Conversion of MNSR (PARR-2) from HEU to LEU Fuel

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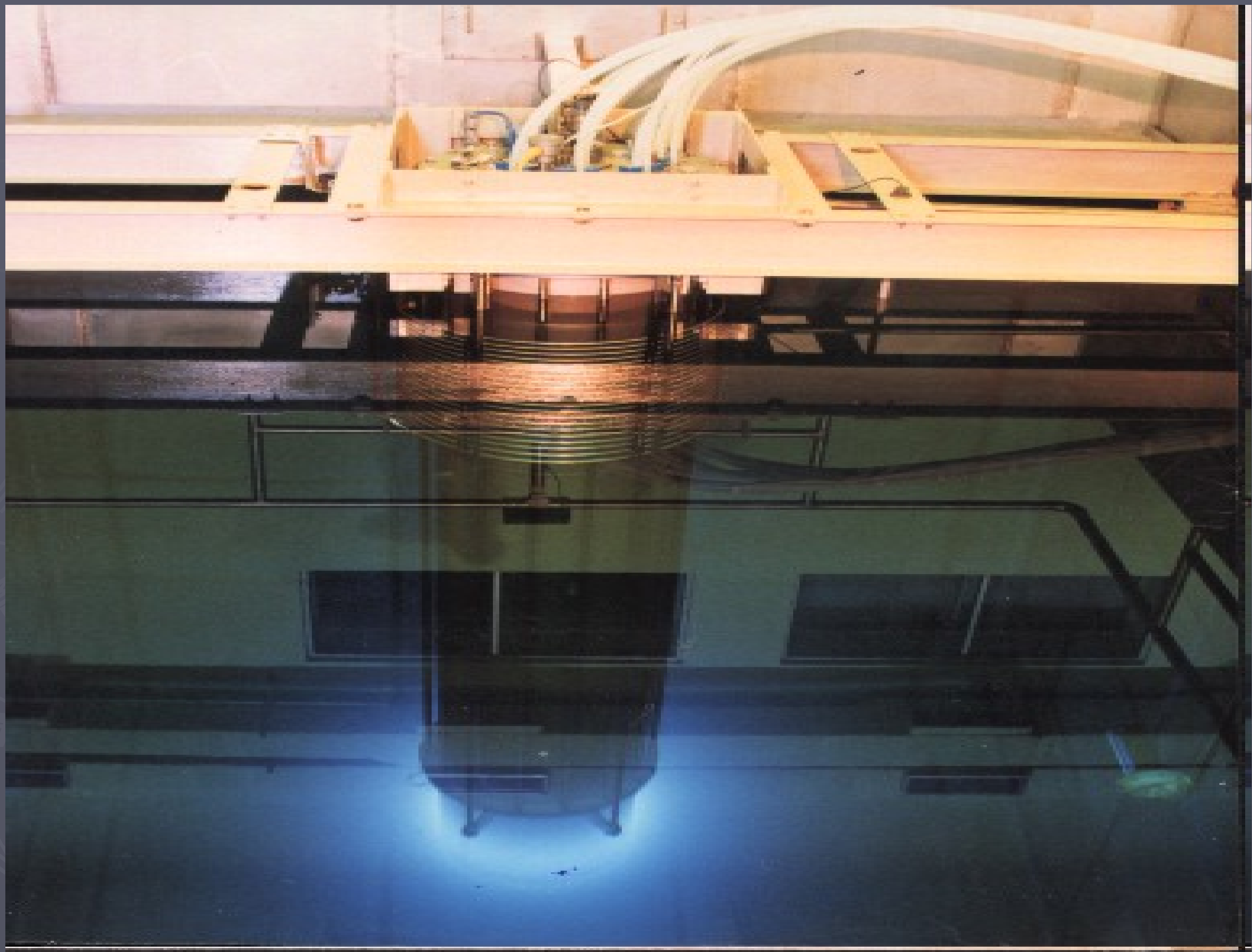
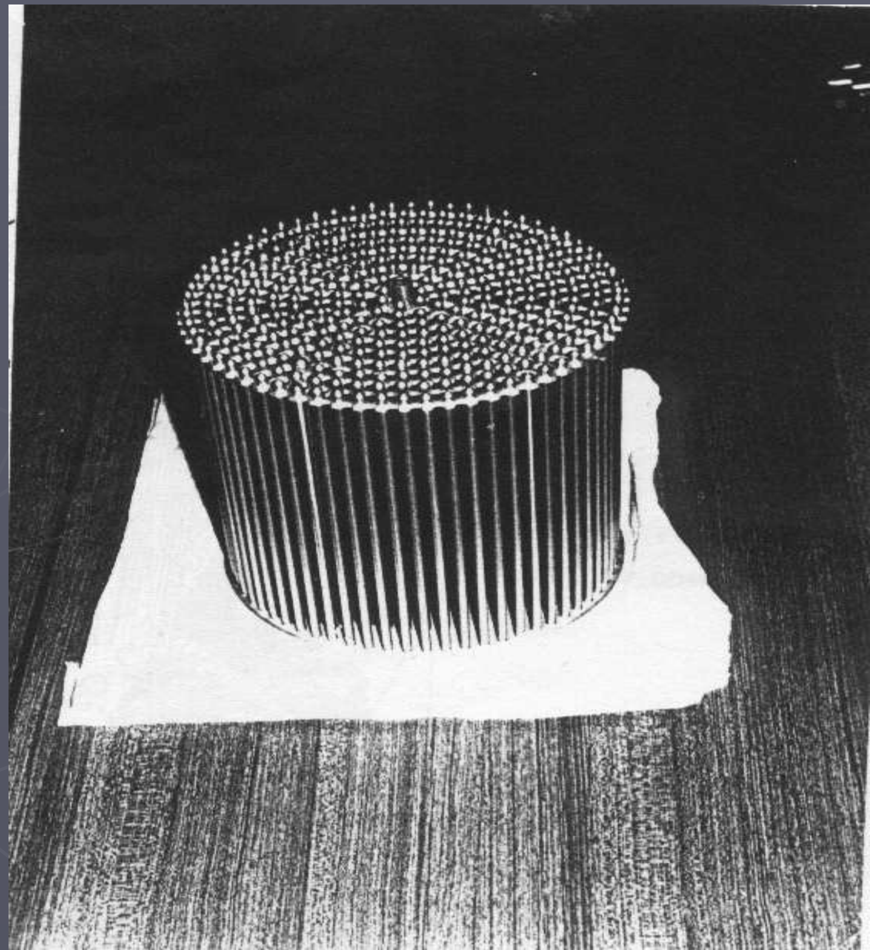
Pakistan Institute of Nuclear Science and Technology (PINSTECH)

Pakistan Research Reactor-2 (PARR-2)



Core Configuration

- HEU fuel pins with 90.2 % enriched in ^{235}U
- Number of fuel pins 344
- Fuel material UAl_4-Al
- Number of dummy pins 6
- Number of tie rods 4
- Central Control Rod 1
- Each fuel pin contains about 2.9g of ^{235}U

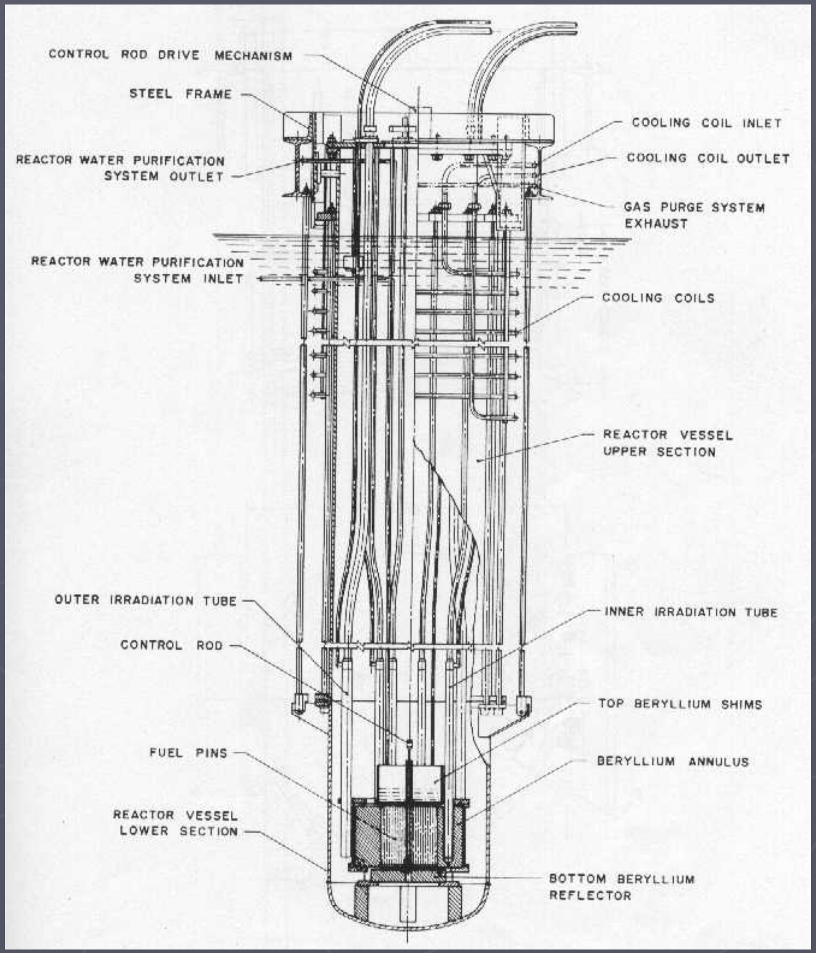


Data for Neutronic Analyses

Fuel pin dimensions

- *HEU Fuel*
  - 4.3 mm diameter of fuel meat and 0.6mm Al clad thickness, 5.5mm outer diameter of fuel pin
- *LEU Fuel*
  - 4.3 mm diameter of fuel meat and 0.6mm Zircalloy-4 clad thickness, 5.5mm outer diameter of fuel pin
  - 4.2 mm diameter of fuel meat and 0.45mm Zircalloy-4 clad thickness, 5.1mm outer diameter of fuel pin
- HEU and LEU fuel pins have 248 mm height with 230mm active height
- *Control Rod Dimensions*
  - One centrally located Cadmium control rod with 3.9 mm diameter and 0.5 mm SS clad
- *Beryllium Reflector*
  - 102 mm thick annular beryllium and 50 mm thick bottom beryllium reflector

Fig. 1: Reactor Vessel Cross section



Methodology for Neutronic Analysis

- Lattice Calculations were performed employing WIMSD code
- WIMSD uses 69 groups, multi region integral transport theory to solve the neutron transport equation for the lattice cells
- Unit fuel cell of PARR-2 core for HEU and LEU fuel was modeled in WIMS
- Similar unit cells were developed for Cross-section calculations of beryllium reflector, grid plate, reflecting water, irradiation positions, shim tray, control rod follower and control rod absorber material.

Methodology (Continued)

- 3-Dimensional Core modeling was performed in CITATION code using XYZ geometry
- Same reactor model was used for the analysis of HEU and proposed LEU cores of PARR-2
- Modeling in CITATION was achieved by conserving the total area of core and beryllium reflector

Fig. 2: Top View of Core

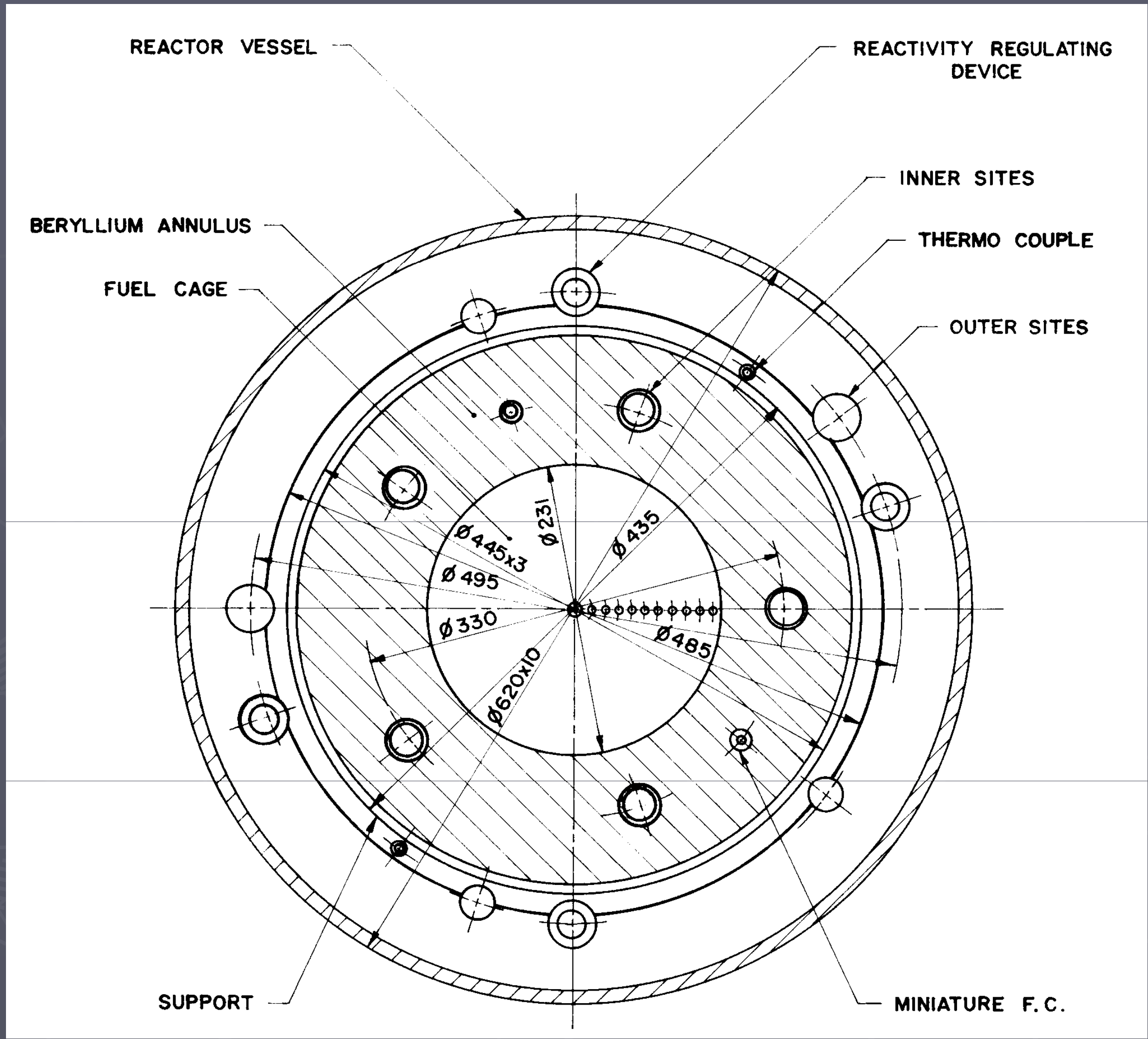
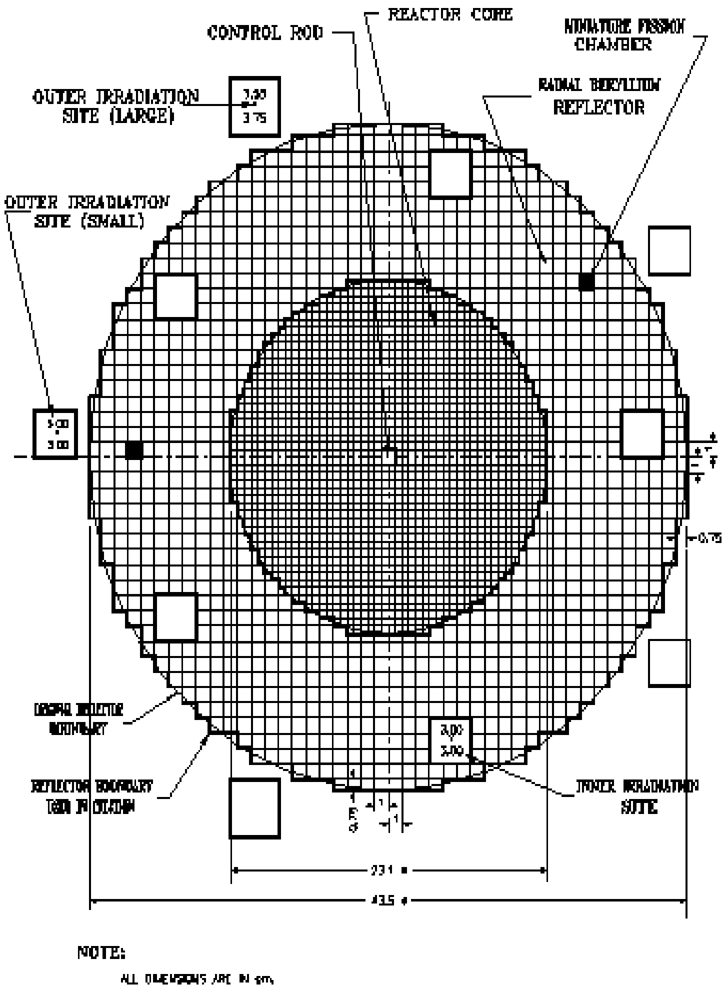


Fig. 3: Core Modeling in CITATION



Results

Table 1: Core Characteristics

Fuel Material	U-Density	U^{235} (g) in Core	Criticality Position (Rod cm out)	Excess Reactivity (mk)	Shut Down Margin (mk)	Control Rod Worth (mk)
HEU (U-Al alloy) 90.2% enriched Pin dia 5.5mm	0.92g/cm^3	995	9.0	4.046	-2.344	-6.39
LEU (Uo_2 fuel) 12.6% enriched Pin dia 5.5mm	9.35g/cm^3	1353	7.0	4.007	-1.43	-5.437
LEU (Uo_2 fuel) 12.3% enriched Pin dia 5.1mm	9.35g/cm^3	1264	7.0	4.160	-1.498	-5.658

Table 2: Average Values of Reactivity Coefficients

Fuel	Parameter	Temp. Range (^0C)	Average Value
HEU (U-Al) Pin dia 5.5mm 90.2 % Enriched	Moderator Temp.Coeff. (pcm/ ^0C)	0-100	-6.5291
	Doppler Coeff. (pcm/ ^0C)	0-400	-0.1397
	Void Coeff. (pcm/%void)	0-100	-337.67
LEU (UO2) Pin dia 5.5mm 12.6 % Enriched	Moderator Temp.Coeff. (pcm/ ^0C)	0-100	-3.9659
	Doppler Coeff. (pcm/ ^0C)	0-400	-1.3951
	Void Coeff. (pcm/%void)	0-100	-356.22
LEU (UO2) Pin dia 5.1mm 12.3 % Enriched	Moderator Temp.Coeff. (pcm/ ^0C)	0-100	-4.1985
	Doppler Coeff. (pcm/ ^0C)	0-400	-1.34239
	Void Coeff. (pcm/%void)	0-100	-348.355

Table 3: Flux at Inner Irradiation Sites and Fission Chambers

Fuel Material	Reactor Power (kw)	Flux at Inner Sites (# /cm²-sec)			Flux at Fission Chambers (# /cm²-sec)		
		Fast (0.821Mev -10Mev)	Epithermal (0.625ev-0.821Mev)	Thermal (0ev-0.625ev)	Fast (0.821Mev -10Mev)	Epithermal (0.625ev-0.821Mev)	Thermal (0ev-0.625ev)
(U-Al alloy) Pin dia 5.5mm 90.2% enriched	30	1.40E+11	5.72E+11	1.02E+12	1.46E+11	6.67E+11	1.09E+12
(Uo_2 fuel) Pin dia 5.5mm 12.6% enriched	30	1.35E+11	5.58E+11	9.36E+11	1.40E+11	6.50E+11	9.96E+11
	32	1.44E+11	5.95E+11	9.98E+11	1.49E+11	6.93E+11	1.06E+12
	33	1.48E+11	6.14E+11	1.03E+12	1.54E+11	7.15E+11	1.10E+12
(Uo_2 fuel) Pin dia 5.1mm 12.3% enriched	30	1.33E+11	5.49E+11	9.41E+11	1.39E+11	6.40E+11	1.00E+12
	32	1.42E+11	5.86E+11	1.00E+12	1.48E+11	6.82E+11	1.07E+12
	33	1.47E+11	6.04E+11	1.04E+12	1.52E+11	7.04E+11	1.10E+12

Table 4: Flux at Outer Irradiation Sites

Fuel Material	Reactor Power (kw)	Flux at Three Small Outer Sites (# /cm²-sec)			Flux at Two large Outer Sites (# /cm²-sec)		
		Fast (0.821Mev -10Mev)	Epithermal (0.625ev-0.821Mev)	Thermal (0ev-0.625ev)	Fast (0.821Mev-10Mev)	Epithermal (0.625ev-0.821Mev)	Thermal (0ev-0.625ev)
(U-Al alloy) Pin dia 5.5mm 90.2% enriched	30	3.20E+10	1.22E+11	5.30E+11	2.88E+10	1.08E+11	4.75E+11
(UO_2 fuel) Pin dia 5.5mm 12.6% enriched	30	3.08E+10	1.18E+11	4.98E+11	2.77E+10	1.05E+11	4.47E+11
	32	3.28E+10	1.26E+11	5.32E+11	2.95E+10	1.12E+11	4.77E+11
	33	3.38E+10	1.30E+11	5.48E+11	3.05E+10	1.16E+11	4.92E+11
(UO_2 fuel) Pin dia 5.1mm 12.3% enriched	30	3.05E+10	1.17E+11	4.96E+11	2.74E+10	1.04E+11	4.45E+11
	32	3.25E+10	1.25E+11	5.29E+11	2.93E+10	1.11E+11	4.75E+11
	33	3.35E+10	1.28E+11	5.46E+11	3.02E+10	1.14E+11	4.90E+11

Fig.4: Axial Thermal Flux Profile at Inner Irradiation Sites at 30kW

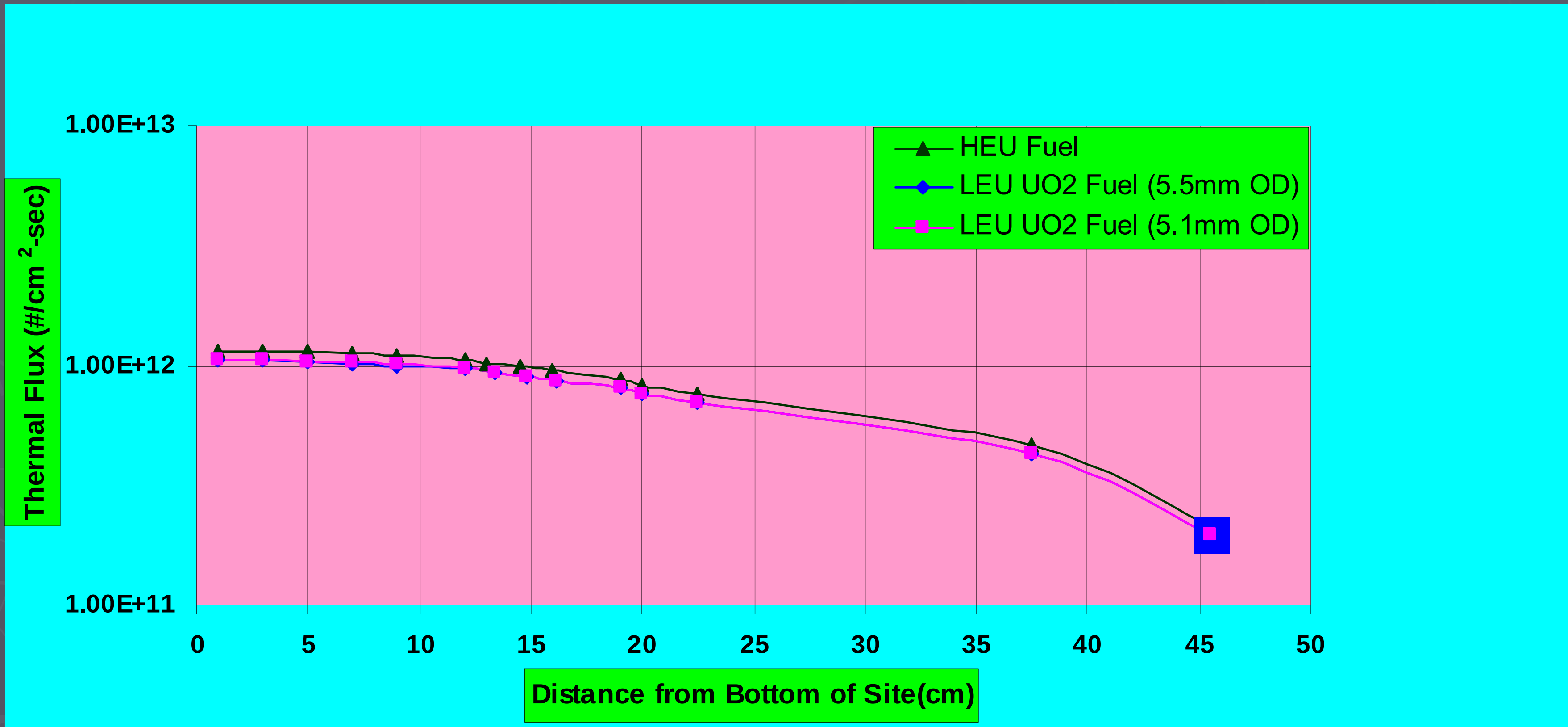
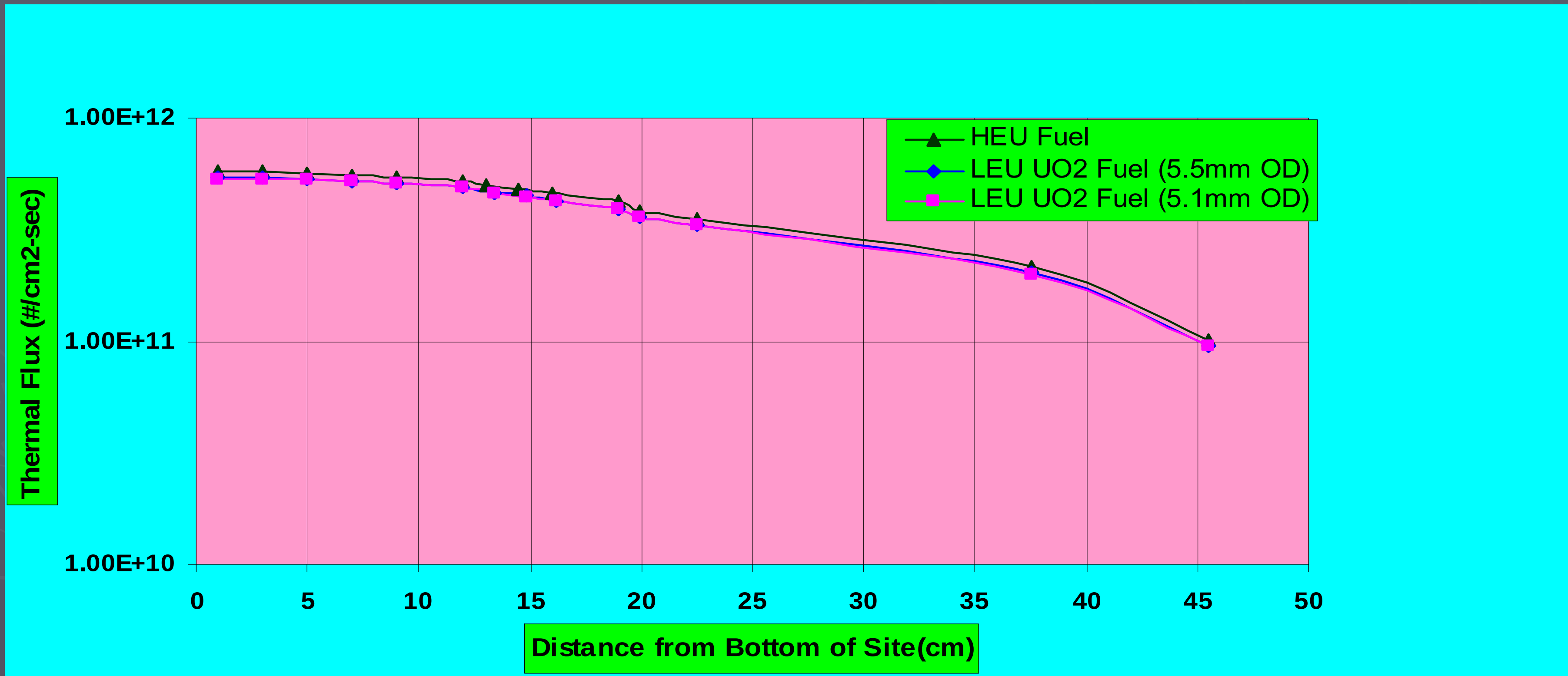


Fig.5: Axial Thermal Flux Profile at outer Irradiation Sites at 30kW



Conclusions

- Neutronic analyses of HEU (90.2% enriched) core through WIMS and CITATION gives results that are comparable to the experimental values. This validates the reactor model
- Analysis of LEU (UO_2 fuel pin dia 5.5mm with 12.6% enrichment and UO_2 fuel pin dia 5.1mm with 12.3% enrichment) core gives results, which qualify both LEU UO_2 fuel for future LEU core of MNSR
- Keeping in view the criterion of 4mk excess reactivity, LEU fuel with reduced pin dimensions should be 12.3% enriched while LEU fuel having consistent dimensions with HEU fuel should be 12.6% enriched
- Neutron flux for LEU fuel at irradiation sites is slightly lower for the reactor operating at 30 kW power. However 33kW operation of LEU fuelled reactor gives desired results.

Acknowledgement

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THANK YOU