THE IMPACT OF HEU TO LEU CONVERSION ON UTILIZATION OF NIRR-1

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OUTLINE OF PRESENTATION

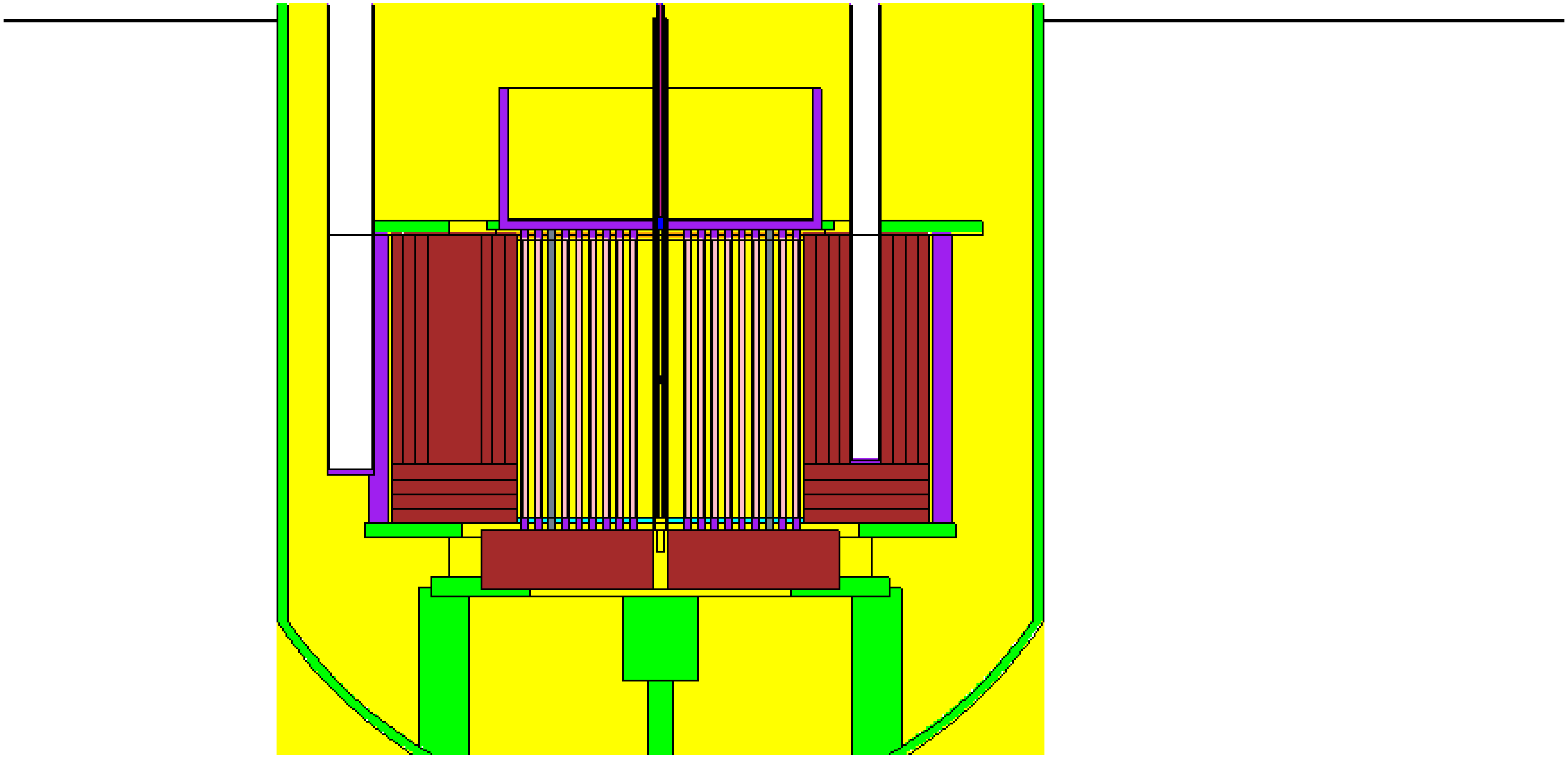
- INTRODUCTION
- MATERIALS AND METTHOD
- RESULTS AND DISCUSSION
- CONCLUSIONS
- ACKNOWLEDGEMENT

INTRODUCTION

- MNSRs are similar to SLOWPOKE, designed by CIAE, 4 in China, 2 decom & 5 outside
- NIRR-1 is 8th Commercial MNSR
- Core is HEU fueled (90%); rated 31kW, ^{235}U load =1 Kg
- SLOWPOKE & INHI have LEU cores
- LEU-conversion is feasible using UO_2 (~12.5%)
- Conversion meets safety standards except
- 10% reduction in n-flux in experimental channels
- Need to check impact of conversion on utilization
- Conversion is a thing of the moment, Utilization is a lifetime of reactor

INTRODUCTION

- Like SLOWPOKE, has high flux–to-power ratio
- Used mainly for NAA & limited RI production
- burn-up <1% neutron spec. parameters remain fairly constant
- Excellent tool for implementation of k0-INAA method
- Optimum utilization requires accurate knowledge of f & α parameters of irradiation channels
- Experimental method was used for current HEU core
- Theoretical/computational method was developed for the proposed LEU core



An MCNP geometric diagram of NIRR-1 axial plane showing one each of the inner and outer irradiation channels

PROFILE OF UTILIZATION-NIRR-1

- 90%-NAA
- 1% RI production for tracer application
- 3% production of radioactive sources for density measurements by gamma-ray transmission.
- 6% for teaching in nuclear engineering.

NAA

- 70% university research projects requiring chemical analysis: Pollution studies, Geochemistry, Archaeology, New materials, Methods developmt etc.
- 30% analysis contracts with industry, mostly for quality assurance

COMPARISON OF HEU & LEU CORES

	HEU	LEU
core diameter& height	230 mm	230 mm
Grid plate	Al	Zircaloy-4
number of fuel pins	347	348
fuel pin diam with cladding	5.5 mm	5.5 mm
fuel length	230 mm	230 mm
cladding	Aluminum	Zircaloy-4
fuel	U-Al alloy	UO_2
enrichment U-235	~90%	~12.5%
total mass of U-235	0.999 kg	1.392 kg
CR diam.	3.9 mm	4.5 mm

MATERIALS & METHOD

- RR of energy–dependent neutron flux density, φ(E), for reaction with σ(E) is given below as:
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- $$R = \int \varphi(E)\sigma(E)dE \qquad (1)$$
- For 640 energy group structure, energy bin is relatively small
$$R = \sum \varphi(E)\sigma(E)$$
- (2)
- The φ(E) data were obtained from the standard MCNP output
- σ(E) data for (n,γ) reaction retrieved from ENDF-VII data libraries

MATERIALS & METHOD

- R_{Cd} data were calculated for E_{Cd} = 0.55 eV

$$R_{CD} = \frac{\sum_{0}^{20MeV} \varphi(E)\sigma(E)}{\sum_{O.55eV}^{20MeV} \varphi(E)\sigma(E)}$$

MATERIALS & METHOD

- f & α parameters are defined as follows:
- $$f = Q_{O,i}(\alpha).(R_{Cd,r} - 1)$$
- where, i is the monitor with well known Q_O value.
- RR of N monitors used to calculate R_{Cd}.
- R_{Cd} data used to calculate f and α based on plot
- of versus $$\log \frac{\overline{E}_{r,i}^{-\alpha}}{(R_{Cd,i} - 1)Q_{O,i}(\alpha)} \quad (4)$$
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$$\log E_{r,i}$$

MATERIALS & METHOD

- By an iterative procedure for a set of N monitors using EXCEL utilities
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$$\alpha + \frac{\sum_{i=1}^{N}\left[\left(\log \overline{E}_{r,i} - \frac{\sum_{i=1}^{N}\log \overline{E}_{r,i}}{N}\right)\left(\log \frac{\overline{E}_{r,i}^{-\alpha}}{(R_{Cd,i}-1)Q_{O,i}(\alpha)} - \frac{\sum_{i=1}^{N}\log \frac{\overline{E}_{r,i}^{-\alpha}}{(R_{Cd,i}-1)Q_{O,i}(\alpha)}}{N}\right)\right]}{\sum_{i=1}^{N}\left(\log \overline{E}_{r,i} - \frac{\sum_{i=1}^{N}\log \overline{E}_{r,i}}{N}\right)^2} = 0$$

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- α value is found as the root of the equation
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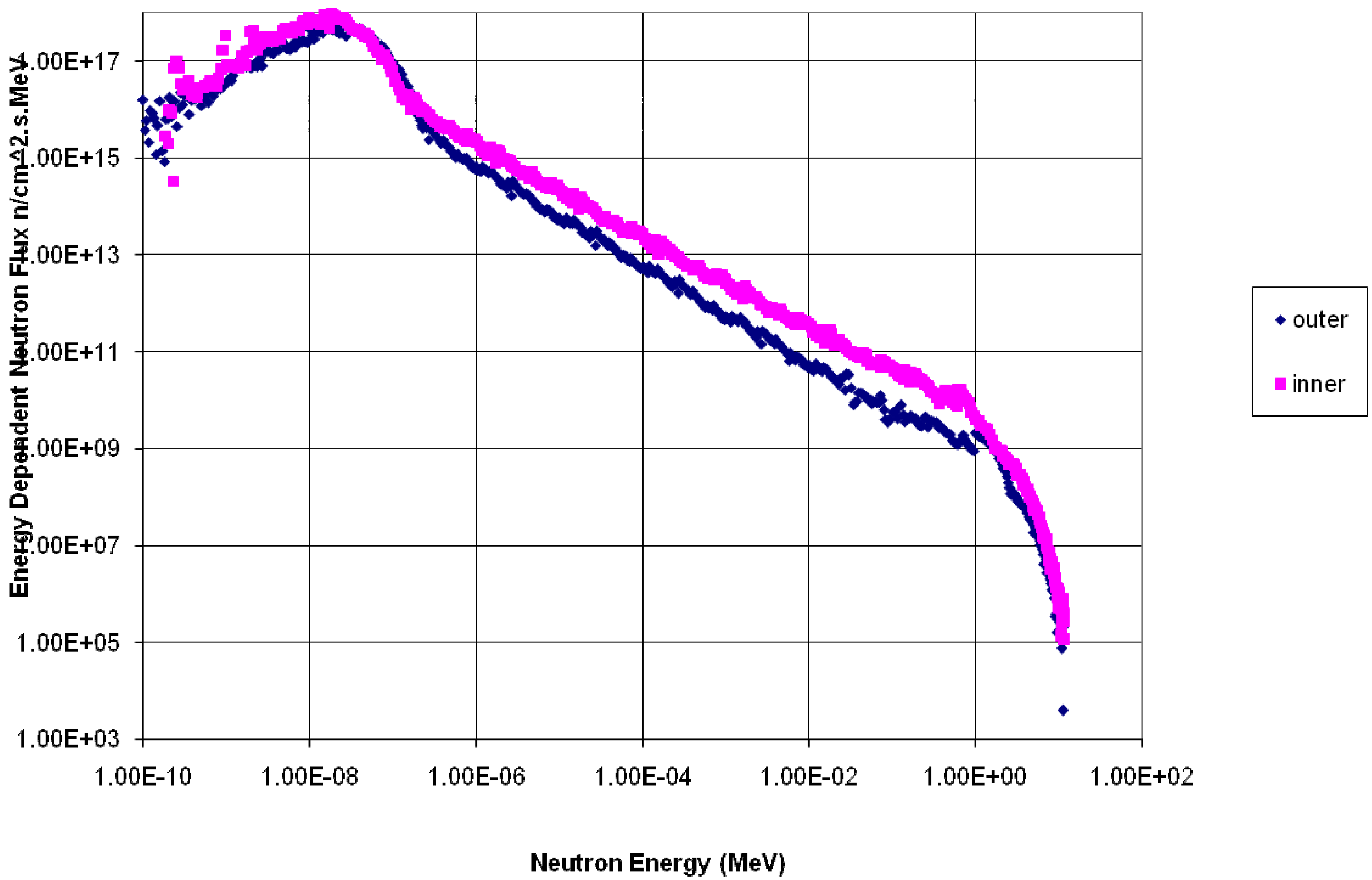
RESULTS and DISCUSSION

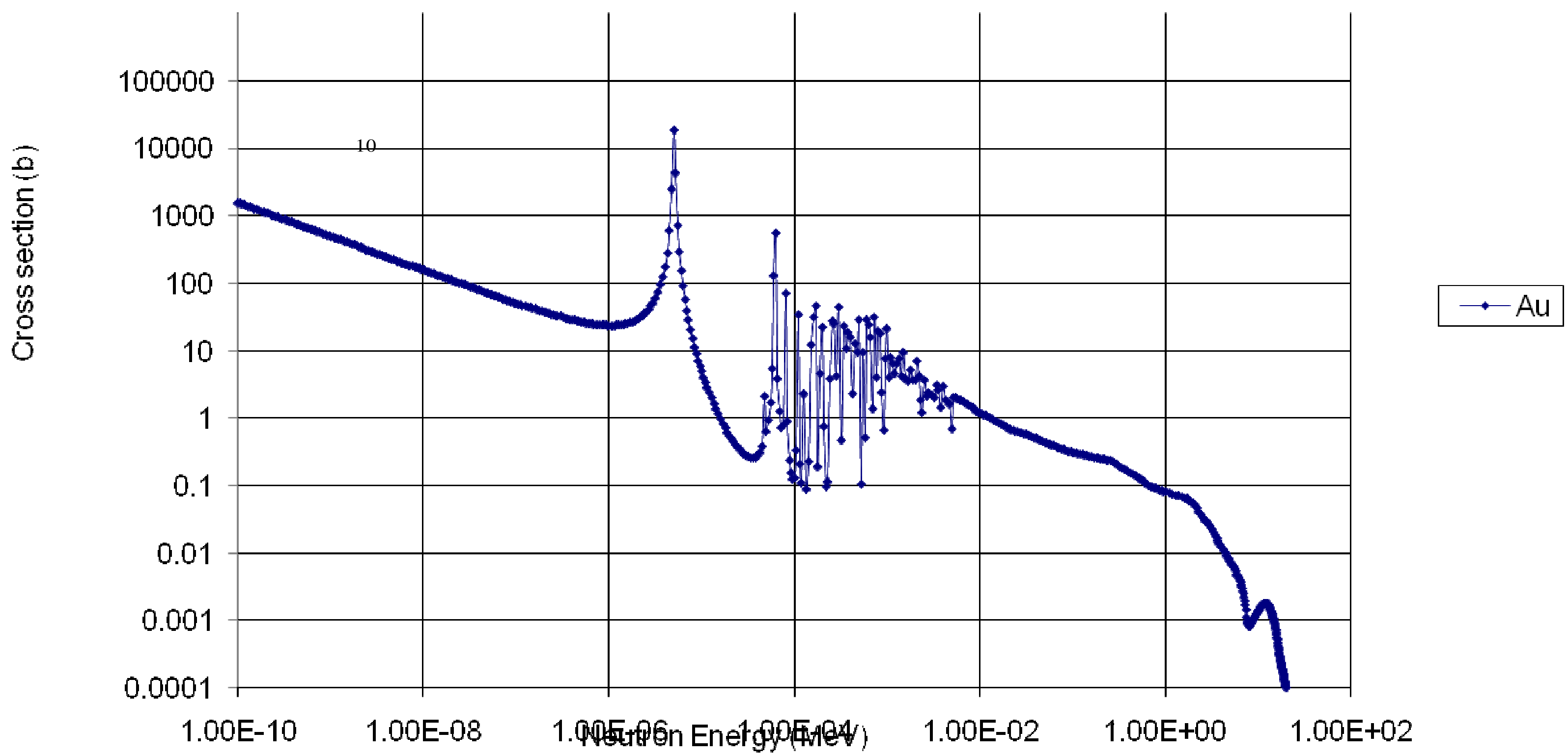
- Neutron spectral distributions by MNCP in Fig. 1
- Neutron flux inner channels show pronounced fast neutron components due to compact nature of cores & proximity to cores.
- $\sigma(E)$ data for (n,γ) from ENDF-VII libraries
- For $^{197}Au(n,\gamma)^{198}Au$, are shown in Fig 2
- R_{Cds} (Table 1) deduced using eq. 4 are substituted in eqs. 4 and 5 to determine f and α values (Table 2)
- Experimental method has been used for HEU core of NIRR-1 & others (Table 3)

MCNP Simulated Energy Dependent Neutron Flux for NIRR-1



Comparison of MCNP simulated energy dependent neutron flux distributions in an inner and an outer irradiation channels of NIRR-1

Cross section for 197Au(n,γ)^{198}Au Reaction



Comparison of measured & calculated RCd

Reaction	Inner		outer	
	Measured	Calculated	Measured	Calculated
$^{197}Au(n,\gamma)^{198}Au$	2.12±0.02	2.04±0.07	4.27±0.06	4.12±0.11
$^{238}U(n,\gamma)^{239}U$	-	1.15±0.03	1.51±0.04	1.49±0.07
$^{59}Co(n,\gamma)^{60}Co$	-	8.05±0.85	-	26.08±2.11
$^{232}Th(n,\gamma)^{233}Th$		2.02±0.06	-	4.68±0.16

Measured & calculated neutron spectrum data for NIRR-1 HEU & LEU cores

•Parameters		•α		•f	
		•Expt.	•MCNP	•Expt.	•MCNP
•HEU	•Inner	•-0.052±0.002	•-0.056±0.004	•19.2±0.5	•17.2±1.1
	•Outer	•0.029±0.003	•0.021±0.005	•48.3±3.3	•46.7±2.9
•LEU	•Inner	•-	•-0.047±0.006	•-	•14.7±0.7
	•Outer	•-	•0.028±0.004	•-	•43.7±2.7

A Comparison of f & α for SLOWPOKE & MNSR

Facility	Inner irradiation channel		Outer irradiation channel	
	f	α	f	α
MNSR, NIRR-1; Zaria, Nigeria, 90% ^{235}U	19.2±0.5	-0.052±0.002	48.3±3.3	+0.029±0.003
MNSR, GHARR-1; Accra, Ghana, 90% ^{235}U	18.8	-0.104	49	-0.0261
MNSR, PROTYPE, Beijing, China, 90% ^{235}U	19.8	-0.009	58.5	+0.023
SLOWPOKE-2, DUSR, Halifax, Canada, 20% ^{235}U	Site #2: 18.8	-0.0425	57.1	-0.0098
	Site #3: 18.9	-0.0422		
SLOWPOKE-2, Ecole Polytechnic, Montreal, Canada, 20% ^{235}U	19.8	-0.052	55.4	-0.006

RESULTS and DISCUSSION

- Measured data for HEU core agree well with calculated data
- Indicating the suitability of the computational method
- Calculated data for LEU in the Table are identical with the current HEU core.
- f data for LEU core in expt channels slightly lower HEU core
- Indicating hardening of the neutron spectra for LEU core due to increase of ^{238}U composition
- Thus, the impact of LEU conversion of NIRR-1 on neutron spectrum parameters for NAA is minimal
- Because the core configuration of the current HEU core is similar to the proposed LEU core except for the minor changes to the CR and guide tube.

CONCLUSIONS

- A method for determination of neutron spect parameters has been developed
- Good agreement found betw measured & calculated data for HEU core
- Neutron spect data were calculated for NIRR-1 LEU core
- For LEU neutron spect data are similar for both cores
- Conversion of MNSR is feasible with no adverse effects on safety & performance

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