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Analysis of the Fourth Zeus Critical Experiment

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The first four Zeus experiments were designed to test the adequacy of ^{235}U cross sections in the intermediate-energy range. Detailed descriptions of the first three experiments in the series have been presented previously. This presentation focuses primarily upon the fourth experiment in the series, which has a harder spectrum than any of the previous three.

The MCNP5 Monte Carlo code was used to construct a detailed model of the experiment. Results from calculations with a number of different MCNP nuclear data libraries are presented. These results are discussed in conjunction with those from the analyses of the previous three experiments. It is shown that ENDF/B-V produces small, nearly constant biases for all four cases. In contrast, ENDF/B-VI and preliminary ENDF/B-VII libraries produce a consistent upward trend as the spectra of the experiments harden. This pattern suggests that the ENDF/B-VI and preliminary ENDF/B-VII cross sections contain a small energy-dependent bias in the intermediate-energy range.

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OVERVIEW OF PRESENTATION

Description of the fourth Zeus experiment

Comparison of MCNP5 results using ENDF/B-V, ENDF/B-VI, and preliminary ENDF/B-VII nuclear data libraries

Comparison with results from previous Zeus experiments

Conclusions

The Fourth Zeus Critical Experiment

The Zeus experiments were designed to test the adequacy of ^{235}U cross sections in the intermediate-energy range

The cylindrical core of the Zeus experiments contains alternating regions of highly enriched uranium (HEU) and graphite

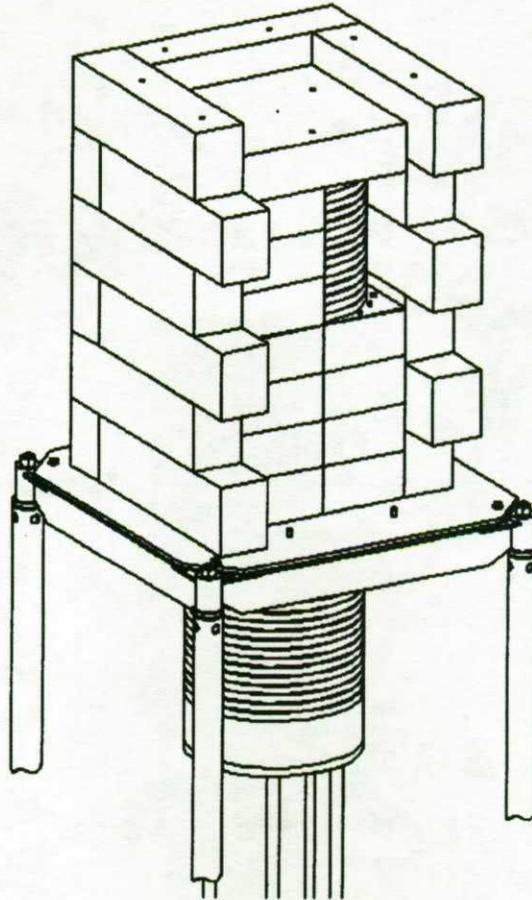
The core is enclosed inside a copper reflector with rectangular external sides

The Zeus experiments were constructed on the Comet vertical assembly machine at the Los Alamos Critical Experiments Facility (LACEF)

The fourth Zeus experiment achieved criticality on November 15, 2001

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SCHEMATIC OF THE ZEUS DESIGN



DETAILS OF THE FOURTH ZEUS EXPERIMENT

Core contains 9 nearly identical units, each of which has a central HEU platter (0.118 inch thick) sandwiched between an upper and lower graphite platter (each 0.3966 inch thick, on average)

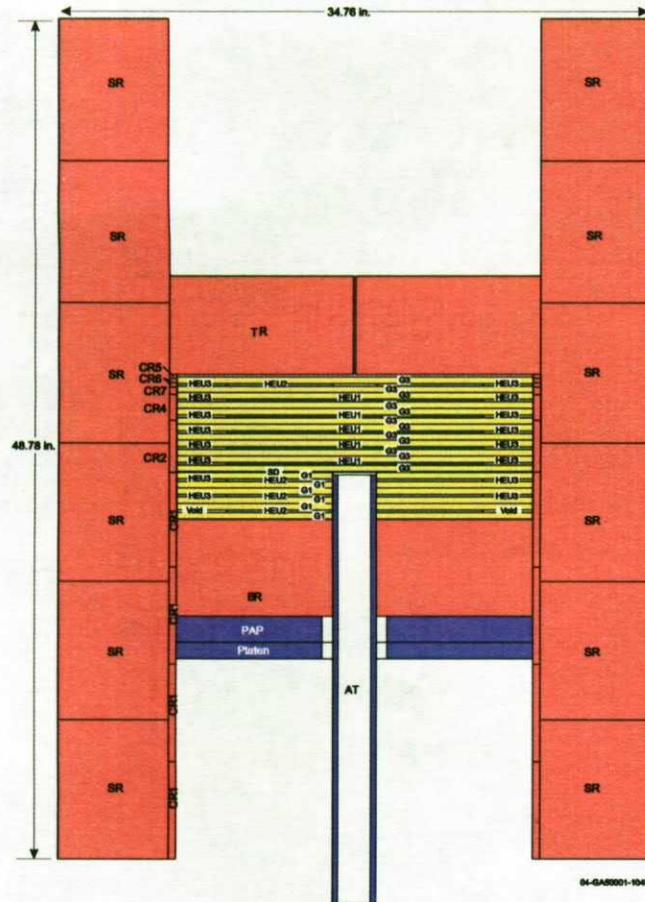
Outer diameter of the platters is 21 inches, except for the bottom HEU platter which has an outer diameter of 15 inches

Distance from one side of the reflector to the other is 34.76 inches

Top and bottom reflectors are 5.68 inches thick

A period of 17.328 seconds was measured
(~29.8¢ supercritical $\Rightarrow k_{\text{eff}} \cong 1.0019$)

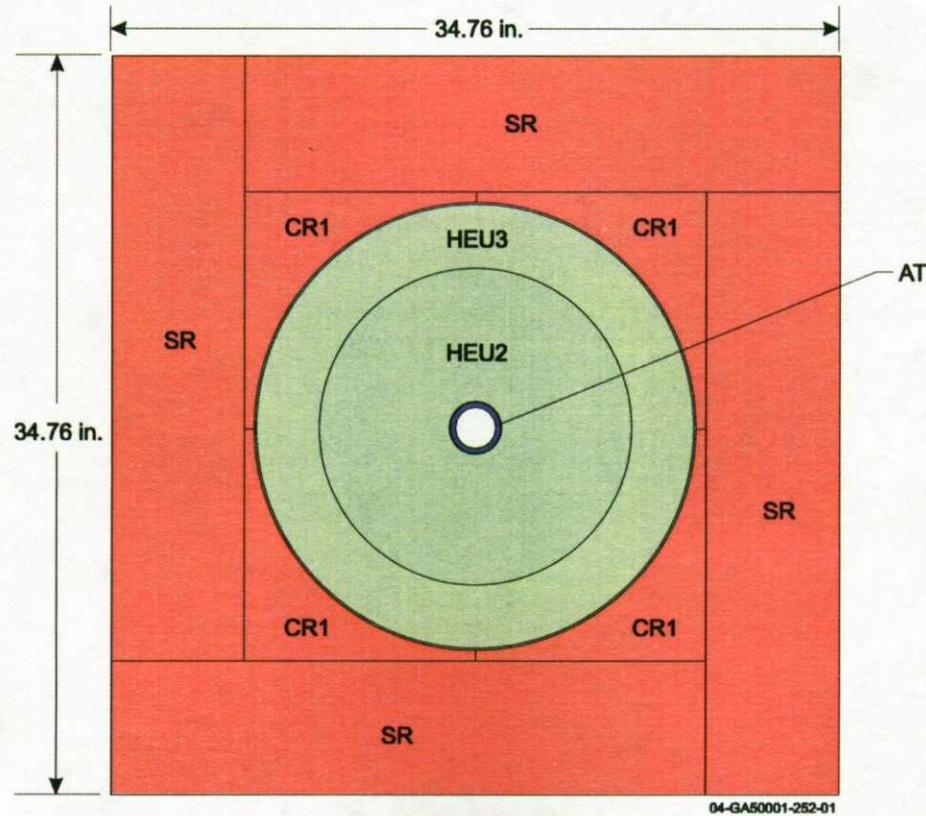
VERTICAL SLICE THROUGH FOURTH ZEUS CORE



- AT = Alignment Tube
- BR = Bottom Reflector
- CR = Corner Reflector
- G = Graphite Platter
- HEU = HEU Platter
- PAP = Platen Adapter Plate
- SD = Diaphragm
- SR = Side Reflector
- TR = Top Reflector

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HOIZONTAL SLICE THROUGH BOTTOM PORTION OF FOURTH ZEUS CORE



MCNP5 CALCULATIONS

Each calculation employed 650 generations with 10,000 neutrons per generation

Results from first 50 generations were excluded from the statistics

Results therefore are based on 6,000,000 active histories for each case

Calculations were performed with each of three sets of continuous-energy nuclear data libraries:

ENDF/B-V (.50c, .55c)

ENDF/B-VI (ENDF66 + ACTI)

Preliminary ENDF/B-VII (T16_2003 + ORNL resonance parameters for uranium isotopes, ENDF/B-VI for all others)

RESULTS FOR k_{eff} AND FISSION FRACTION

Source	k_{eff}	Δk
Measurement	1.0019 ± 0.0008	—
Preliminary ENDF/B-VII	1.0038 ± 0.0003	0.0019 ± 0.0009
ENDF/B-VI	1.0050 ± 0.0003	0.0031 ± 0.0009
ENDF/B-V	1.0011 ± 0.0003	-0.0008 ± 0.0009

Source	Fission Fraction (%)		
	Fast	Intermediate	Thermal
Preliminary ENDF/B-VII	50.63	49.37	0
ENDF/B-VI	50.45	49.55	0
ENDF/B-V	52.16	47.84	0

CONCLUSIONS FOR FOURTH ZEUS EXPERIMENT

The fourth Zeus experiment satisfies its design objective by producing a very hard intermediate / soft fast spectrum

ENDF/B-V, ENDF/B-VI, and preliminary ENDF/B-VII nuclear data libraries all produce acceptable results for the fourth Zeus experiment, although both the ENDF/B-VI and ENDF/B-VII results differ from the measured value by more than two standard deviations

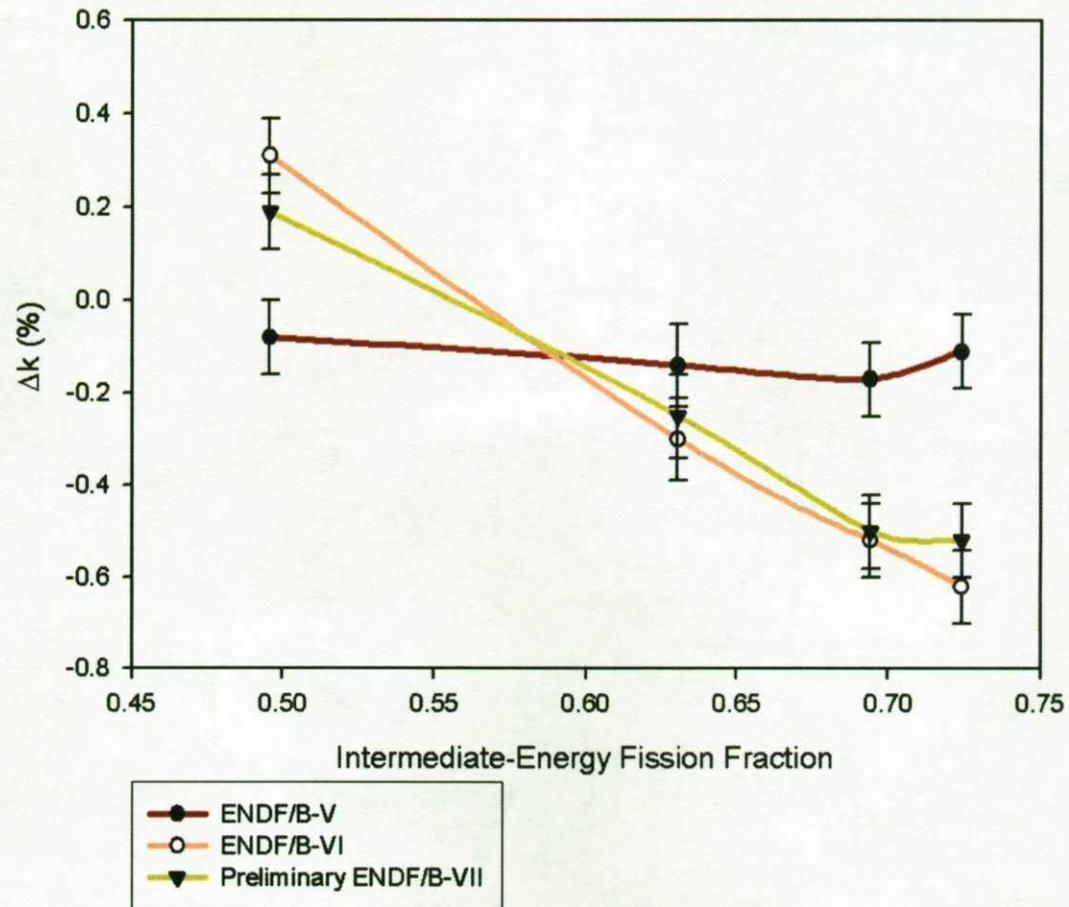
CHARACTERISTICS OF THE FIRST FOUR ZEUS EXPERIMENTS

Experiment	HEU Platters	Graphite Platters	Critical Mass (kg U)	C : ²³⁵ U
1	10	79.5**	126.5	51.2 : 1
2	9	54	112.8	38.6 : 1
3	9*	36	106.6	27.4 : 1
4	9*	18	106.8	13.6 : 1

*Bottom platter has outer radius of 15 inches rather than 21

**Core contained 79 full-height graphite platters, as well as a half-height graphite platter and a very thin stainless steel platter used as a shim

RESULTS FOR k_{eff}



CONCLUSIONS FOR ZEUS EXPERIMENTS

ENDF/B-V produces a small, essentially constant bias relative to the measured values of k_{eff}

ENDF/B-VI and preliminary ENDF/B-VII exhibit sizeable swings in their bias ($\sim 0.010 \Delta k$ for ENDF/B-VI, $\sim 0.0075 \Delta k$ for ENDF/B-VII)

Biases for ENDF/B-VI and preliminary ENDF/B-VII become more positive as their spectra harden

This behavior suggests a spectrum-dependent bias in the ENDF/B-VI and preliminary ENDF/B-VII cross sections within the upper intermediate-energy range

Detailed evaluation of the four Zeus experiments moderated by graphite appears as HEU-MET-INTER-006 in the 2004 edition of the *International Handbook of Evaluated Criticality Safety Benchmark Experiments*