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Analysis of Enriched Uranyl Nitrate in Nested Annular Tank Array

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INTRODUCTION

Two series of experiments were performed at the Rocky Flats Critical Mass Laboratory during the 1980s using highly enriched (93%) uranyl nitrate solution in annular tanks. [1, 2] Tanks were of typical sizes found in nuclear production plants. Experiments looked at tanks of varying radii in a co-located set of nested tanks, a 1 by 2 array, and a 1 by 3 array. The co-located set of tanks had been analyzed previously [3] as a benchmark for inclusion within the *International Handbook of Evaluated Criticality Safety Benchmark Experiments*. [4]

The current study represents the benchmark analysis of the 1 by 3 array of a series of nested annular tanks. Of the seventeen configurations performed in this set of experiments, twelve were evaluated and nine were judged as acceptable benchmarks.

DESCRIPTION OF THE ACTUAL WORK

Information from the references was evaluated according to the requirements of the ICSBEP. [4] Detailed benchmark models were developed and Monte Carlo n-Particle version 5 (MCNP5) [5] was used to analyze the experiments and perform uncertainty perturbations. Configurations included critical assemblies such that between two and six annular stainless steel tanks were filled with approximately 356.4 g/L of uranium in dilute nitric acid to achieve criticality. Some configurations contained borated concrete or plaster plugs placed in the centers of the annular tanks. One concrete plug was laminated with cadmium. Slabs of cast borated plaster were also placed between tanks for some of the configurations. The entire assembly of tanks was surrounded by concrete slabs, walls, and floors, as shown in Figures 1 and 2, where plugs and slabs were not present.

RESULTS

Results from the benchmark analysis of the twelve configurations are shown in Table I. The uncertainty in the benchmark model is approximately between 0.8 and 0.9% for most configurations. The largest two contributors to the uncertainty in the benchmark models are the uncertainty in the thickness of the annular regions of the tanks containing the uranium solution and the density of the concrete utilized in the walls, slabs, and plugs. The uncertainty in thickness of the plaster slabs was also a significant contributor in the last three configurations shown in Table I. The eigenvalue results calculated for the cases using borated plaster slabs were predicted up to 2.5% lower than the expected benchmark values. The experimental report [1] stated that the plaster slabs were comprised of the same material as the plugs without providing further details. There might be an inconsistency between the actual and reported composition or dimensions of the slabs that would account for the difference between the benchmark and model results. Insufficient information is available to accurately determine the actual cause for this discrepancy.

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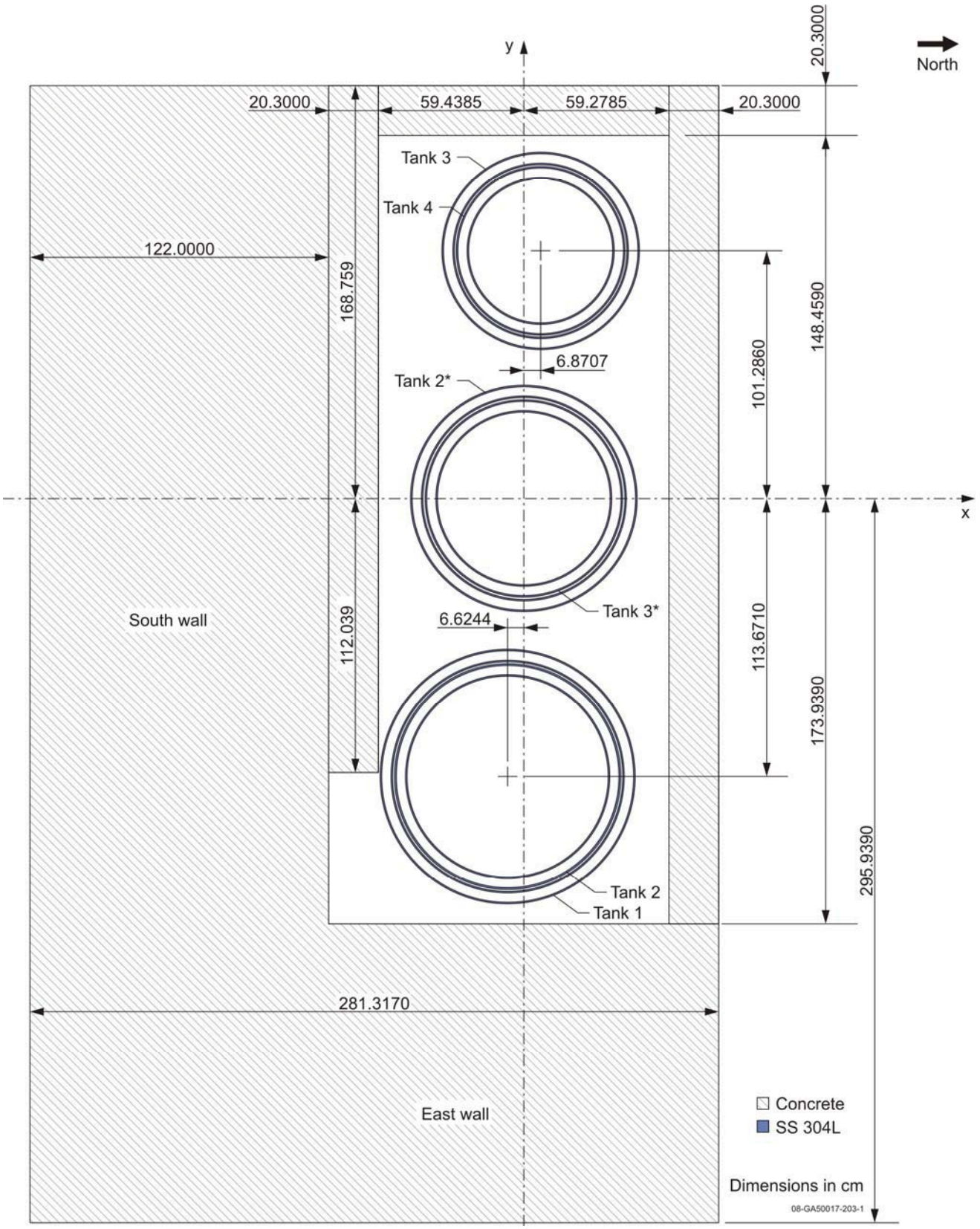

Fig. 1. Top View of the 1 by 3 Array of Nested Annular Tanks Containing Highly Enriched Uranyl Nitrate Solution.

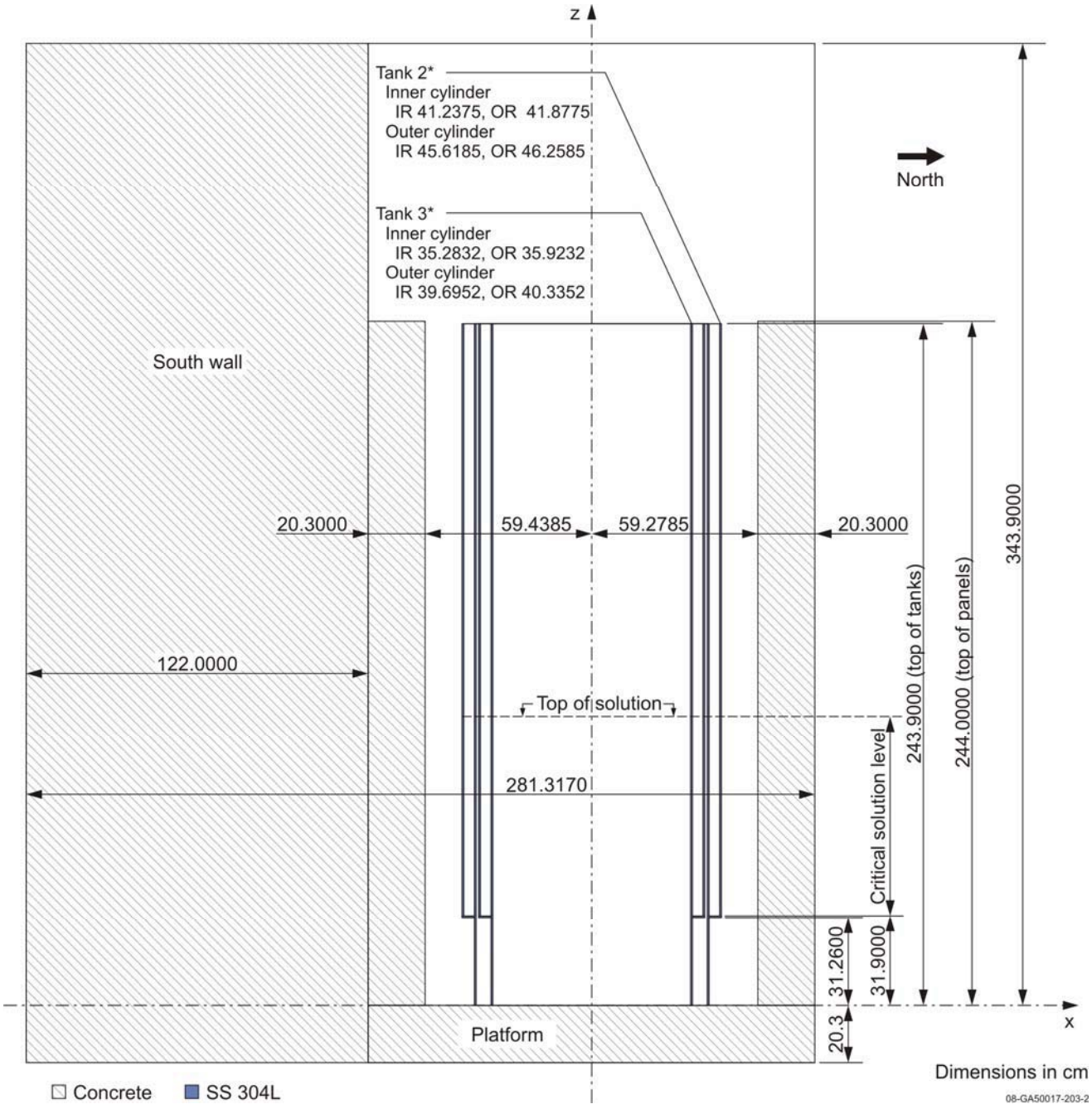

Fig. 2. Side View of the 1 by 3 Array of Nested Annular Tanks Containing Highly Enriched Uranyl Nitrate Solution.

Table I. Benchmark Results for the Nested Annular Tanks Containing Highly Enriched Uranyl Nitrate Solution

Case #	Critical Solution Height (cm)	Absorber/Moderator Material	Tanks Filled with Solution†	Benchmark Value			MCNP5 Results (ENDF/B-VI.8)		
				k_{eff}	±	σ	k_{eff}	±	σ
1	71.34	None	All	1.0004	±	0.0081	0.9946	±	0.0001
2	84.18		1, 2, 2*, 3*	1.0005	±	0.0083	0.9964	±	0.0001
3	142.58		2*, 3*	1.0002	±	0.0081	0.9865	±	0.0001
4	118.14		1, 2*, 3*	1.0007	±	0.0081	0.9885	±	0.0001
5	134.64	Borated Concrete Plugs	All	0.9999	±	0.0084	1.0028	±	0.0001
6	162.68		1, 2, 2*, 3*	1.0001	±	0.0087	1.0074	±	0.0001
7	132.68	Borated Concrete Plug and 2 Borated Plaster Plugs	All	1.0001	±	0.0076	0.9908	±	0.0001
8	164.56		1, 2, 2*, 3*	1.0005	±	0.0082	0.9990	±	0.0001
9	126.99	Borated Concrete Plugs (1 with Cadmium Lining)	All	1.0004	±	0.0078	0.9988	±	0.0001
10	176.00	Borated Concrete Plug, 2 Borated Plaster Plugs, and 2 Borated Plaster Slabs	All	1.0001	±	0.0089	0.9804	±	0.0001
11	89.51	Borated Concrete Plug, Borated Plaster Plug, and 2 Borated Plaster Slabs (No Plug in Center Tanks)	All	1.0000	±	0.0089	0.9784	±	0.0001
12	103.22		2*, 3*, 3, 4	1.0001	±	0.0084	0.9763	±	0.0001

† Tank 2* is nominally equivalent in dimensions to tank 2, and tank 3* is nominally equivalent in dimensions to tank 3. Whereas they are different tanks in the physical experiment, the connotation aids in recognizing the similar geometries in the system