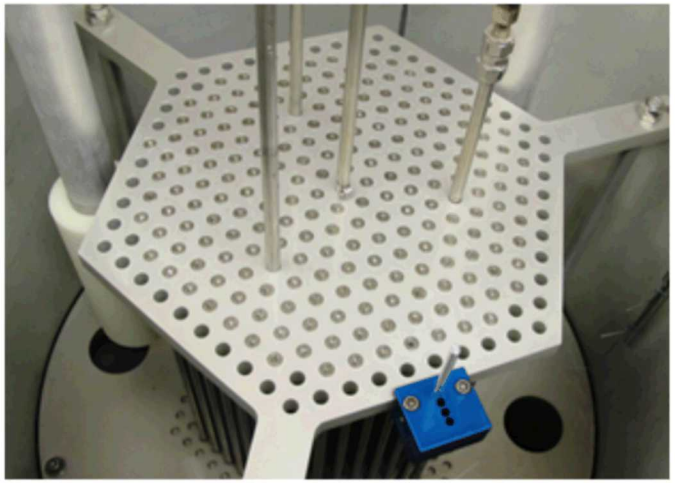
- UO_2 fuel (4.3%)
- Triangular pitch (0.787 and 1.1 inch)
- Fuel locations 397 and 271
- Fuel rod diameter 0.544 inch
- Fuel length 19.37 inch
- LCT-079, 099

Critical Experiment	BUCCX		7uPCX	
Fuel	UO_2		UO_2	
Enrichment (%)	4.306		6.903	
Moderator	Light Water		Light Water	
Fuel OD (cm)	1.265		0.526	
Fuel Length (cm)	48.7		48.8	
Fuel Density (g/cm^3)	10.4		10.3	
Fuel Rod OD (cm)	1.382		0.635	
Array Configuration	Triangular Pitch		Square Pitch	
Pitch (cm)	2.0	2.8	0.800	0.855
Fuel to Water Volume Ratio	0.640	0.238	0.672	0.524
H to ^{235}U Atom Ratio	131	332	62.0	79.5
H to U Atom Ratio	4.48	12.1	4.33	5.55

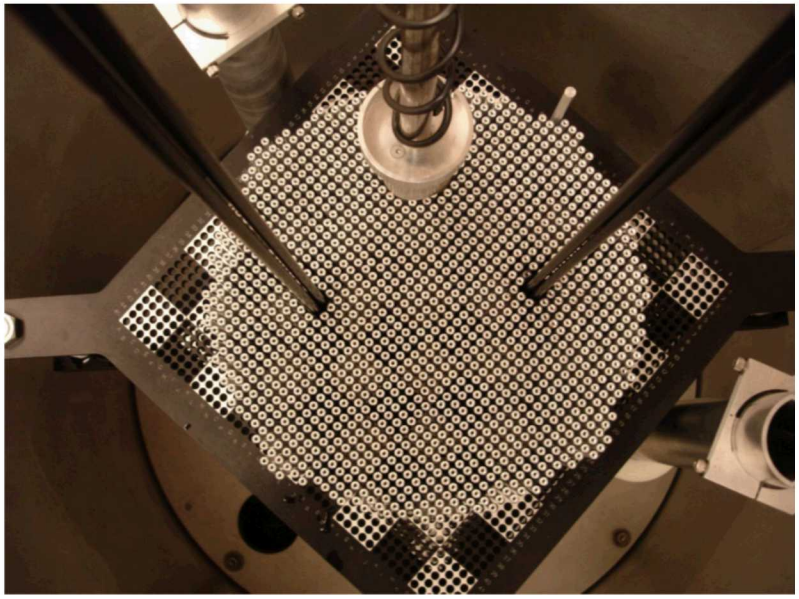
7uPCX



BUCCX



7uPCX Pitch Experiments

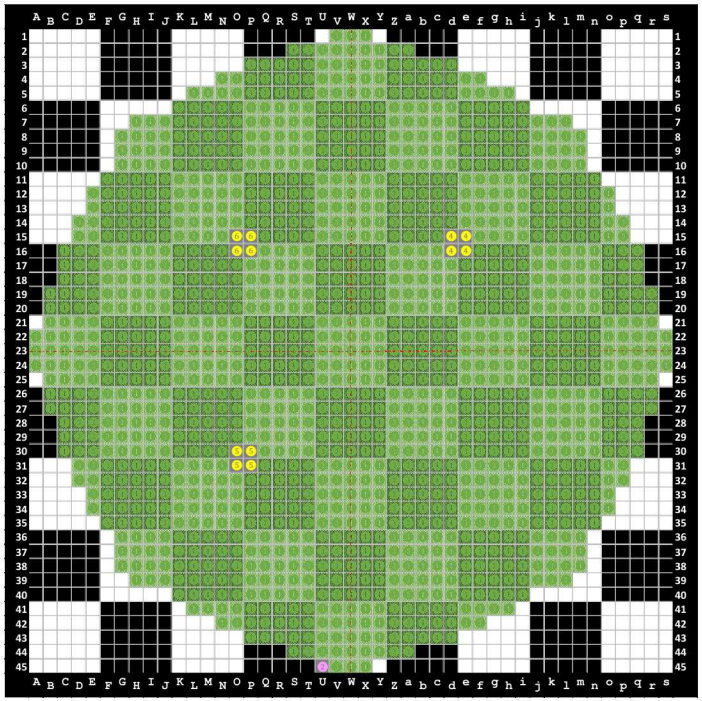


Experiment motivation

- Explore assembly fuel-to-water ratio out to and slightly beyond optimum moderation
- Criticality Safety Benchmarks (ICSBEP)

Fuel pitch variations

- Use existing grid plates
  - 0.800 cm
  - 0.855 cm
- Remove fuel rods to increase pitch
  - Every other rod staggered by row
  - Every other column and row of fuel rods



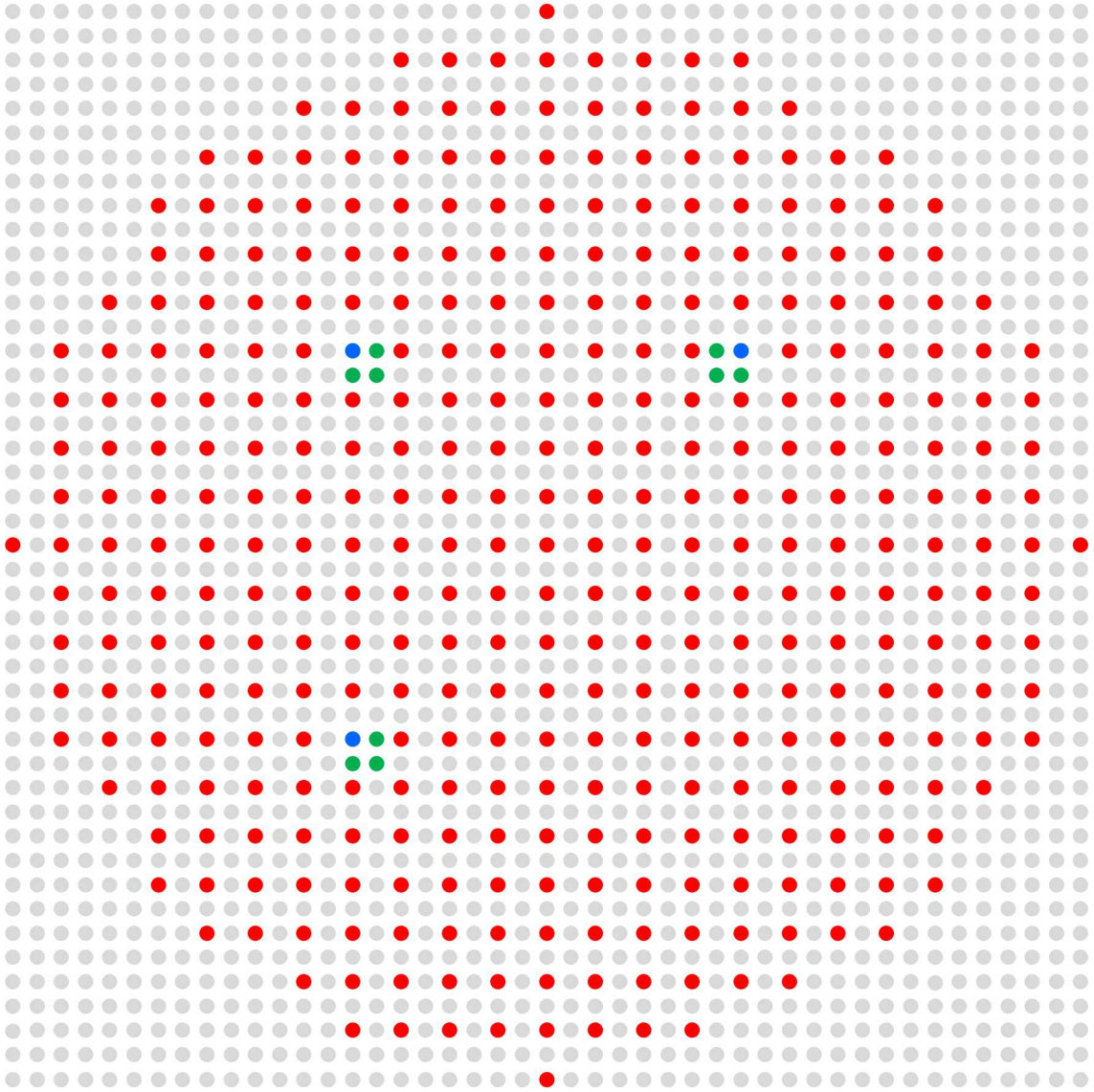
Pitch (fuel-to-moderator ratio)

- 0.800 cm (0.671)
- 0.855 cm (0.524)
- 1.131 cm (0.225)
- 1.209 cm (0.189)
- 1.600 cm (0.097)
- 1.710 cm (0.083)

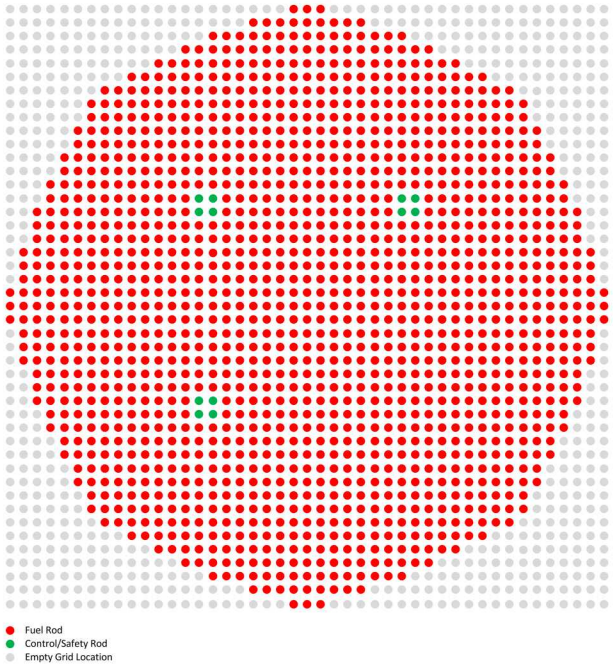
Control/Safety rods

- Fuel followers

7uPCX Pitch Variations

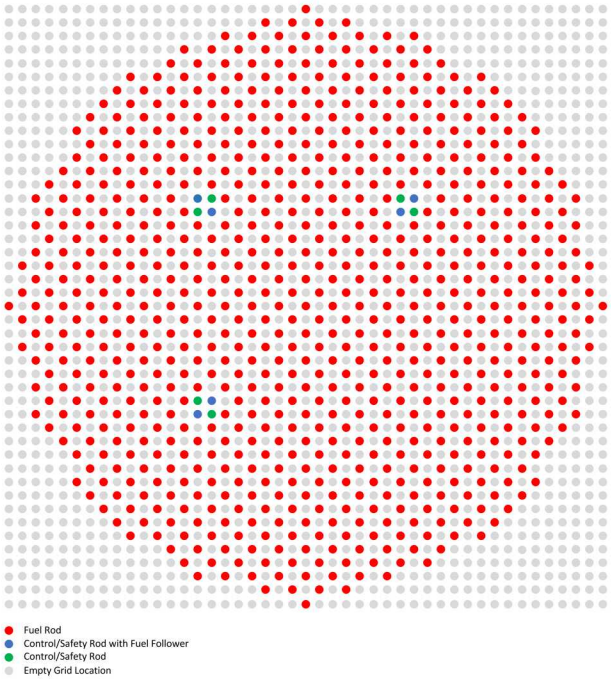


7uPCX Pitch Variations



Pitch = 0.800 cm and 0.855 cm

Fuel rods = 1470

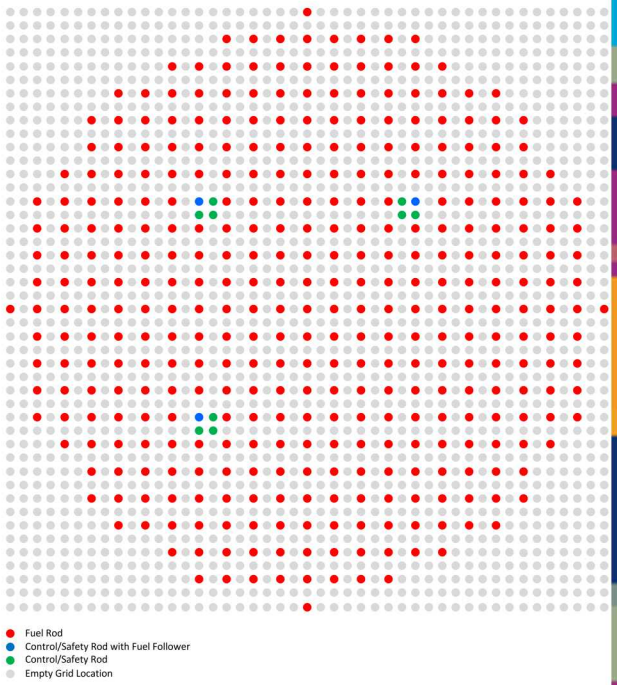


Pitch = 1.131 cm and 1.209 cm

Pitch increased by a factor $\sqrt{2}$

Fuel rods = 735

Fraction of fuel rods removed 1/2



Pitch = 1.600 cm and 1.710 cm

Pitch increased by a factor 2

Fuel rods = 367

Fraction of fuel rods removed 3/4

Experiment Method

Test the effect of increased moderation on the 7uPCX critical arrays.

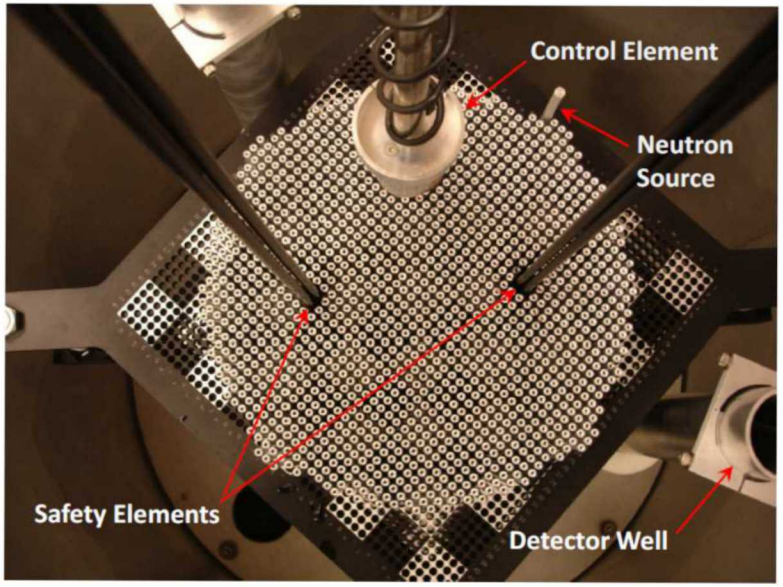
- Strongly over-moderated to optimum moderation (and slightly under-moderated)
  - Configuration of the sleeves (titanium and aluminum) the same for each case
  - Number of fuel rods in the array will differ due to the effects of titanium and aluminum

Critical array size for each configuration determined by an approach-to-critical experiment

- Array fully reflected by water
- Approach parameter is the number of fuel rods
  - Load from center toward the outside while maintaining a roughly cylindrical cross section of the array
  - Inverse count rate as function of number of fuel rods extrapolated to zero to obtain critical array size
- Initial two arrays for each configuration determined by calculations
  - 1st array: $k_{eff} = 0.90$
  - 2nd array: $k_{eff} = 0.95$
- Subsequent measurements guided by count rate results
  - Loading order guided by fuel element incremental worth calculations

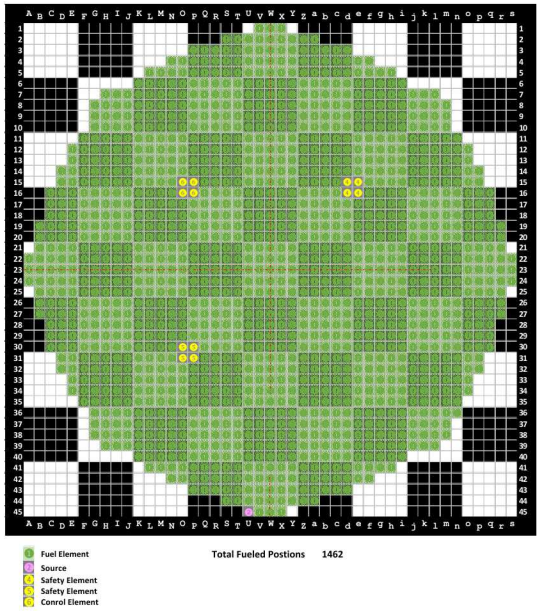
16 critical experiments

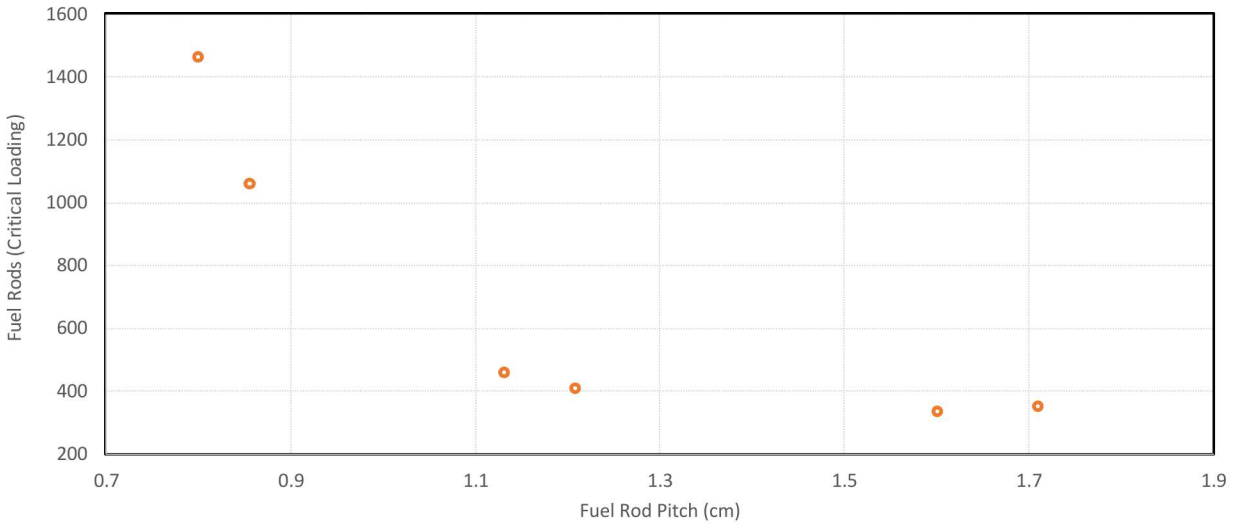
- 6 cases (at each fuel rod pitch)
- 10 cases with internal unfueled array positions

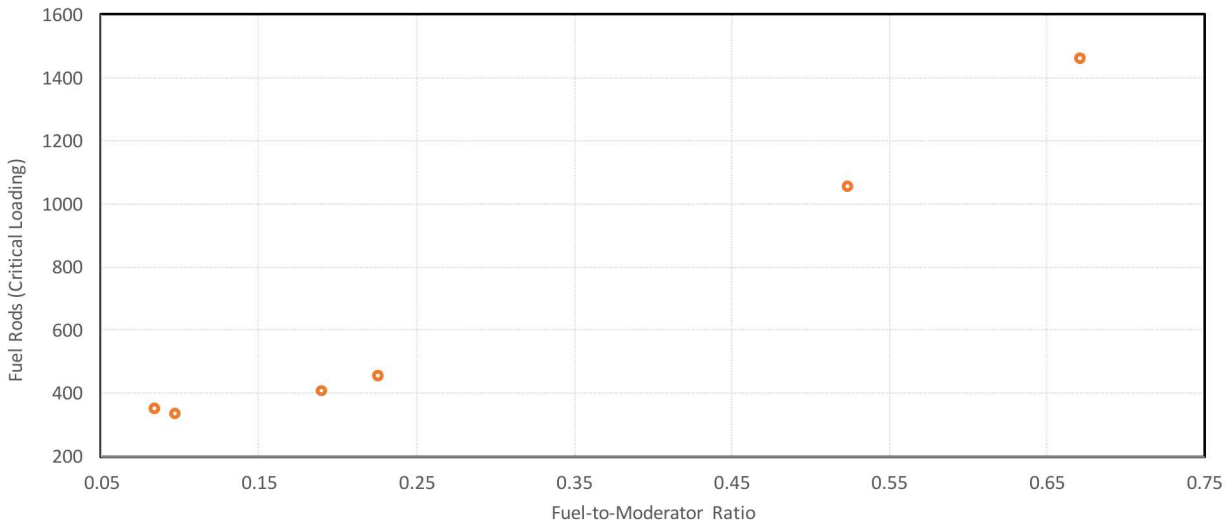


Calculated Critical Arrays Sizes

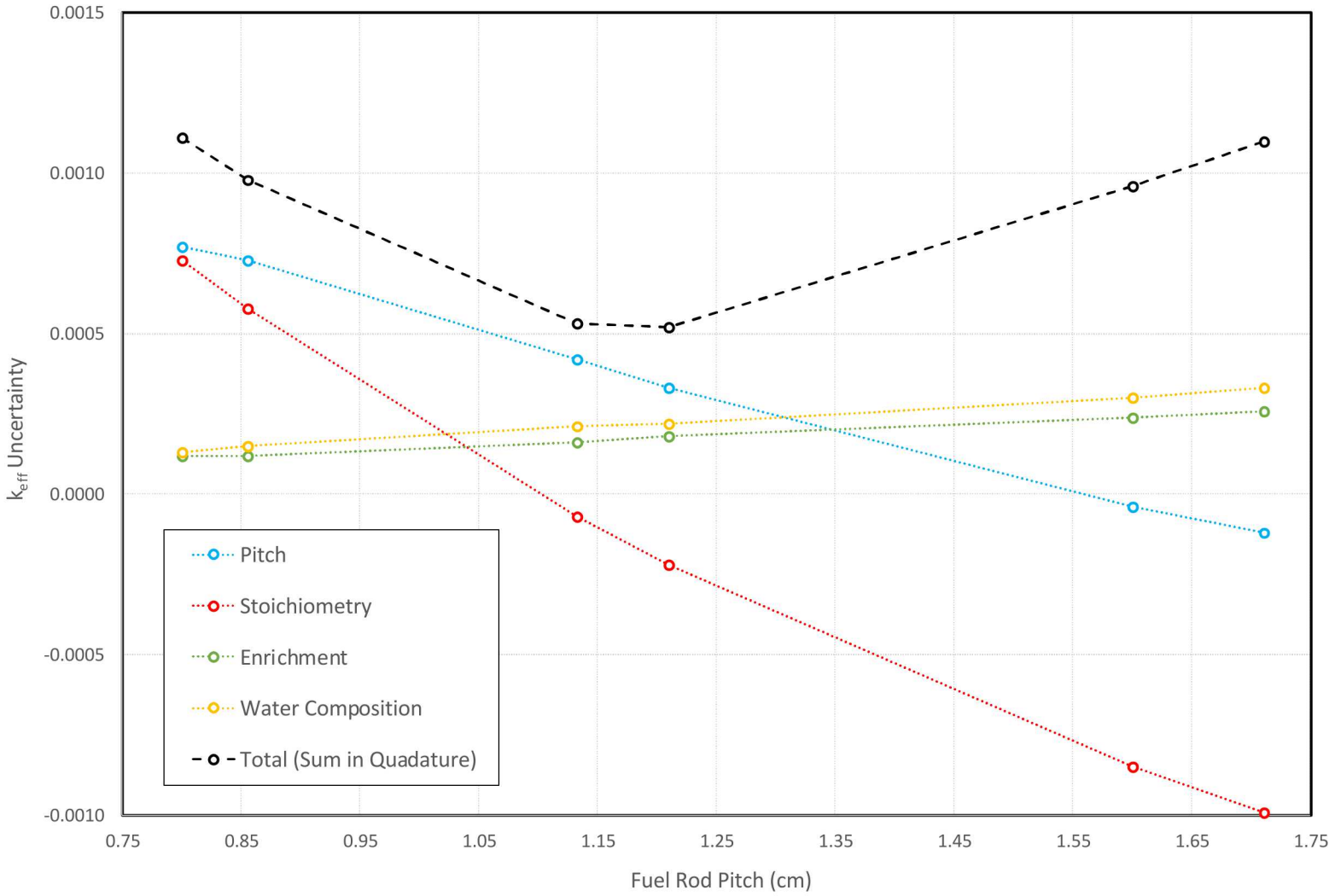
Pitch (cm)	Fuel : Moderator	Critical Array Size
0.800	0.671	1462
0.855	0.524	1058
1.131	0.225	457
1.209	0.189	407
1.600	0.097	336
1.710	0.083	350



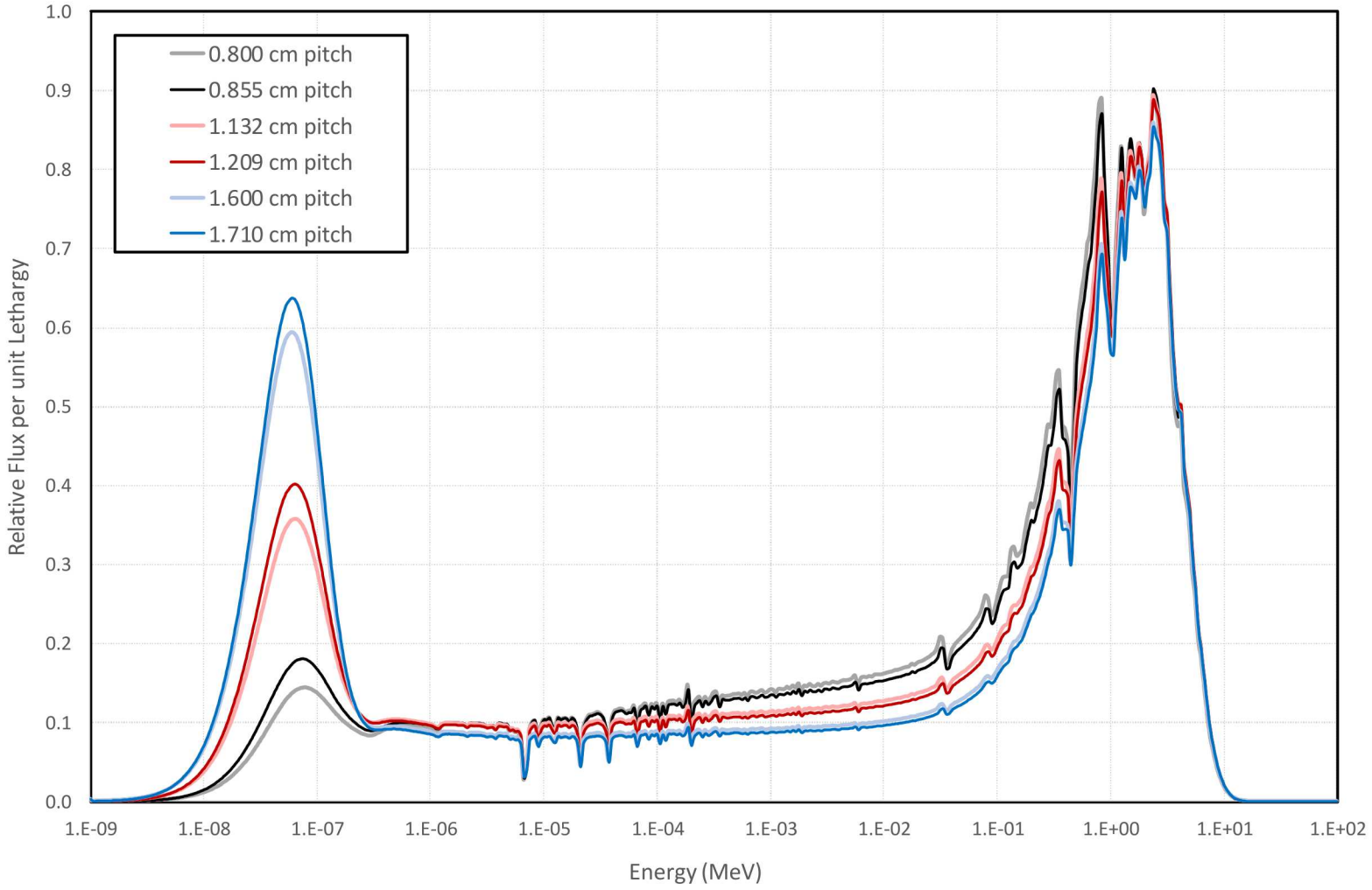




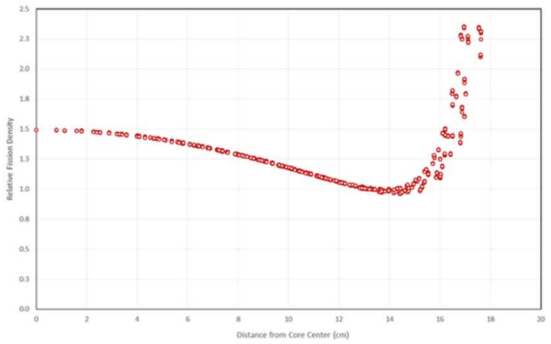
k_{eff} Uncertainty

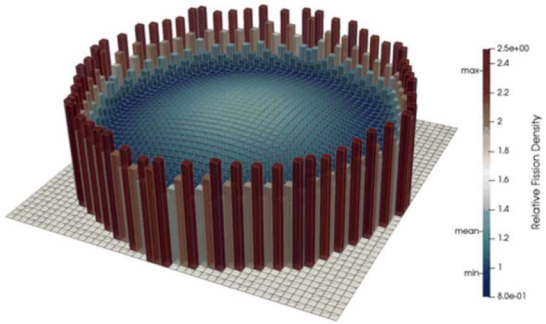


Neutron Spectra in the Fuel at each Pitch

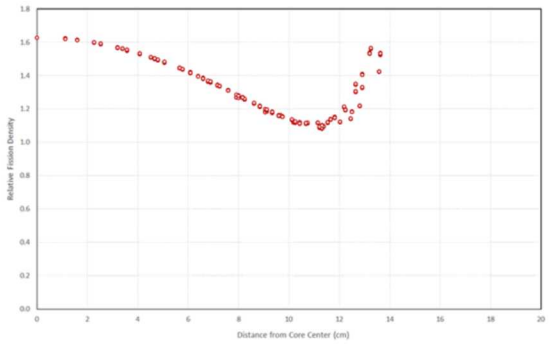


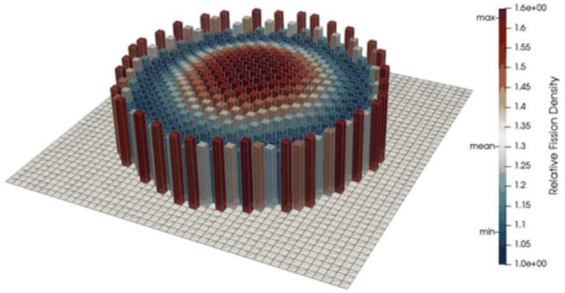
Fission Density



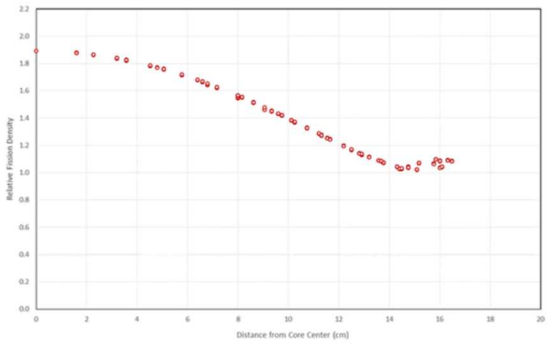


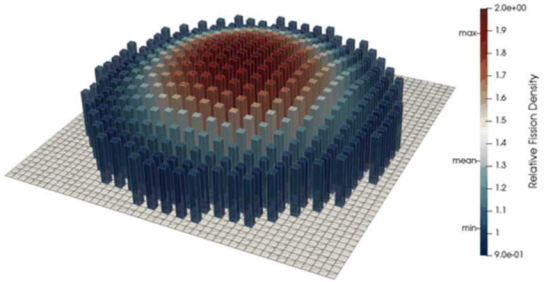
Pitch = 0.800 cm
Fuel rods = 1462
Fuel-to-moderator ratio = 0.671





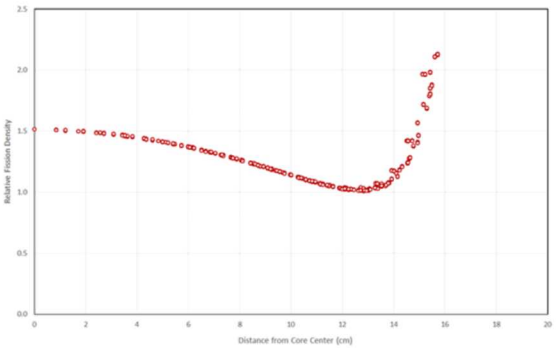
Pitch = 1.131 cm
Fuel rods = 457
Fuel-to-moderator ratio = 0.225

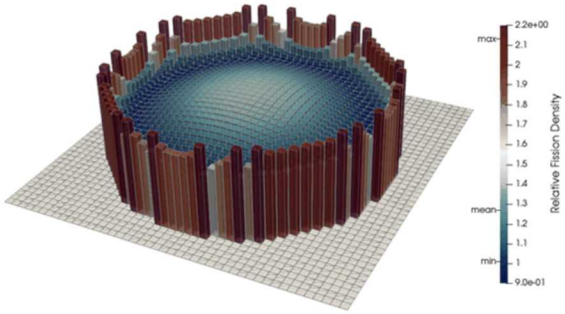




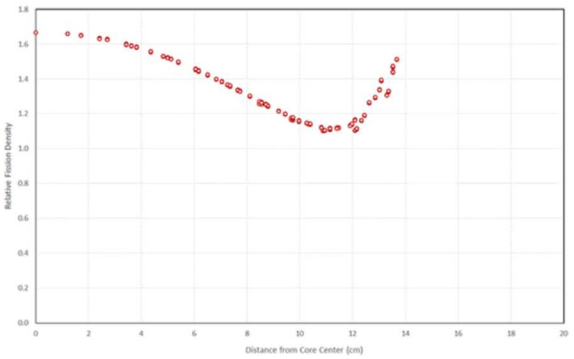
Pitch = 1.600 cm
Fuel rods = 336
Fuel-to-moderator ratio = 0.097

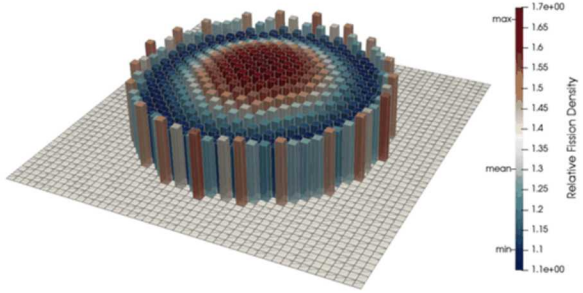
Fission Density



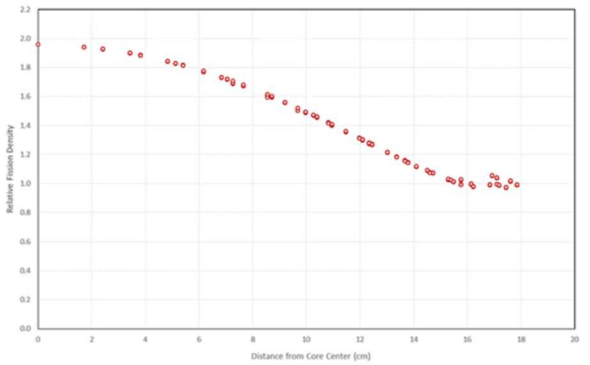


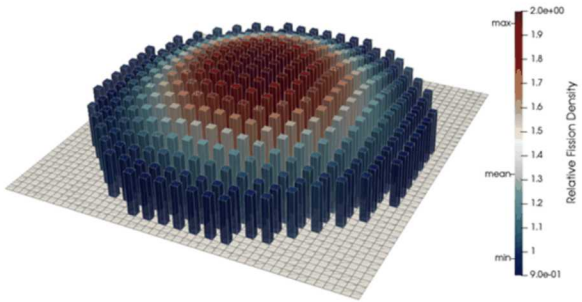
Pitch = 0.855 cm
Fuel rods = 1058
Fuel-to-moderator ratio = 0.524





Pitch = 1.209 cm
Fuel rods = 407
Fuel-to-moderator ratio = 0.189

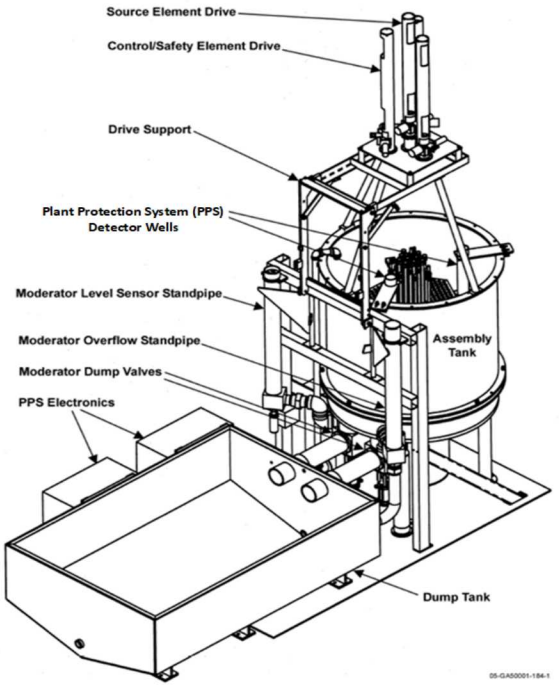




Pitch = 1.710 cm
Fuel rods = 350
Fuel-to-moderator ratio = 0.083

Conclusions/Future Plans

- Experiments (February – April).
  - 6 different fuel rod pitches
    - Multiple configurations for each
- IER-230 milestones
  - CED-3a (Completed FY19 Q3)
  - CED-3b (FY20 Q3 – On schedule)
  - CED-4a (FY21 Q1 – On schedule)
    - ICSBEP review (October 2020)
  - CED-4b (FY21 Q4 – On schedule)



Acknowledgements

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