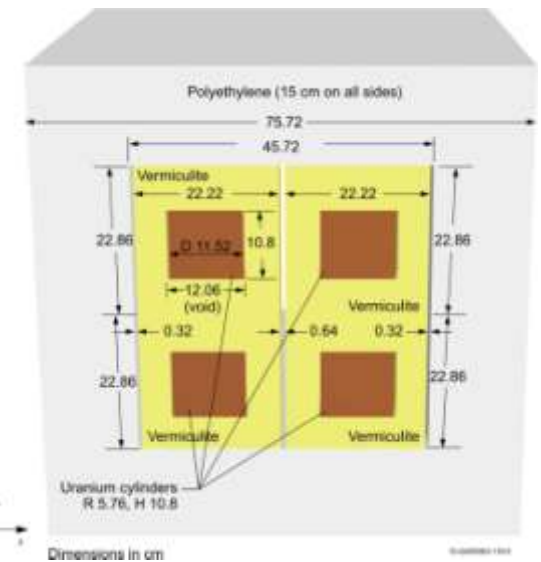
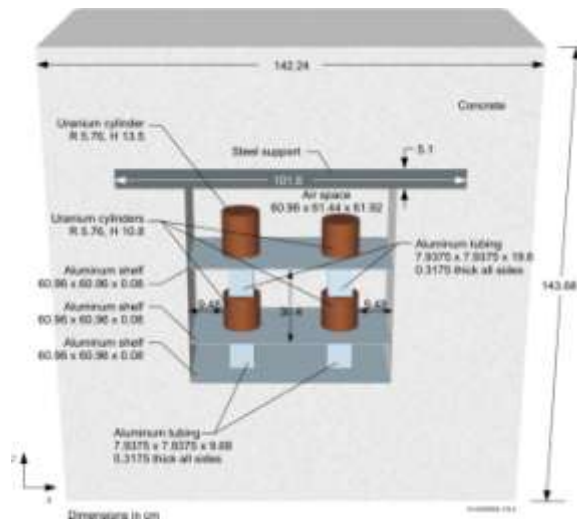


Benchmark Evaluation of HEU Cylinders Reflected by Concrete and Cylinders Separated by Vermiculite

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ANS Winter Conference

November 9, 2010



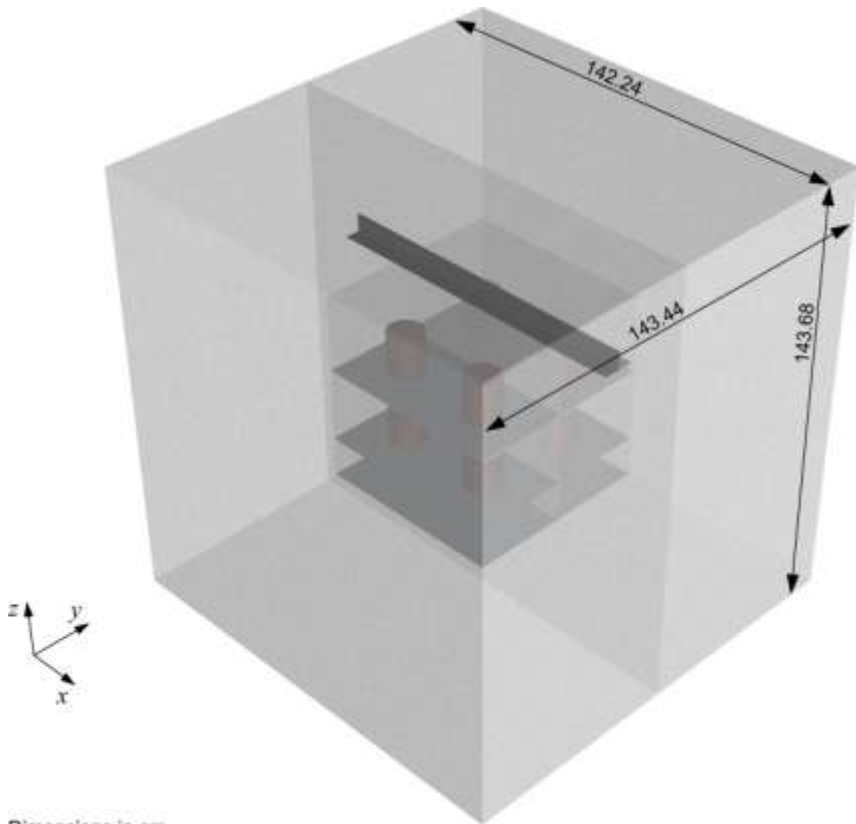
Benchmark Evaluations of HEU Cylinders

- HEU-MET-FAST-054
 - Highly Enriched Metal Cylinders Reflected by Concrete
 - 2x2x2 Array of HEU Cylinders
 - Reactivity changes made with smaller cylinders or small plates
 - Varied thickness of concrete reflector
 - Determined to be unacceptable
- HEU-MET-FAST-056
 - Highly Enriched Metal Cylinders Separated by Vermiculite and Reflected by Polyethylene
 - 2x2x2 Array of same HEU Cylinders as used for HMF054
 - Stacks of Vermiculite formed around HEU cylinders on all sides
 - Minimum 15 cm polyethylene reflector
 - Acceptable Evaluation

HEU Cylinders Reflected by Concrete

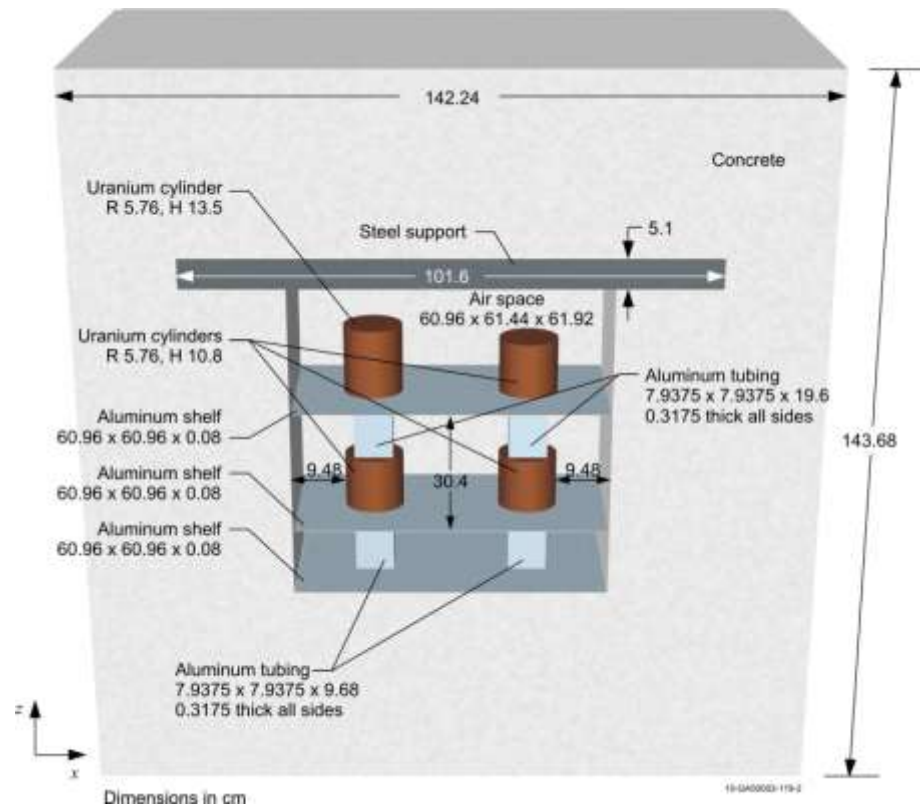
- Experiments Performed by D.W. Magnuson in November of 1972
- Part of a series of experiments on HEU arrays performed at the Oak Ridge Critical Experiments Facility
 - Others from the series have been evaluated (HEU-MET-FAST-053)
 - Reused HEU metal cylinders from Tinkertoy experiments (HEU-MET-FAST-023 and HEU-MET-FAST-026)
- Documented in published report *Critical Three-Dimensional Arrays of Neutron Interacting Units: Part IV*, D.W. Magnuson, 1973. Y-DR-109
- Each experimental case varied the thickness and proximity of the reflector
- 14 total experiments performed

HEU Cylinders Reflected by Concrete – Case 1



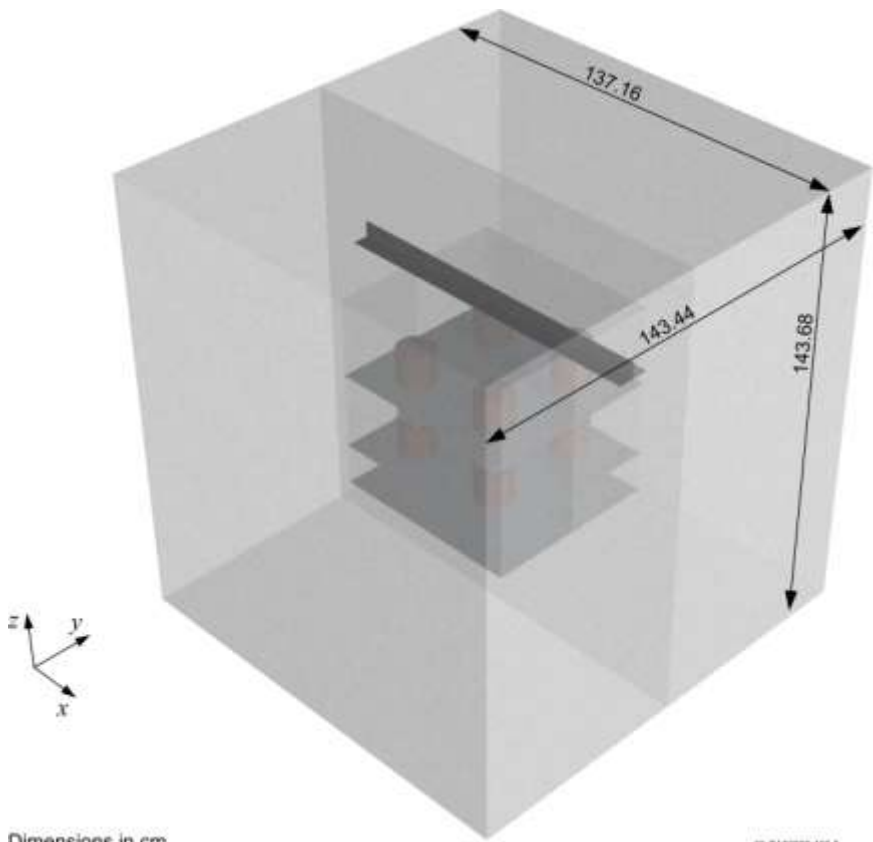
Dimensions in cm

19-GA0003-116-1



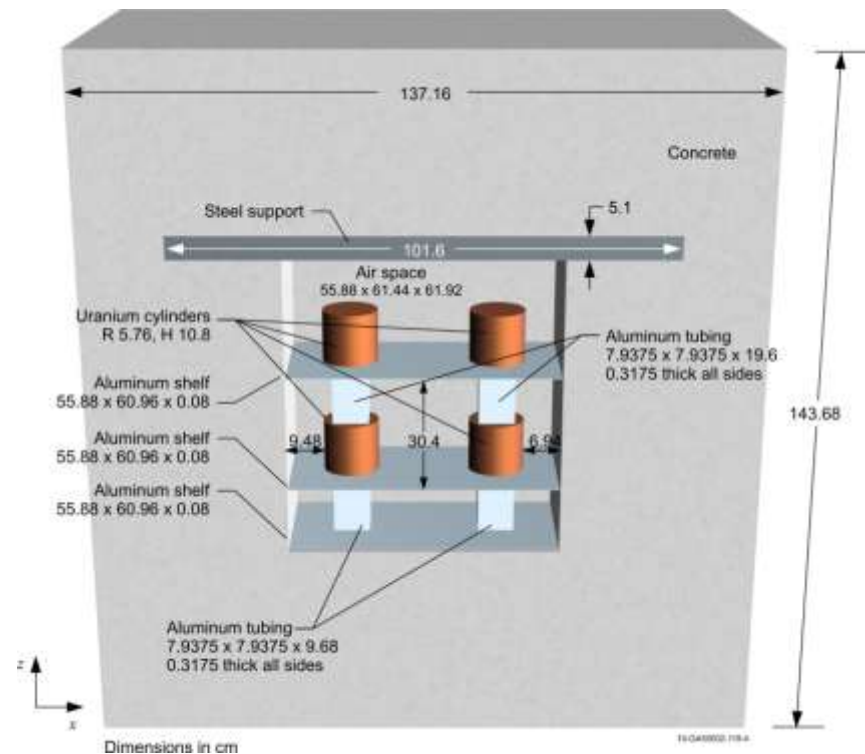
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HEU Cylinders Reflected by Concrete – Case 3



Dimensions in cm

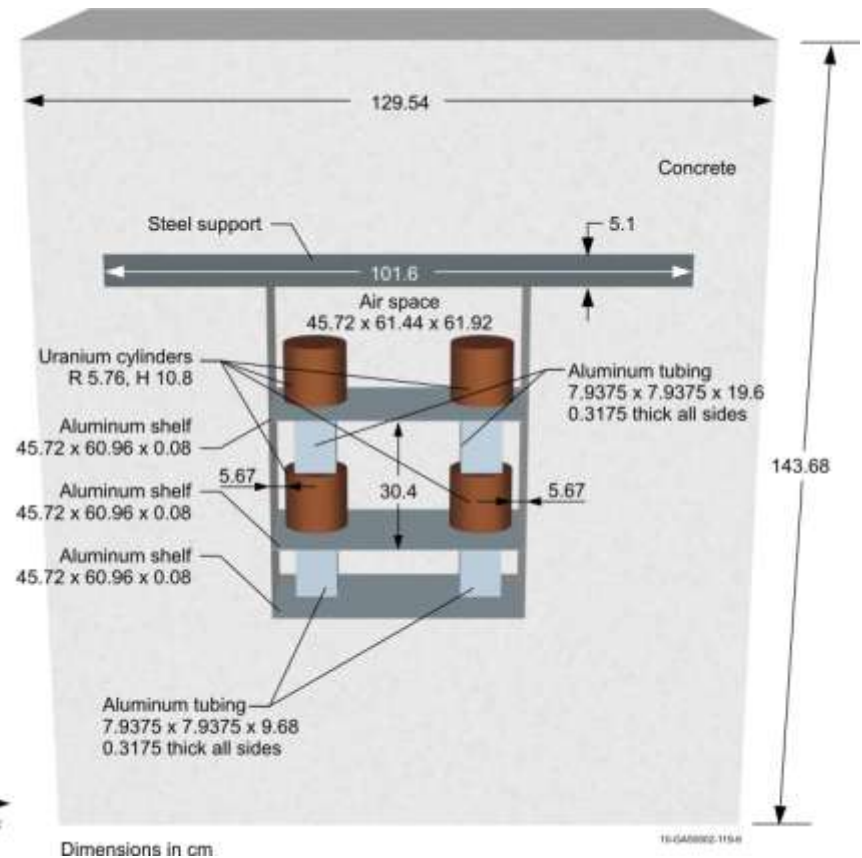
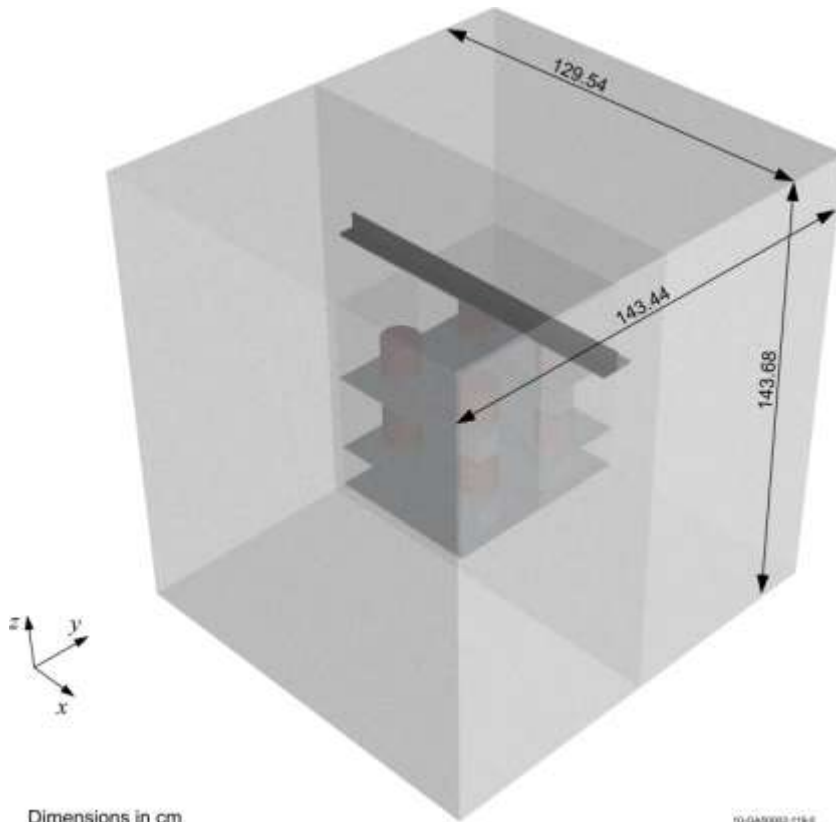
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Dimensions in cm

10-0450002-119-4

HEU Cylinders Reflected by Concrete – Case 11



HEU Cylinders Reflected by Concrete

- Problems and Issues
 - Concrete Composition
 - Magnuson concrete, apparently mixed for experiment
 - Multiple partial composition analysis, but with conflicting results
 - Loss-on-Drying technique was used (~25-30% accurate)
 - Results highly sensitive to hydrogen content
 - Increase of 30% caused a 1.667% increase in k_{eff}
 - Density
 - Published report gives density as 2.15 g/cm^3
 - Density calculation in the logbook gave 2.0764 g/cm^3
 - Calculated from 360 blocks weighing 7 tons (6350.3 kg).
 - Analysis included in logbook contained reports of density of 100.4 lb/ft^3 (1.60825 g/cm^3)
 - Second density calculation in logbook gives 2.15 g/cm^3
 - Calculated from 10 blocks weighing 40.38 lbs (18.314 kg)

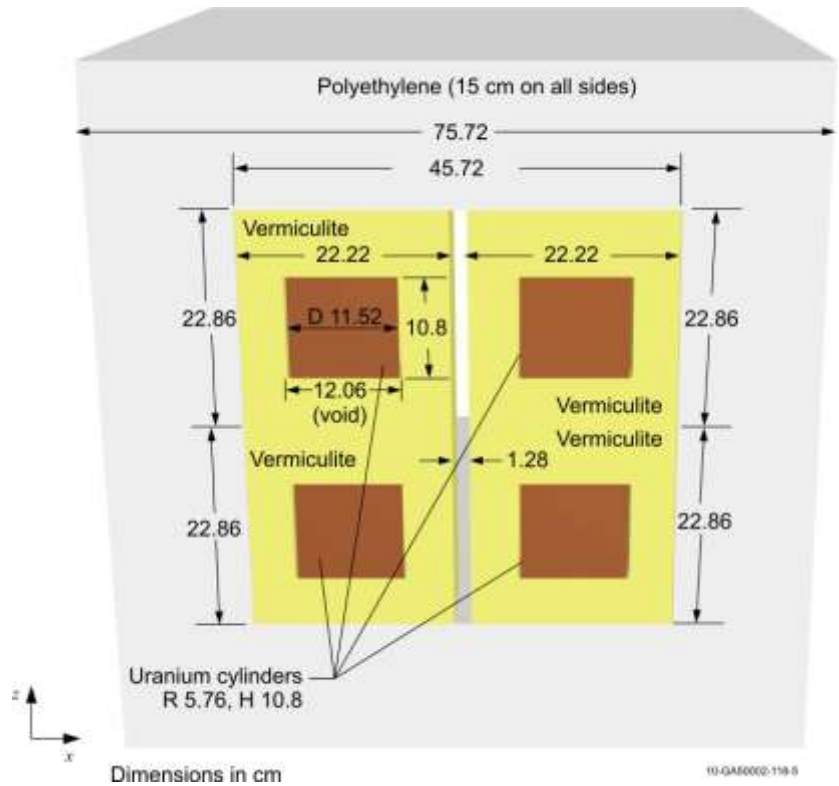
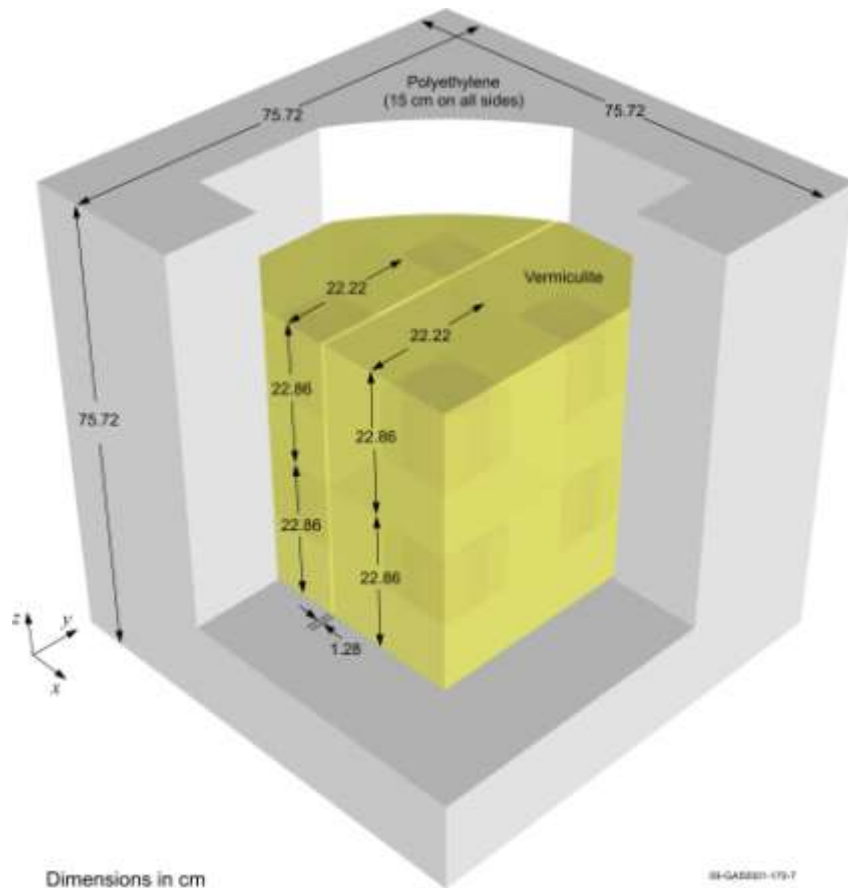
HEU Cylinders Reflected by Concrete

- Problems and Issues, continued
 - Prompt critical experiments
 - Several cases were reported as prompt critical
 - What was the extrapolation method?
 - Was the split table fully closed?
 - Unclear from logbook notes what method was used or what was the critical gap
 - Subcritical experiments
 - There were also several highly subcritical experiments, with the same issues as the prompt critical experiments
- Conclusions
 - Evaluation determined the experiment was unacceptable as a benchmark experiment
 - Results are being published in ICSBEP Handbook

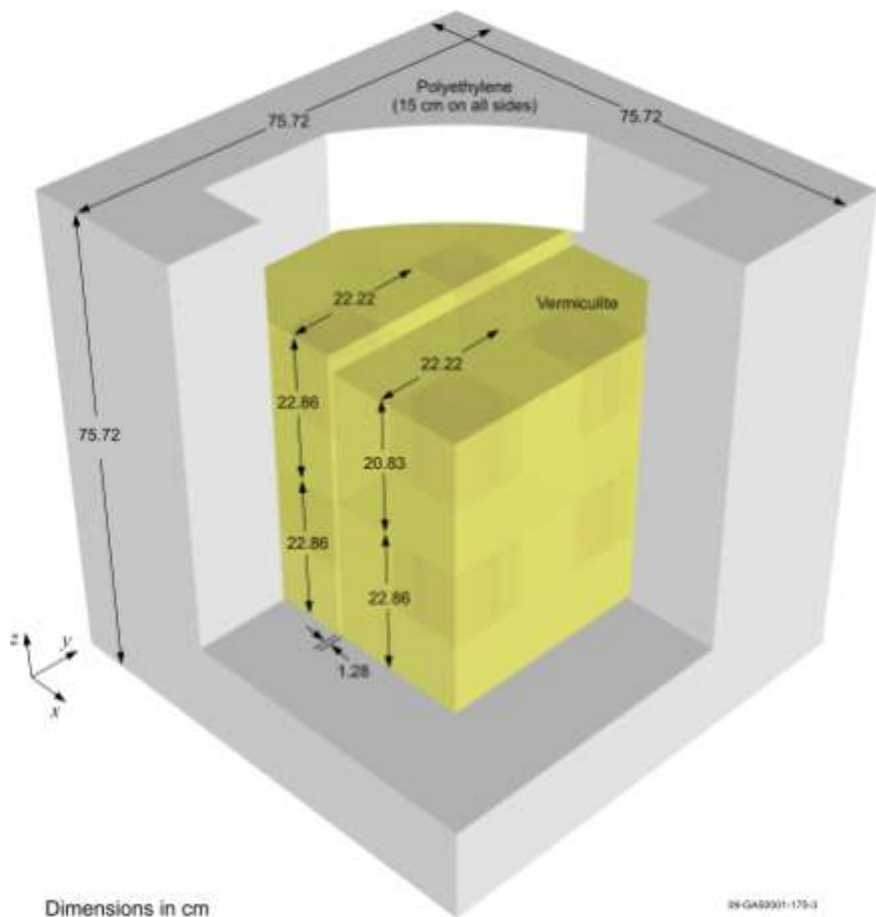
HEU Cylinders Separated by Vermiculite

- Experiments Performed by D.W. Magnuson in November of 1972 at the same time as the concrete experiments
- Published in the same report, Y-DR-109
- Used polyethylene blocks for reflection
- Reused the Tinkertoy cylinders in a 2x2x2 array
- Used large vermiculite sheets, and hand-cut pieces to size to fill space around cylinders inside the reflector
- Experiments varied the amount of vermiculite above certain cylinders
- Minimum 15cm reflector on all sides (greater than this on two sides)
- 4 total cases
 - Since they are so similar, cases 2-3 are used for repeatability, and only case 1 is considered a benchmark experiment for evaluation

HEU Cylinders Separated by Vermiculite- Case 1

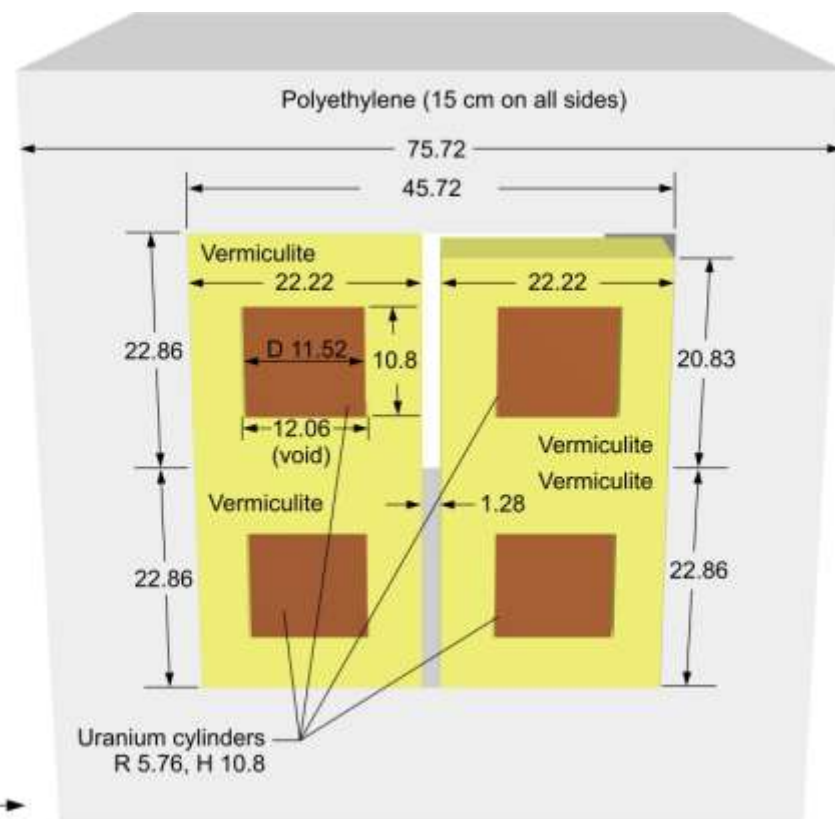


HEU Cylinders Separated by Vermiculite- Case 2



Dimensions in cm

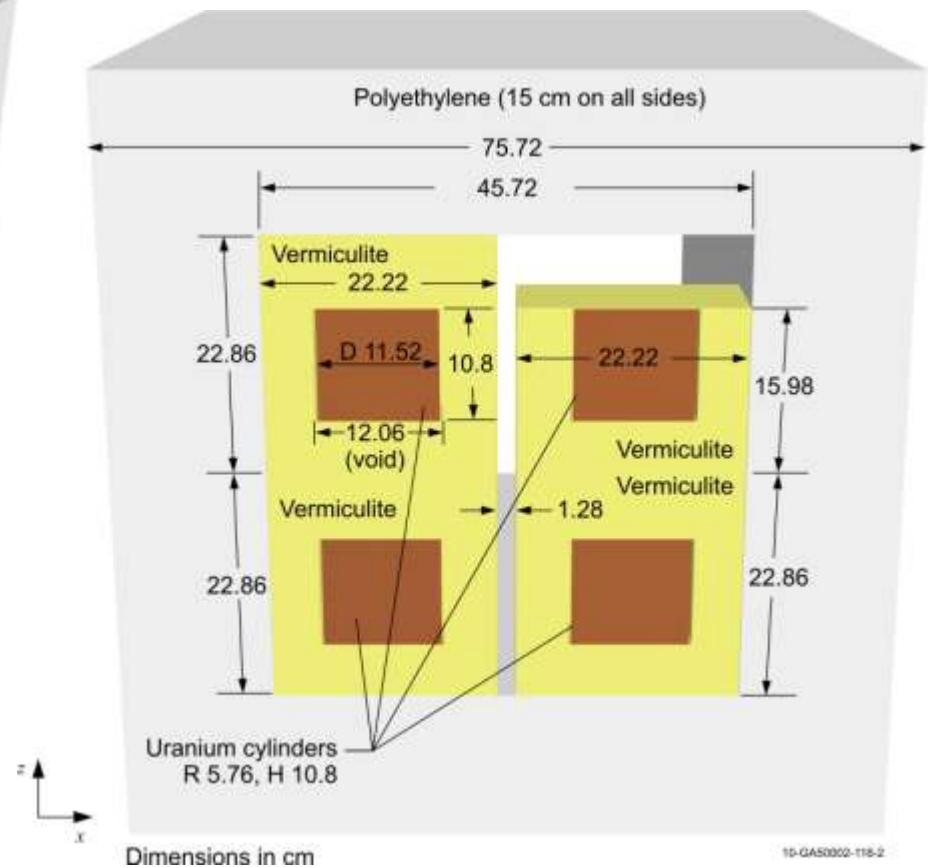
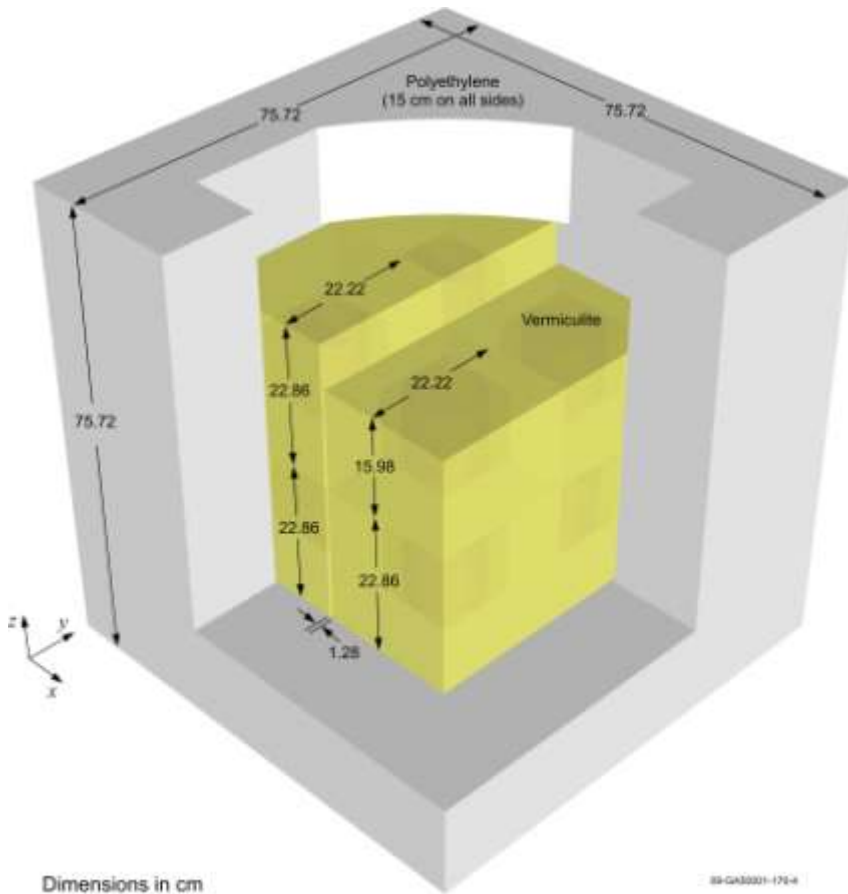
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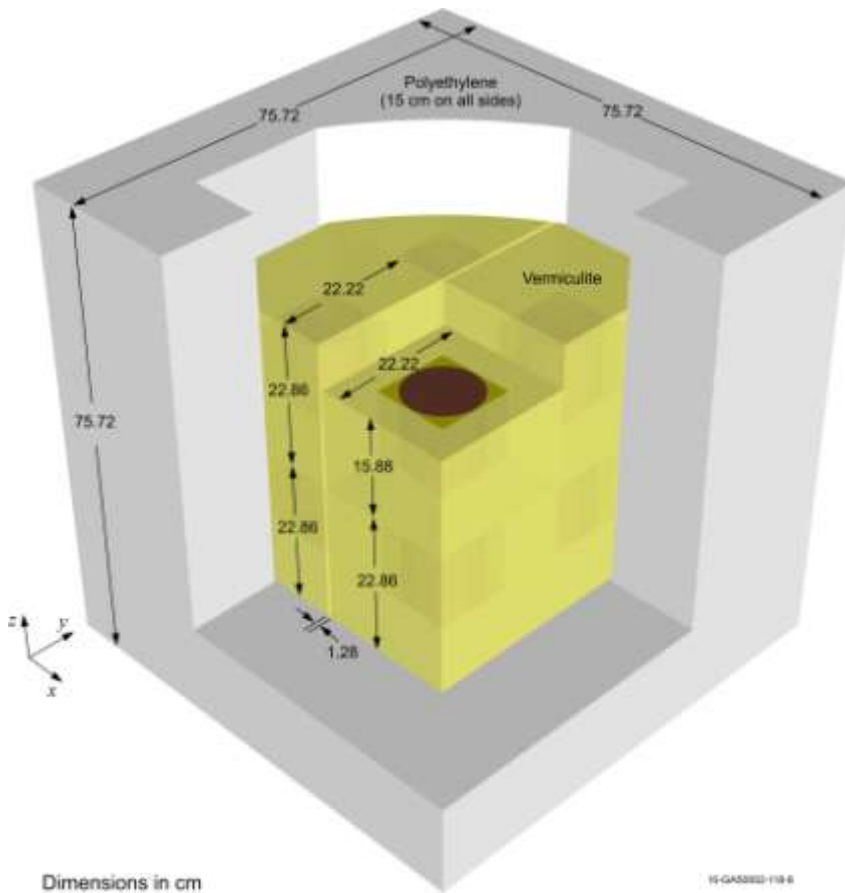
Dimensions in cm

10-GAS0002-118-1

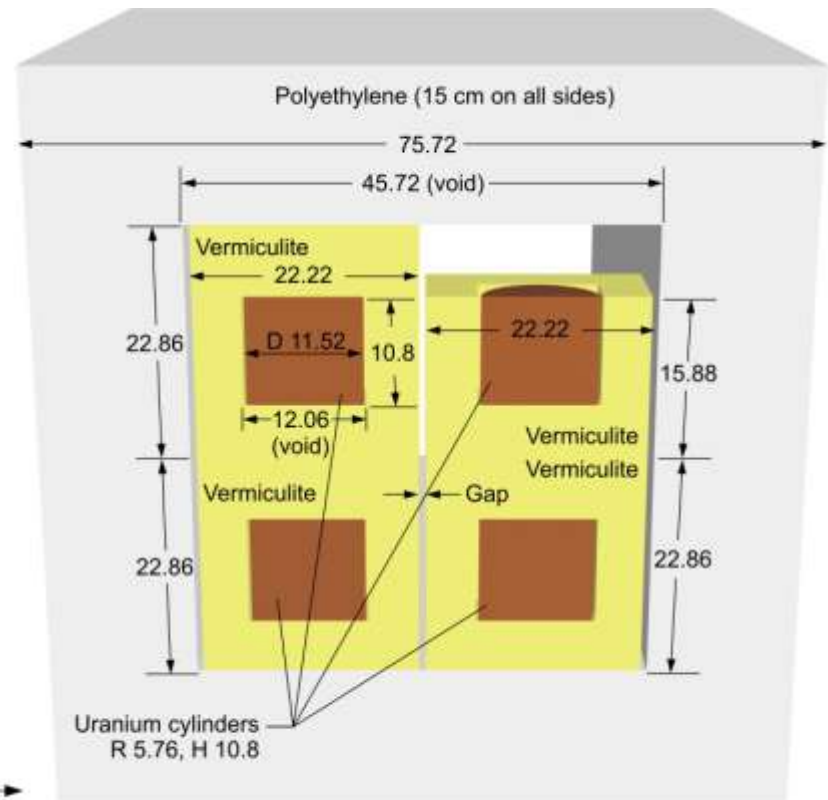
HEU Cylinders Separated by Vermiculite- Case 3



HEU Cylinders Separated by Vermiculite- Case 4



10-GAS002-118-B



10-GAS002-118-B

HEU Cylinders Separated by Vermiculite

- Uncertainties
 - Largest uncertainty from the polyethylene density: $\Delta k_{\text{eff}} = 0.00275$
 - Other uncertainties evaluated were:
 - Uranium density, mass, dimensions, impurities, isotopic content, and spatial variation
 - Vermiculite composition, impurities, density, mass, dimensions, and gap
 - Polyethylene mass, dimension, and impurities
 - Total uncertainty in k_{eff} : 0.0055
- Biasses
 - Vermiculite pieces modeled as one solid mass
 - Support holes in cylinders were removed
 - Reflector gaps and room return
 - All simplifications had a negligible effect

HEU Cylinders Separated by Vermiculite

- K_{eff} Data

Case Number	Experimental k_{eff}	Benchmark k_{eff}	MCNP5 Calculated k_{eff} (ENDF/B-VII.0)	(C-E)/E %
1	1.0005 ± 0.0055	1.0005 ± 0.0055	1.0106 ± 0.00005	1.001
2	1.0007 ± 0.01076	1.0007 ± 0.01076	1.0100 ± 0.00005	0.929
3	1.0016 ± 0.00878	1.0016 ± 0.00878	1.0116 ± 0.00005	0.998
4	1.0013 ± 0.00914	1.0013 ± 0.00914	1.0129 ± 0.00005	1.159

- Conclusions

- Acceptable benchmark evaluation for case 1 (other cases used for repeatability), published in ICSBEP Handbook