The University of Missouri Research Reactor HEU to LEU Fuel Conversion Project Status

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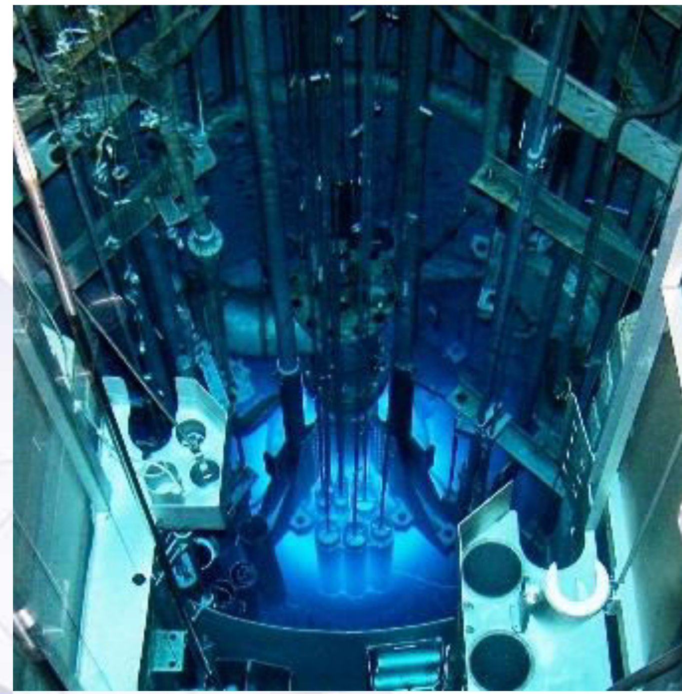

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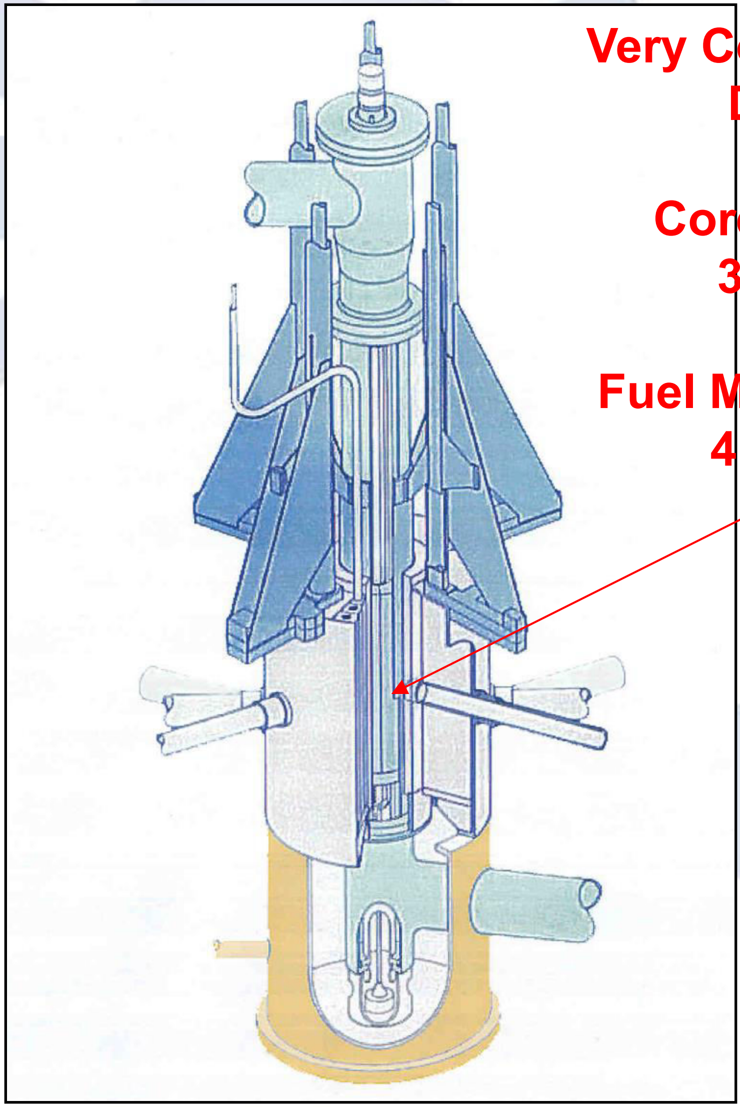
University of Missouri (MURR); St Louis, MO

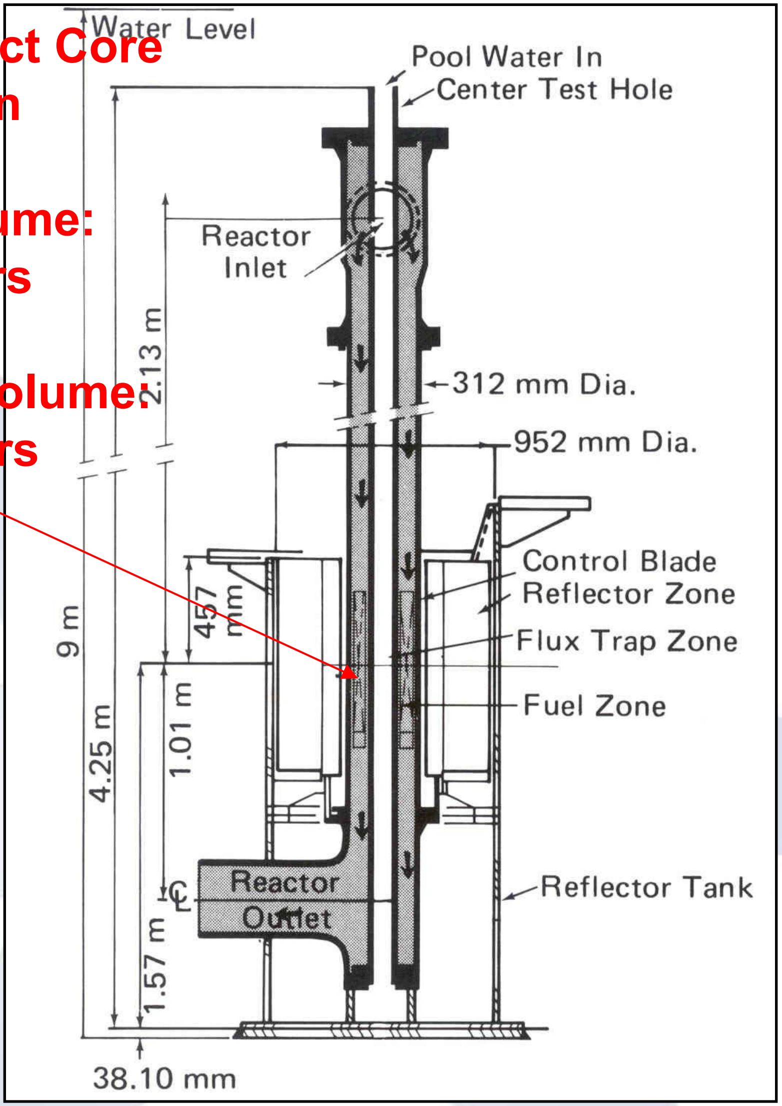
Presentation Overview

- General Description of the Reactor and Fuel
- LEU Contingency Core Design - “CD35”
- LEU Core CD35 Steady-State Safety Basis
- Peak Fuel Temperatures during a LOF and LOC Accident using RELAP - CD35 Core
- Fuel Conversion Affects on Beryllium Lifetime
- Transition Fuel Cycle - CD35 Core
- Summary of Recent Accomplishments

Reactor Core Assembly 3D View

Reactor Core Assembly 2D View



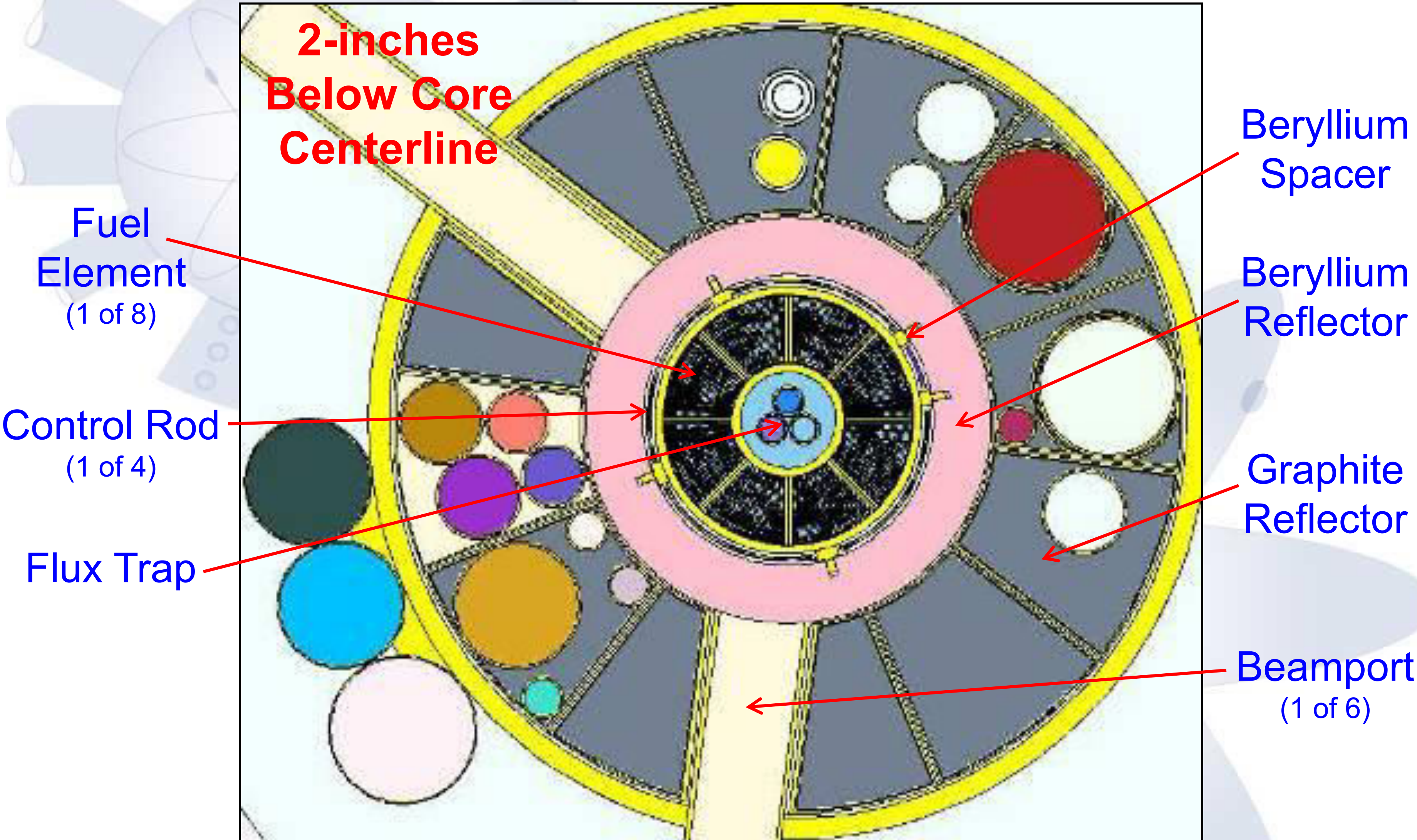


Very Compact Core Design

Core Volume: 33 liters

Fuel Meat Volume: 4.3 liters

Cross Section View of Core (MCNP Model)



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Development of LEU Core CD35 Design

- Feasibility Study Design (FSD): 24 variable thickness U-10Mo foils with minimum 10 mil clad (Al + Zr interlayer)
- Element redesigned with nominal clad thickness ≥ 12 mil
- Fuel design optimized for lifetime and power peaking
- "CD35" has 23 plates; thicker minimum plate thickness than FSD; same lifetime as HEU

Note: Plate 1 is the innermost plate, Plate 23 or 24 is the outermost plate.

Elem10 ent Design		FSD	CD35
Fuel Foil Thickness (mil)	Plate 1	9	9
	Plate 2	12	12
	Plate 3	18	16
	Plates 4-22	18	20
	Plate 23	18	17
	Plate 24	17	N/A
Clad Thickness (mil)	Plate 1	20	17.5
	Plate 2	13	16
	Plate 3	10	14
	Plates 4-22	10	12
	Plate 23	10	16
	Plate 24	16	N/A
Plate Thickness (mil)	Plate 1	49	44
	Plates 2-22	38	44
	Plate 23	38	49
	Plate 24	49	N/A
Coolant Channel Thickness (mil)	Channel 1	95	95.5
	Channels 2-5	92	93
	Channels 6-19	92	92
	Channels 20-23	92	93
	Channel 24	92	95.5
	Channel 25	95	N/A

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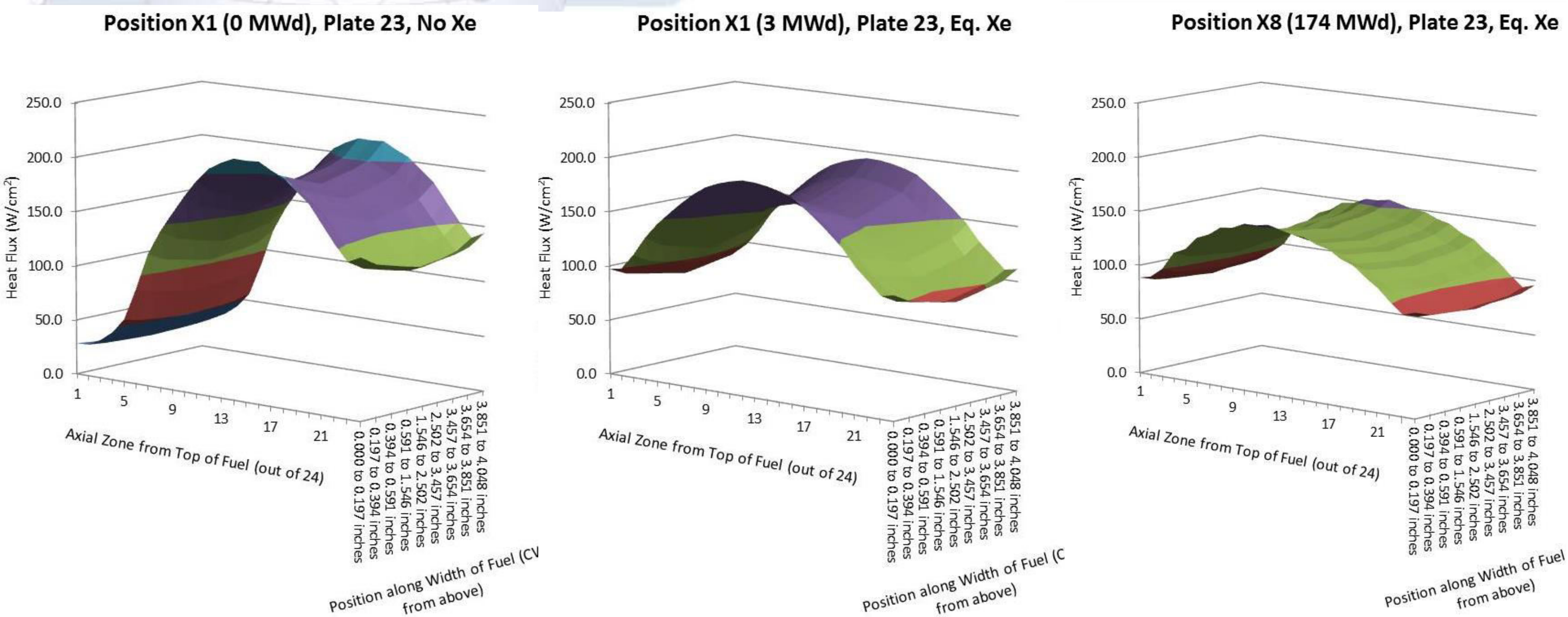
Current HEU and Proposed LEU Core CD35 Fuel Cycles

Parameter	Current HEU Fuel	Proposed LEU Fuel - CD35
Refueling:	Weekly – replace all 8 fuel elements; **fuel elements are used in 18-20 core loadings**	Weekly – replace all 8 fuel elements; **fuel elements are used in 18-20 core loadings**
EOC Core MWd (control blades full out):	**~640 MWd core** with equilibrium xenon	**~765 MWd core** with equilibrium xenon
Maximum burnup:	**150 MWd/element** < 1.6E+21 peak fissions/cc (< 43 at% peak burnup) HEU Technical Specification limit is 2.3E+21 peak fissions/cc	**180 MWd/element** < 3.4E+21 peak fissions/cc (< 44 at% peak burnup)
Fuel Cycle:	**22 elements/year at 10 MW** 32 fuel elements in active fuel cycle	**22 elements/year at 12 MW** 32 fuel elements in active fuel cycle

Power Distributions for Steady-State FI and CHF Analyses

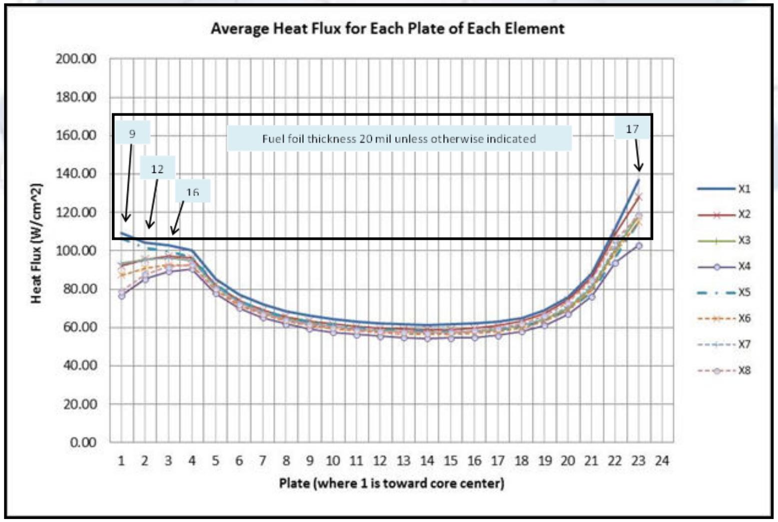
- As elements reach end-of-life, peak heat flux becomes less
- However, flow instability (FI) could occur at lower power in channel of depleted element; fuel swelling and oxide growth constricts coolant channel

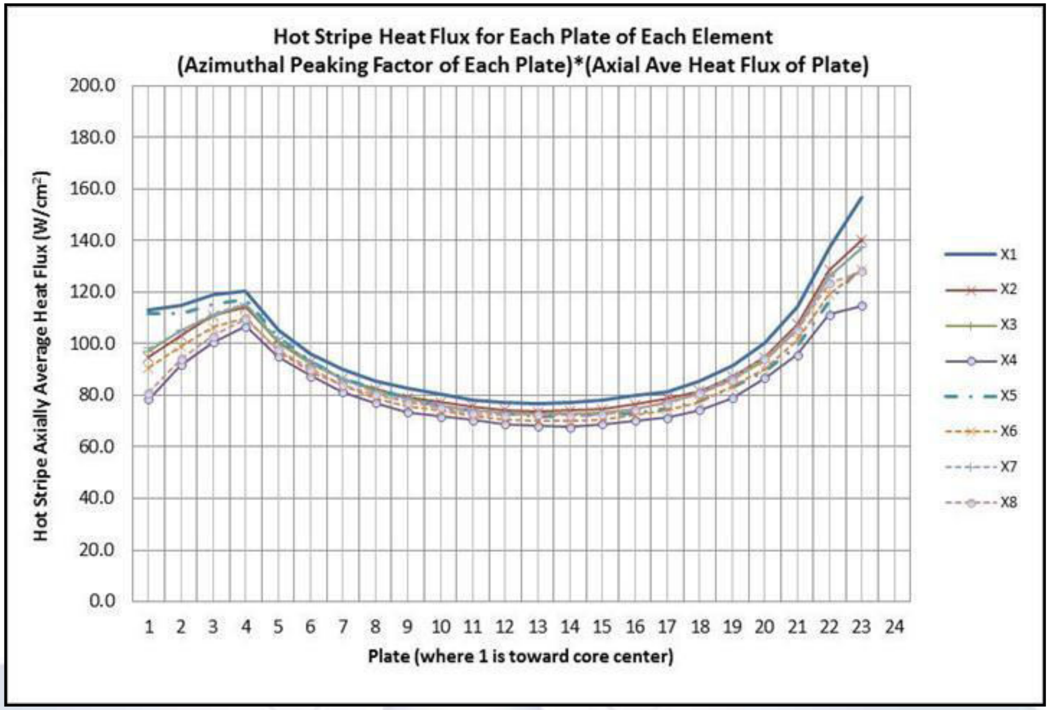


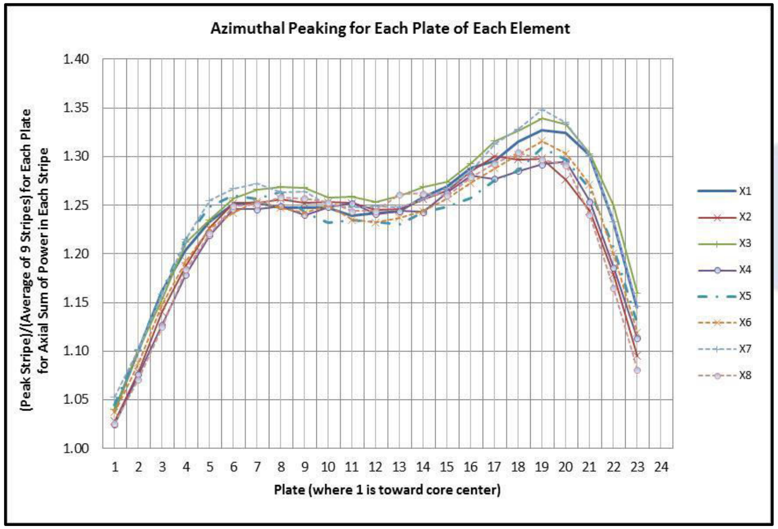
Position X1 (0 MWd)	Position X1 (3 MWd)	Position X8 (174 MWd)
148.1 W/cm²	**156.8 W/cm²**	**128.2 W/cm²**
218.1 W/cm²	**196.7 W/cm²**	**155.5 W/cm²**

Upper value is Hot-Strip Heat Flux
Lower value is Hot-Spot Heat Flux

Power Distributions for Steady-State FI and CHF Analyses



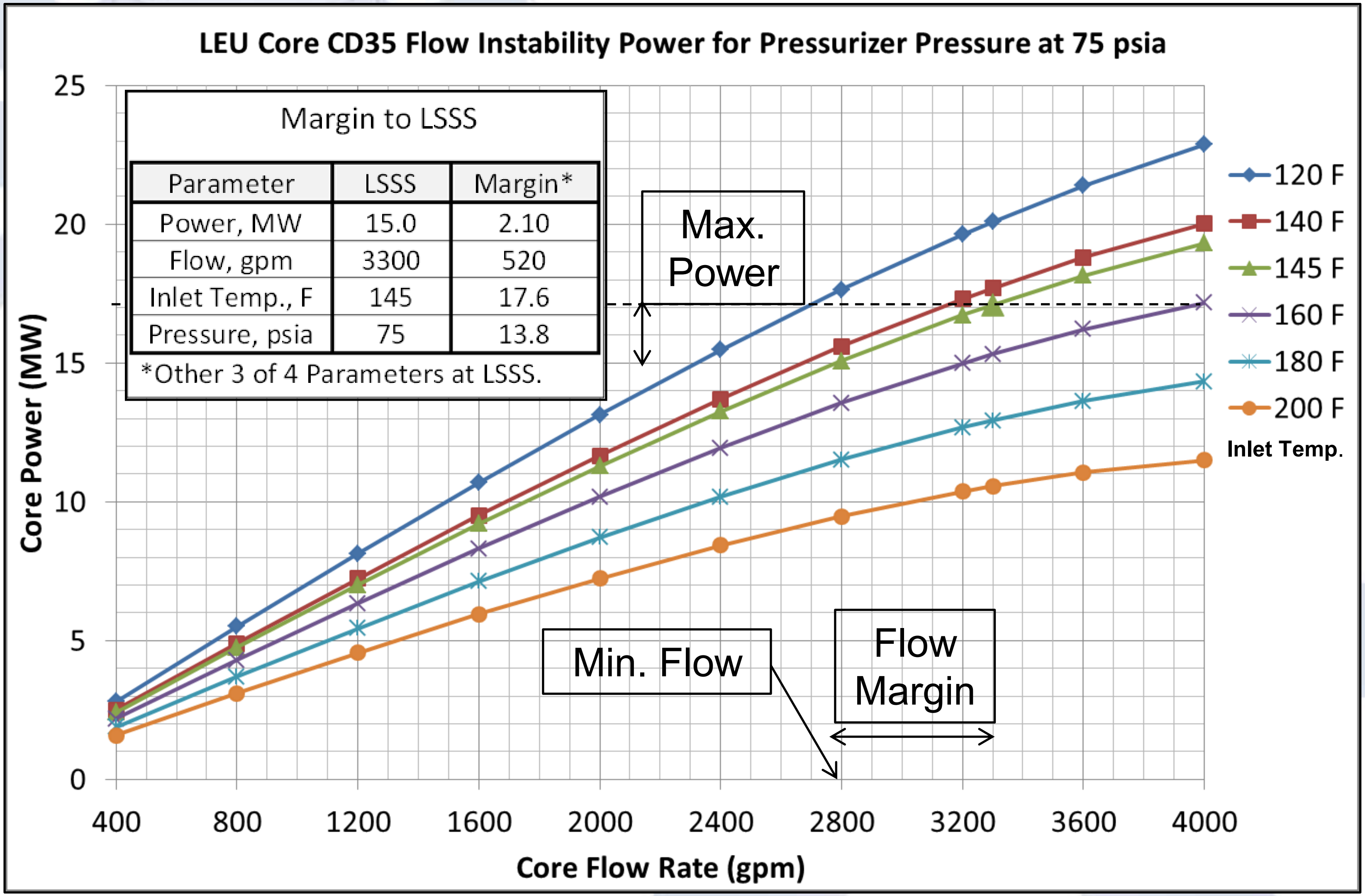




Greatest CD35 hot stripe heat flux in case for:

- Reference core
- Equilibrium Xe
- Samples in Flux Trap
- Control Blades A&D depleted and positioned 1 inch above Blades B&C

LEU Core CD35 Flow Instability Power at 75 psia



Parameter	LSSS	Margin*
Power, MW	15.0	2.10
Flow, gpm	3300	520
Inlet Temp., F	145	17.6
Pressure, psia	75	13.8

Loss of Flow Accident

Normal Flow Path

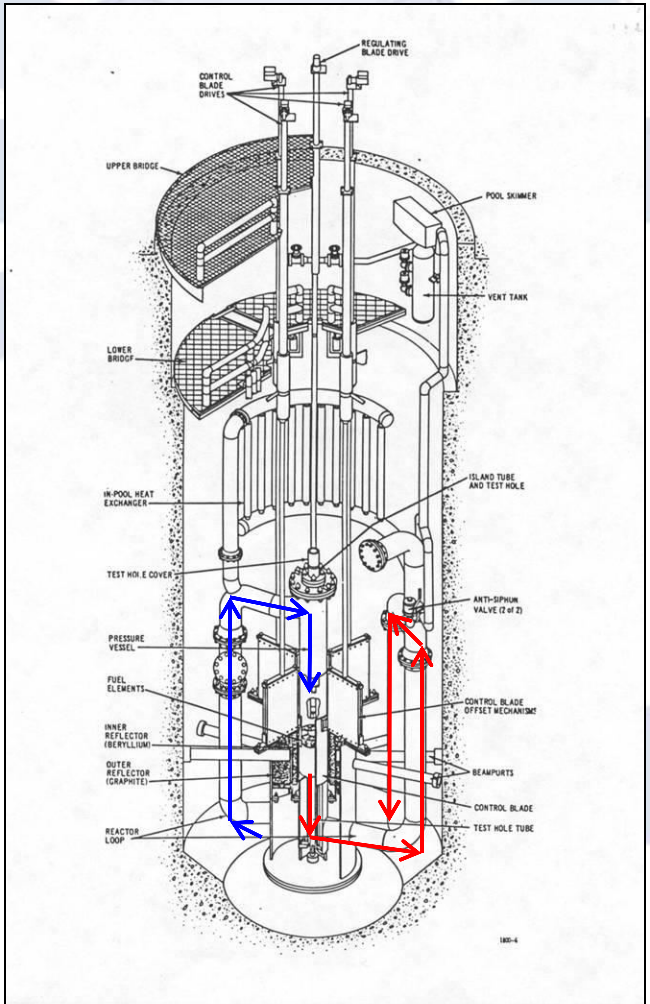


Figure 1-1. Reactor Arrangement

Accident Flow Path

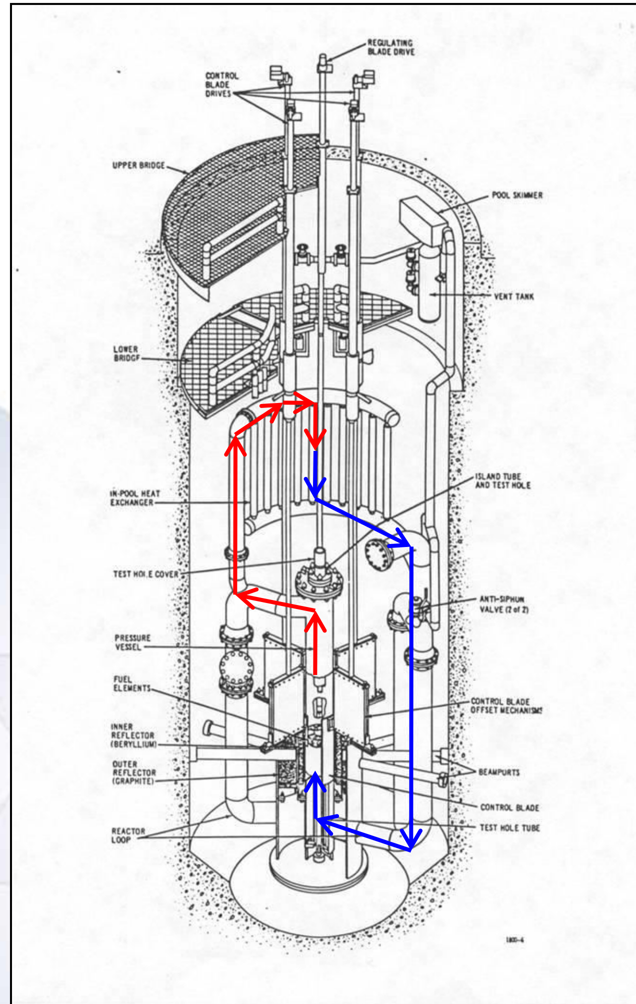


Figure 1-1. Reactor Arrangement

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Loss of Coolant Accident

Start of Accident

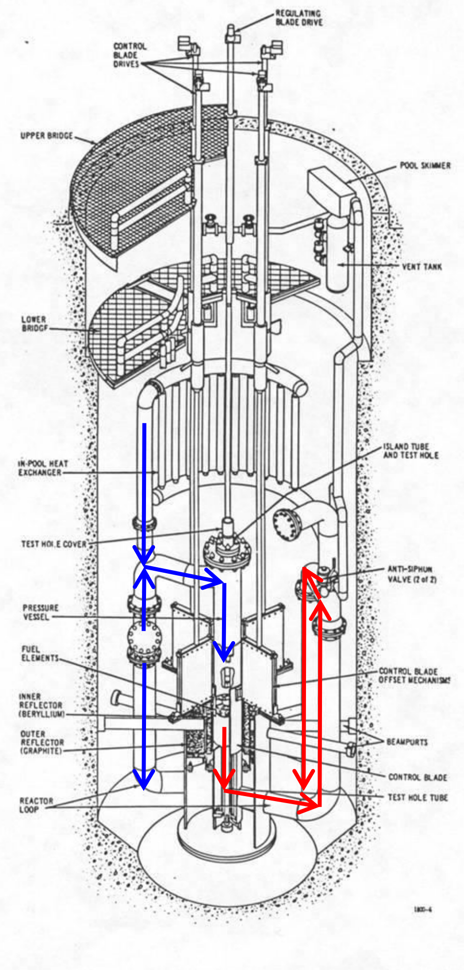


Figure 1-1. Reactor Arrangement

Coolant Left in Primary

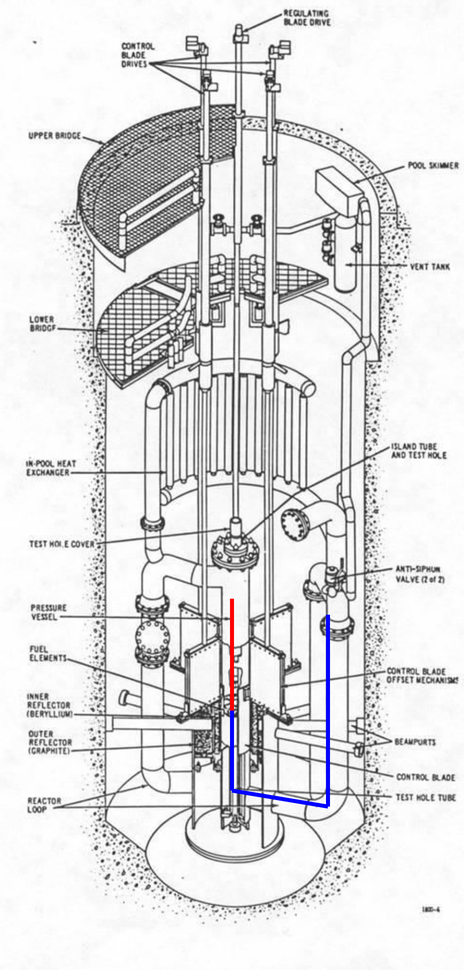
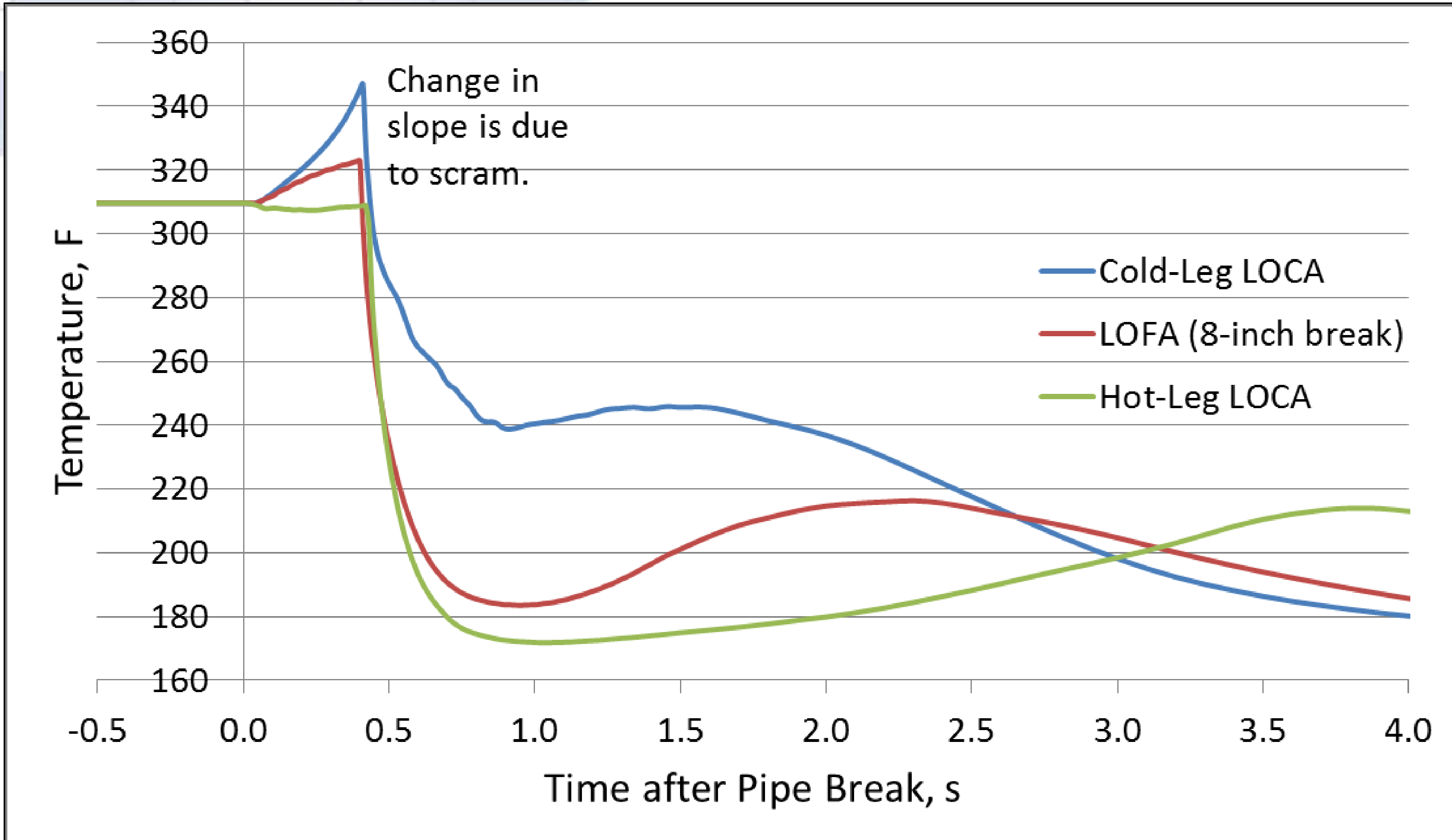


Figure 1-1. Reactor Arrangement

CD35 LOF and LOC Accidents
Fuel Plate 23 Centerline Temperature



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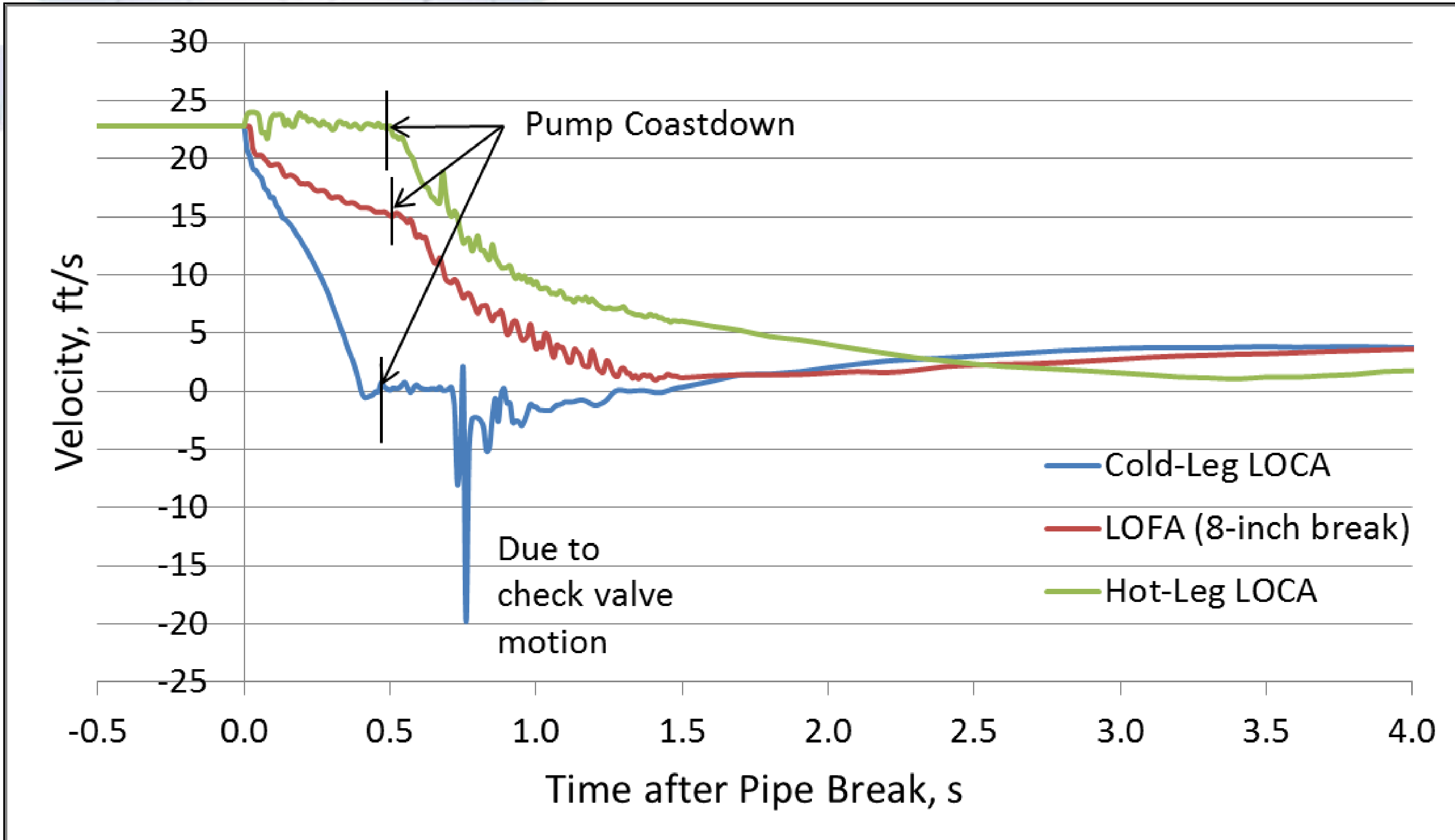
CD35 LOF and LOC Accidents Coolant Channel 23 Flow Velocity



LOF and LOC Accidents Using RELAP Peak Fuel Temperatures

Accident	HEU Core at 10 MW[1]	LEU Core at 12 MW[2]	Temperature Delta[3]
LOCA – Cold Leg	342 °F	347 °F	+5 °F
LOCA – Hot Leg	254 °F	310 °F	+56 °F
LOFA	273 °F	323 °F	+50 °F

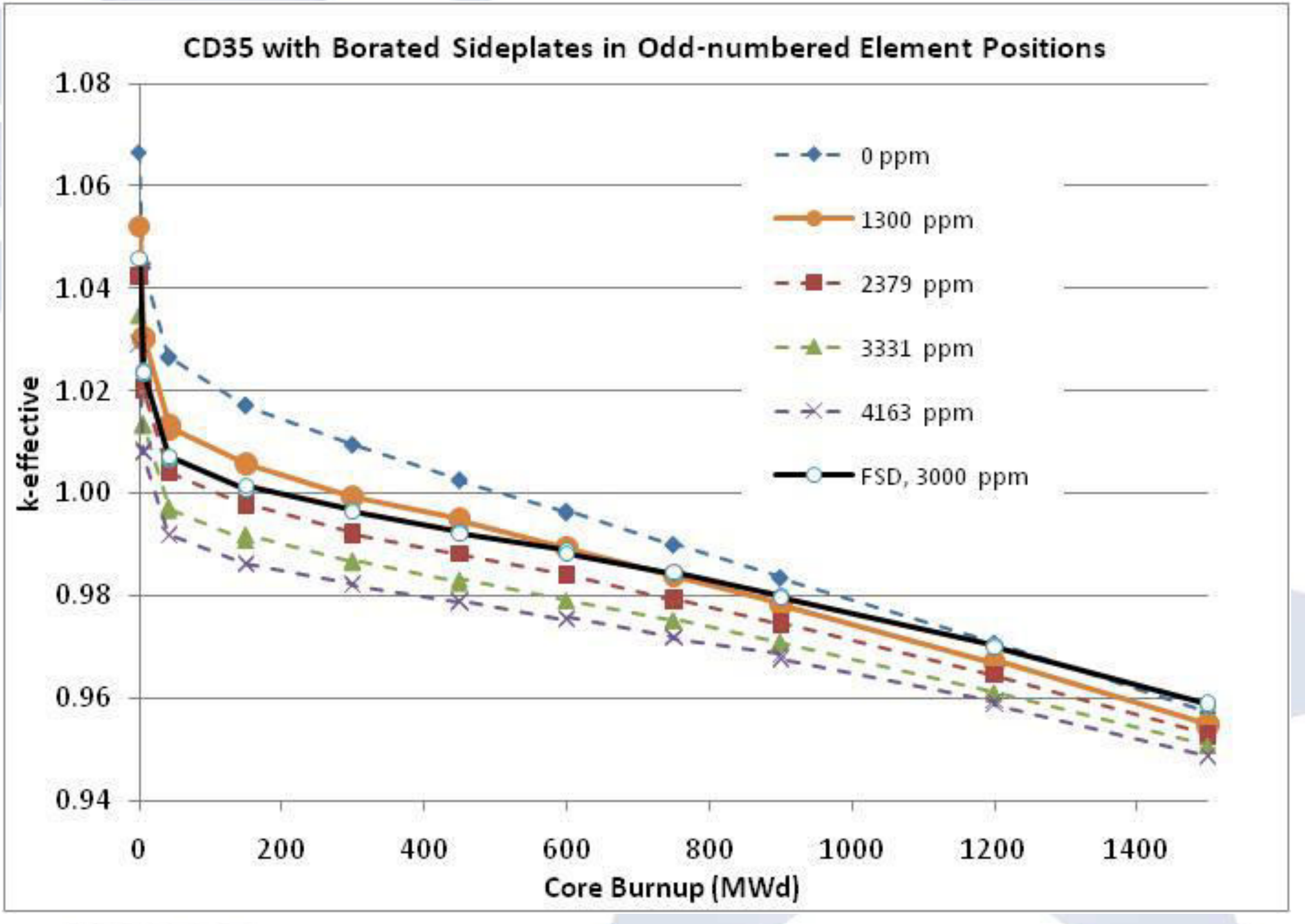
Notes:

1. Core inlet water temperature set at LSSS of 155 °F.
2. Core inlet water temperature set at LSSS of 145 °F.
3. Increase in temperatures is a result of a 20% increase in power and lower fuel plate heat conductance.

Fuel Conversion affect on Beryllium Lifetime

- Beryllium is replaced about every 8 years (~26,000 MWD) with current operating schedule (151 Hrs/wk) using HEU fuel at 10 MW
- Fuel conversion to LEU fuel at 12 MW will alter thermal heating and swelling-induced stresses
- MCNP analyses indicate an increase in the average gas concentration in the peak region from 1,530 ppm to 1,690 ppm (10.5 % greater)
- MCNP analyses indicate a decrease in the average heating rate in the peak region from 4.65 w/cm^3 to 3.63 w/cm^3 (24 % less)
- Based on this information, what is the overall affect? Will work with ATR & HFIR to better estimate it

CD35 Transition Core – Borated Side Plates

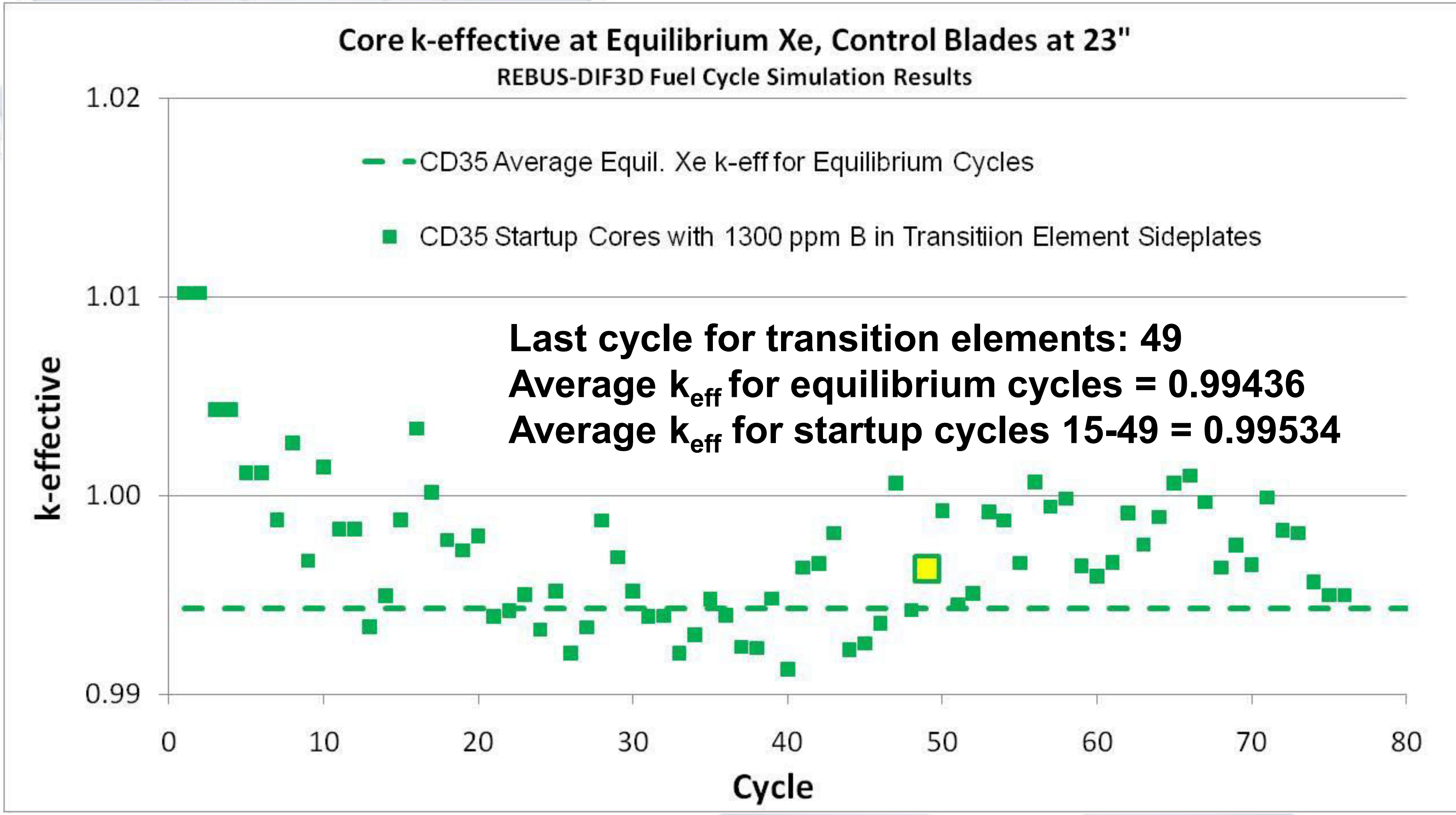


Transition LEU Core CD35 - Fuel Cycle

Weekly LEU Cores	Core Elements (Boron/Standard)	Boron Side Plate LEU Fuel Elements	Standard Side Plate LEU Fuel Elements	BOC Core MWDs
C1 → C14	6/2	12	8	0 - 435
C15 → C27	4/4	12	16	340 - 640
C28 → C49	2/6	12	22	514 - 720
End of Transition Fuel Cycle—Normal LEU Fuel Cycle				
C50 +	0/8	0	32	632 Ave.

- Boron side plate fuel elements contain 1300 ppm (0.13%) of B-10.
- MURR will average retiring two fuel elements at 180 MWd burnup due to reactivity limitations and adding two new elements eleven times per year.

Potential Transition Fuel Cycle Cores Compared to the Intended Routine Cycle



Summary of Recent Accomplishments

- Completed alternate LEU fuel element design CD35 for thicker clad and thicker plates than feasibility study design.
- Completed steady-state safety basis for CD35 LEU core at 12 MW:
  - J. Stillman, et al., “Technical Basis in Support of the Conversion of the University of Missouri Research Reactor (MURR) Core from Highly-Enriched to Low-Enriched Uranium – Core Neutron Physics,” September 2012
  - E. E. Feldman, et al., “Technical Basis in Support of the Conversion of the University of Missouri Research Reactor (MURR) Core from Highly-Enriched to Low-Enriched Uranium – Steady-State Thermal-Hydraulic Analysis,” January 2013
  - L. Foyto, et al., “Draft Chapter 4, Reactor Description, Safety Analysis Report, Highly-Enriched to Low-Enriched Uranium Conversions,” January 2013

Summary of Recent Accomplishments

- Increasing formality of information exchange with FD Pillar:
  - J. Stillman, et al., "Conceptual Design Parameters for MURR LEU U-Mo Fuel Conversion Design Demonstration Experiment," September 2012
  - J. Stillman, et al., "Irradiation Experiment Conceptual Design Parameters for MURR LEU U-Mo Fuel Conversion," March 2013
  - Rev 1 completed (June) to describe impacts of tolerances & uncertainties
- Completing Phase 1 of Transient and Accident Analyses for LEU core CD35 as required by Chapter 13 of the LEU Conversion SAR – MCNP
- Completing Phase 1 of Ancillary Analyses
  - Effect of LEU at 12 MW on Beryllium Lifetime
  - Transition Element Design and Strategy for CD35 LEU Fuel Cycle

Thank You For You Attention, Any Questions???

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