UH_3 CRITICAL ASSEMBLIES

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ABSTRACT

In 1987 the COMET universal critical assembly machine at Los Alamos Scientific Laboratory was used to perform a series of seven Uranium-Hydride critical experiments. Two 2-cm and four 3-cm thick disks of canned UH_3 powder were used in the experiments. The cans were 6-inch diameter. The experiments had outer reflectors of depleted uranium (D38) and inner reflectors of D38, beryllium, and SAE 1020 steel. The inner reflector was about 1-inch thick and the outer reflector was 2-inches thick, radially and axially. Each assembly was critical with a positive period. The delayed critical condition was found by extrapolation of the slightly supercritical data. Good agreement was observed between calculation and experiment. All seven assemblies targeted the intermediate energy range with more than 50% of the fissions occurring in the range between 0.625 eV and 100 keV.

1.0 INTRODUCTION

The COMET universal critical assembly machine was used to perform a series of seven Uranium-Hydride critical experiments. A summary of the experimental results is shown in Table I. The experiments had outer reflectors of depleted uranium (D38) and inner reflectors of D38, Be, and Fe. The seven experiments are described in detail in Reference 1. All seven assemblies were critical with a positive period. The delayed critical separation distance was found by extrapolating the positive period data to delayed critical.

There are six nominal 6.0-inch diameter UH_3 disks (actually 5.944-inch), four of which are 1.2 inches and two are 0.8 inches thick. The disks are canned in 0.010-inch thick stainless steel. There is a lip at the top of each can, to facilitate a weld seal, which results in a 0.0625-inch void that was filled with stainless steel plates for proper stacking alignment.

Photographs of the UH_3 experiment on the COMET assembly are shown in Figures 1 and 2. Figure 1 shows the assembly with the UH_3 in place. Also seen in the photograph are the lifting mechanism, support columns, detection equipment, and surrounding environment. Note that the movable part of the UH_3 assembly is spaced 3.5 inches above the Al top of the lifting piston to reduce neutron return from the raising mechanisms. Figure 2 shows a doubly reflected assembly. The moveable components are stacked on a 0.5-in. thick Al support plate and contained by a steel cylinder with 6.044-inch inner diameter and 6.064-inch outer diameter. The UH_3 disks and the movable parts of the assembly are stacked as follows:

1) the aluminum support plate,
2) the lower depleted uranium (D38) outer reflector,
3) the lower D38, Be, or Fe inner reflector,
4) the lower 2-cm can of UH_3,
5) the lower 3-cm can of UH_3,
6) the Al spacer rings, the height of which are varied,
7) the upper 3-cm can of UH_3,
8) the upper 2-cm can of UH_3,
9) the upper inner reflector, and
10) the upper outer reflector.

Nuclear densities of the constituents of the six cans of uranium hydride used in the calculational models are given in Table II. Nuclear densities of the other constituents used in the models are also given in Table II.

The models chosen for the seven UH_3 experiments are symmetrical cylindrical arrangements of the component parts. Every region is a cylinder or an annulus centered on a central vertical axis. The calculational models are shown in Figure 3. The dimensions were given as a mixture of cm and inches by the experimentalists. All dimensions were converted to cm in Figure 3, the calculational models.

2.0 RESULTS

The calculated results for the seven experimental assemblies are shown in Table III. The experimental uncertainty in k_{eff} ranged between ±0.0031 and ±0.0041. Most of the calculated results show good agreement with the experimental results. Experiment 6 calculates slightly low. The reason is unknown at this time.

The neutron leakage spectrum was measured for the Be reflected UH_3 assembly. A steel collimator with brass inserts was placed above the critical assembly. The neutron leakage measurements were made at low energies (0.2 to 1000 keV) with a proton-recoil detector, and at high energies (1.0 to 10.0 MeV) with a liquid scintillator. The data shown in Figure 4 have not been normalized to fission power in the core.

The calculated neutron spectra for all seven assemblies are shown in Figure 5. The neutron spectra were calculated using TWODANT with ENDF/B-V 44 group cross sections.

3.0 CONCLUSION

The seven uranium-hydride critical assemblies have intermediate neutron spectra with between 50.2% (experiment 6) and 70.9% (experiment 4) of the fissions occurring between 0.625 eV and 100keV. The calculational results showed good agreement with the experimental results.

4.0 REFERENCES

1. R. J. LaBauve, R. W. Brewer, and R. D. Mosteller, "Reflected Uranium-Hydride Critical Assembly," International Handbook of Evaluated Criticality Safety Experiments, HEU-COMP-INTER-003, Nuclear Energy Agency, Organization for Economic Co-Operation and Development (not yet published).

Table I. Summary of Experimental Results

Experiment Number	Outer Reflector	Inner Reflector	UH_3 can stacking (bottom to top)	Critical separation (inches)
1	D38	D38	A-II-I-B	0.8835
2	D38	Be	A-II-I-B	1.3905
3	D38	Be	A-II-I-B	1.4588
4	D38	Fe	A-II-I-B	0.5406
5	none	Be	I-IV-III-II	0.3703
6	none	D38	I-IV-III-II	0.2173
7	none	D38	B-A-III-II-I	0.4022

Table II. Nuclear Densities of All Model Constituents (atoms/barn-cm)

Isotope	"A"	"B"	"I"	"II"	"III"	"IV"
H	$7.2639x10^{-2}$	$7.3240x10^{-2}$	$7.3871x10^{-2}$	$7.5396x10^{-2}$	$6.9913x10^{-2}$	$7.2725x10^{-2}$
O	$6.0377x10^{-4}$	$4.9360x10^{-4}$	$8.5553x10^{-4}$	$5.6703x10^{-4}$	$4.8424x10^{-4}$	$6.3713x10^{-4}$
C	$9.6792x10^{-5}$	$1.2804x10^{-4}$	$1.4562x10^{-4}$	$1.9943x10^{-4}$	$1.5288x10^{-4}$	$1.5539x10^{-4}$
N	$4.4263x10^{-4}$	$2.3019x10^{-4}$	$1.3593x10^{-3}$	$1.9699x10^{-4}$	$2.0644x10^{-4}$	$2.4400x10^{-4}$
Fe	$8.9855x10^{-5}$	$6.7706x10^{-5}$	$3.6677x10^{-5}$	$3.8266x10^{-5}$	$1.0366x10^{-4}$	$2.0413x10^{-4}$
Au	$3.0333x10^{-4}$	$3.0012x10^{-4}$	$3.7472x10^{-4}$	$3.6162x10^{-4}$	$3.3764x10^{-4}$	$3.4333x10^{-4}$
^{234}U	$2.4557x10^{-4}$	$2.5226x10^{-4}$	$2.5279x10^{-4}$	$2.5484x10^{-4}$	$2.5651x10^{-4}$	$2.4873x10^{-4}$
^{235}U	$2.3030x10^{-2}$	$2.2951x10^{-2}$	$2.3450x10^{-2}$	$2.3409x10^{-2}$	$2.3550x10^{-2}$	$2.2939x10^{-2}$
^{236}U	$1.0085x10^{-4}$	$1.0055x10^{-4}$	$1.1027x10^{-4}$	$1.0757x10^{-4}$	$1.0829x10^{-4}$	$1.0390x10^{-4}$
^{238}U	$1.3124x10^{-3}$	$1.3058x10^{-3}$	$1.3421x10^{-3}$	$1.3371x10^{-3}$	$1.3584x10^{-3}$	$1.3117x10^{-3}$
Reflectors/other materials						
Depleted Uranium						
^{235}U	$9.3760x10^{-5}$					
^{238}U	$4.7969x10^{-2}$					
Beryllium						
^{9}Be	$1.2295x10^{-1}$					
Stainless Steel, SAE 1020						
Fe	$6.9267x10^{-2}$					
C	$5.4977x10^{-4}$					
^{55}Mn	$1.6969x10^{-4}$					
Iron						
Fe	$8.5834x10^{-2}$					
Aluminum						
^{27}Al	$6.0239x10^{-2}$					

Table III. Calculational Results

Experiment Number	Benchmark k_{eff}	KENO 44-group, ENDF/B-V	MCNP4B2 ENDF/B-V	MCNP4XS ENDF/B-VI.4	TWODANT, ENDF/B-V
1	1.0000 ± 0.0037	1.0025 ± 0.0022	1.0070±0.0008	1.0033±0.0008	0.9998
2	1.0000 ± 0.0041	1.0050 ± 0.0021	1.0085±0.0008	1.0060±0.0008	1.0089
3	1.0000 ± 0.0039	1.0060 ± 0.0023	1.0080±0.0008	1.0067±0.0008	1.0070
4	1.0000 ± 0.0041	0.9961 ± 0.0020	1.0040±0.0008	1.0028±0.0008	0.9943
5	1.0000 ± 0.0036	0.9990 ± 0.0022	0.9960±0.0008	0.9979±0.0008	0.9973
6	1.0000 ± 0.0031	0.9857 ± 0.0022	0.9949±0.0008	0.9918±0.0008	0.9852
7	1.0000 ± 0.0039	0.9935 ± 0.0024	0.9986±0.0008	0.9938±0.0008	0.9928

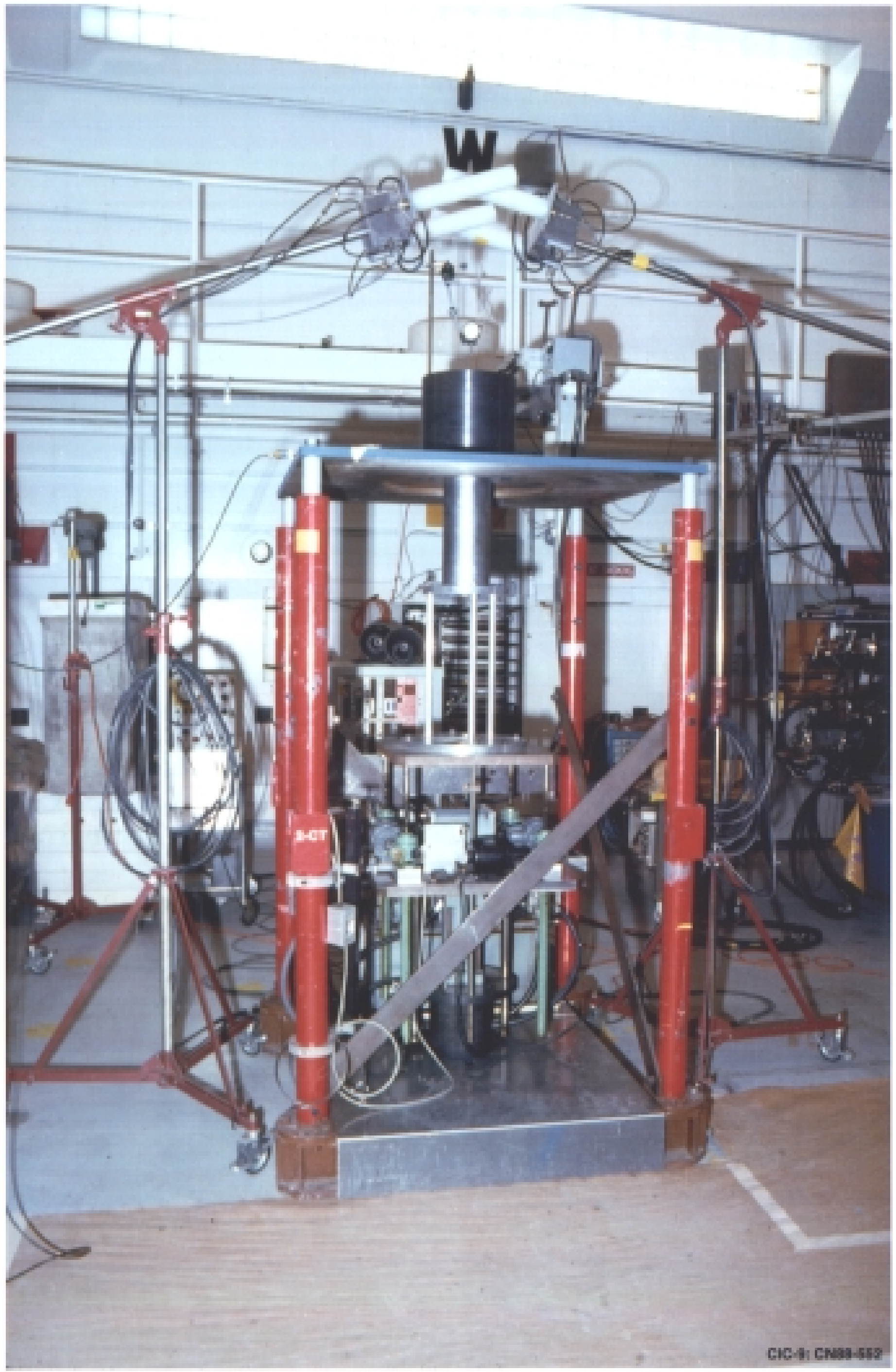

Figure 1: Photograph of the UH_3 Experiment

Figure 2: Photograph of a Doubly Reflected Assembly

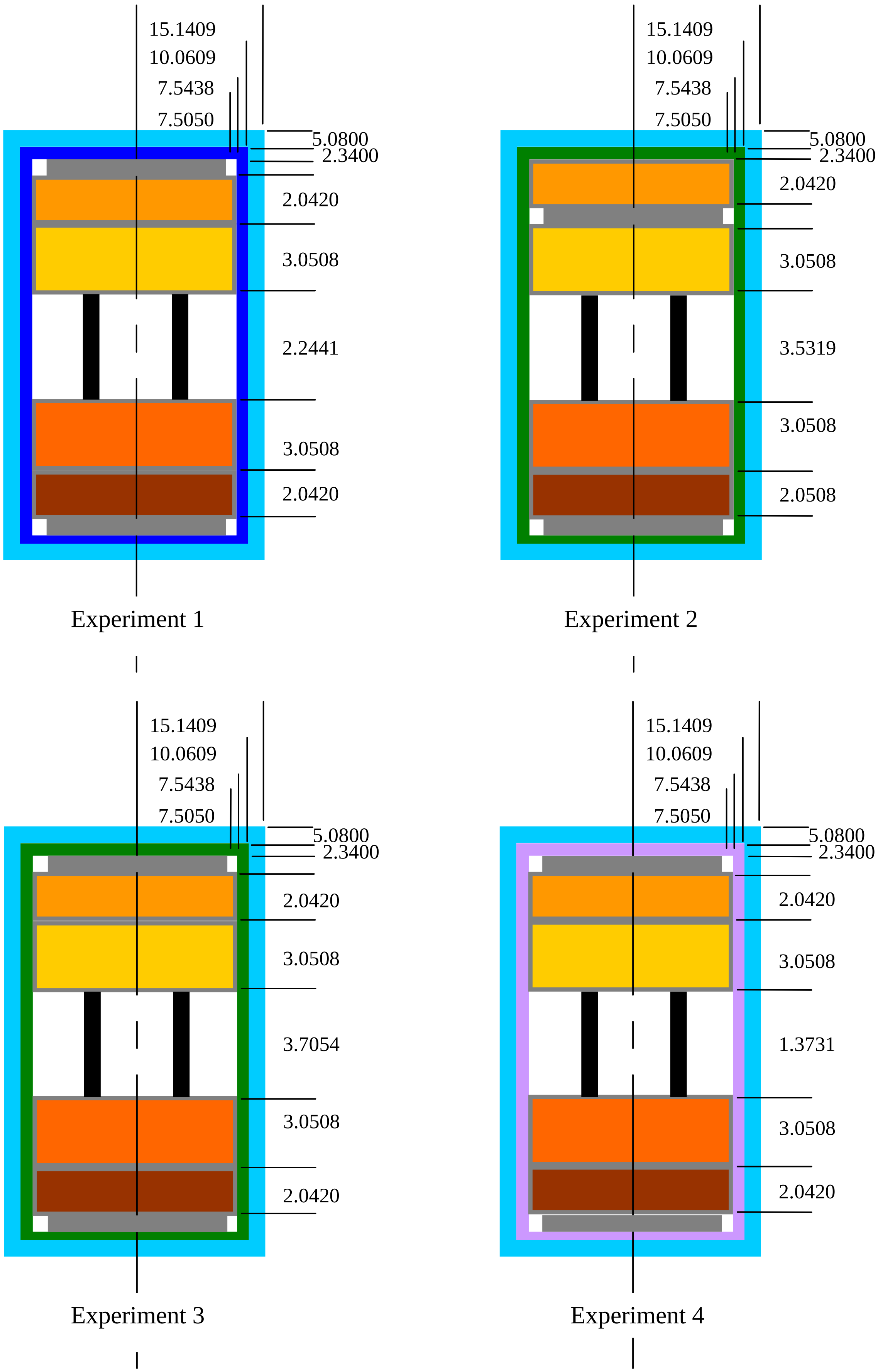

Figure 3: Schematic of the Calculational Models

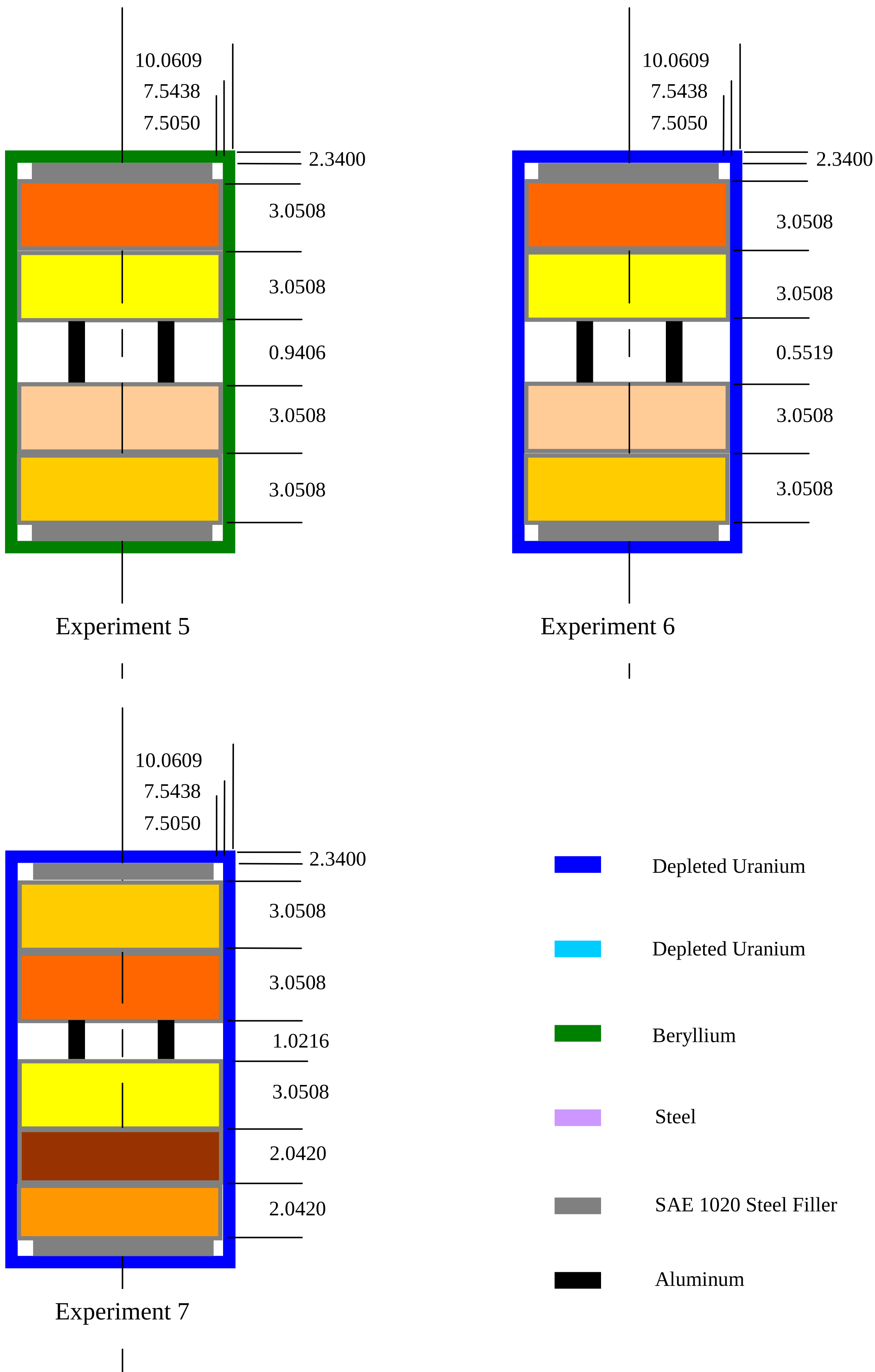

Figure 3: Schematic of the Calculational Models (continued)

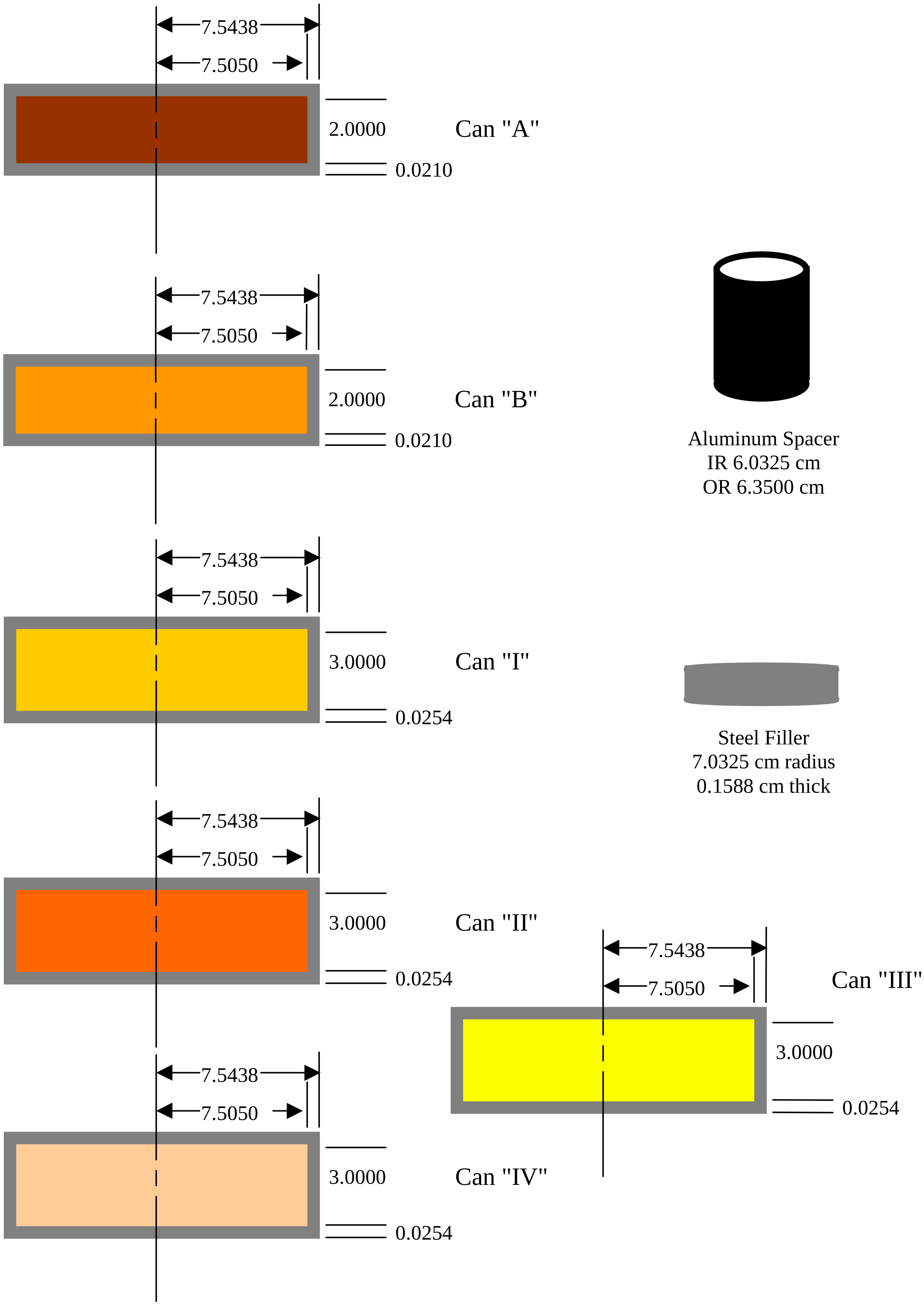

Figure 3: Schematic of the Calculational Models
(continued)

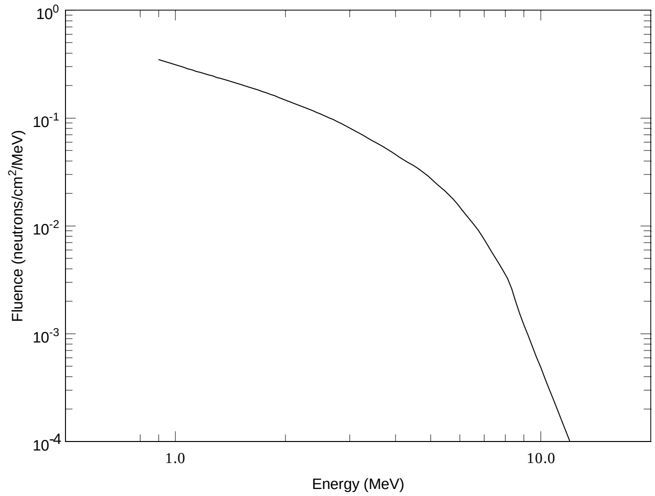

Figure 4: Measured Neutron Leakage Spectrum for the Be Reflected Assembly

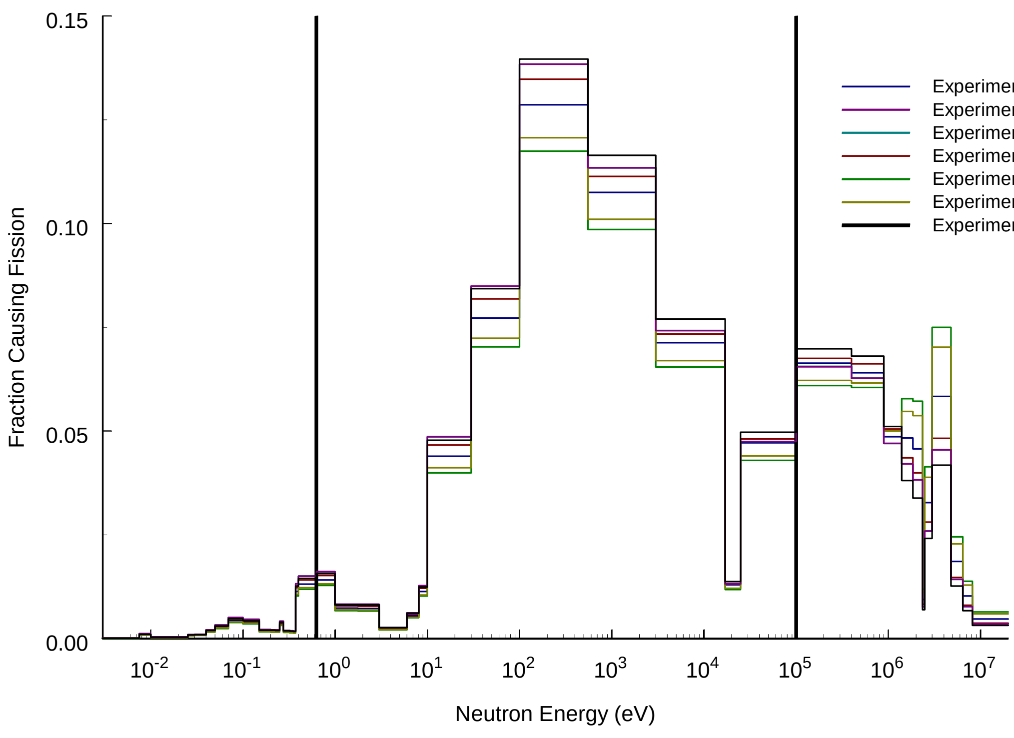

Figure 5: Calculated Neutron Spectra