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Calculation of 1.25% ²³⁵U Enriched UO₂ Solution Safe Slab, Safe Cylinder Diameter, Minimum Safe Mass, and Ion Exchange Module for the CVDF

S. P. Roblyer

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Abstract: Support calculations were performed to establish safe parameters such as fissionable material slab thickness, diameter and safe mass. These calculations were performed by MCNP for the balance of plant equipment that contains homogenous UO₂ solutions with a maximum enrichment of 1.25 wt% ²³⁵U. The calculations were performed with the most limiting concentration of moderator and reflection so that only the safety parameters identified in the problem description need to be controlled. These calculations represent the most limiting cases for all uranium enrichments and transuranic levels due to fuel exposure for balance of plant equipment used for handling of waste water containing fissionable materials from the MCO draining and drying activities.

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CHECKLIST FOR INDEPENDENT TECHNICAL REVIEW

NUMBER: HNF-SD-SNF-CSER-009, REV. 0DOCUMENT REVIEWED: Calculation of 1.25% 235U Enriched UO2 Solution Safe Slab,
Safe Cylinder Diameter, Minimum Safe Mass, and Ion Exchange Module.AUTHOR(s): S. P. Roblyer

I. Method(s) of Review

- ☒ Input data checked for accuracy
☒ Independent calculation performed
☒ Hand calculation
☐ Alternate computer code: _____
 NA ☐ Comparison to experiment or previous results
 NA ☐ Alternate method (define) _____

II. Checklist (either check or enter NA if not applied)

- ☒ Task completely defined
☒ Activity consistent with task specification
☒ Necessary assumptions explicitly stated and supported
☒ Resources properly identified and referenced
☒ Resource documentation appropriate for this application
☒ Input data explicitly stated
 NA ☒ Input data verified to be consistent with original source
☒ Geometric model adequate representation of actual geometry
☒ Material properties appropriate and reasonable
 NA ☒ Mathematical derivations checked including dimensional consistency
☒ Hand calculations checked for errors
☒ Assumptions explicitly stated and justified
☒ Computer software appropriate for task and used within range of validity
☒ Use of resource outside range of established validity is justified
☒ Software runstreams correct and consistent with results
☒ Software output consistent with input
☒ Results consistent with applicable previous experimental or analytical findings
☒ Results and conclusions address all points and are consistent with task requirements and/or established limits or criteria
☒ Conclusions consistent with analytical results and established limits
☒ Uncertainty assessment appropriate and reasonable
☐ Other (define) _____

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Robert H. Ruben

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CALCULATION OF 1.25% ²³⁵U ENRICHED UO₂ SOLUTION SAFE SLAB, SAFE CYLINDER DIAMETER, MINIMUM SAFE MASS, AND ION EXCHANGE MODULE FOR THE CVDF

1.0 PROBLEM

Determine the safe slab thickness, safe cylinder diameter, and minimum safe mass of 1.25% ²³⁵U enriched UO₂ solution. The safe slab corresponds to the spill depth of the MCO waste water. The safe diameter corresponds to the favorable geometry 300 gallon receiver tank inner diameter. The minimum safe mass is the basis of the mass limits for unfavorable geometry vessels such as the filter and ion exchange module, and the storage tank.

2.0 ASSUMPTIONS

- 2.1 Enrichment: 1.25% ²³⁵U
- 2.2 UO₂ density: 10.96 g/cm³
- 2.3 Water density: 1.0 g/cm³
- 2.4 UO₂ solution is homogeneous.
- 2.5 1.25% ²³⁵U enriched uranium is limiting from a reactivity standpoint for all fuels and isotopics produced in exposed fuel.
- 2.6 Concrete is reflector of floor and ceiling, water is reflector otherwise.
- 2.7 Criticality safety limit is 0.95 (95% C.I. plus bias).
- 2.8 IXM module is composed of 6 cylinders with maximum outer height of 42.25 inches and maximum outer diameter of 16.0 inches.

3.0 RESULTS

The following results were determined from the calculations: A safe parameter such as slab thickness is the thickness of reflected optimum solution that corresponds to an 95% confidence interval k_{eff} of 0.95.

- 3.1 Optimum solution
 - 3.1.1 Optimum solution occurs at an H/U ratio of 5.0
 - 3.1.2 Optimum solution occurs for a solution of UO₂ and water with no IXM resins.
- 3.2 Safe slab thickness is 26.6 cm (10.5 inches)
- 3.3 Safe cylinder diameter

- 3.3.1 Single Cylinder: 59.8 cm (23.5 inches)
- 3.3.2 Double Parallel Cylinder, no separation control: 52.5 cm (20.6 inches)
- 3.3.3 Double Parallel Cylinder, six inch separation control: 59.8 cm (23.5 inches)
- 3.4 Minimum safe mass: 614.9 kg
- 3.5 The IXM module with dimension restrictions of Assumption 2.8 is safe for all UO_2 mixtures of 1.25% ^{235}U enriched uranium.

4.0 REFERENCES

Breismeister, J. F., Editor, 1993, *MCNP--A General Monte Carlo Code N-Particle Transport Code, Version 4a*, LA-12625, Los Alamos National Laboratory, Los Alamos, New Mexico.

Schmittroth, F., and R. H. Ruben, 1996, *MCNP Criticality Validation and Bias for LEU Systems*, WHC-SD-SNF-ANAL-013, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

5.0 CALCULATION

The following sections will discuss the UO_2 solution as a function of H/U ratio, the determination of the optimum solution density or H/U ratio, the criticality safety limit and the measurement and calculational bias, the safe slab thickness, the safe cylinder diameter, and safe mass of a reflected sphere. The reactivity calculations were performed by the MCNP code. The input run streams are listed in the Appendix A. A sample output, documenting code version, is listed in Appendix B.

5.1. 1.25% ^{235}U Enriched UO_2 Solution

The solution density and component weight fractions of the UO_2 solution was determined for a range of H/U ratios. The results of this calculation are listed in Table 5.1-1.

Table 5.1-1. 1.25 wt% Enriched UO₂ Mixture Weight Fractions and Densities

H/U	H/ ²³⁵ U	Density (g/cm ³)	Code Input ²³⁵ U	Data ²⁸⁵ U	(Weight Fractions)		U Density (g/cm ³)
					H	O	
1.0	79.0	8.2934	1.06629E-02	8.42371E-01	3.61230E-03	1.43354E-01	7.075
2.0	158.0	6.7531	1.03295E-02	8.16027E-01	6.99866E-03	1.66645E-01	5.580
3.0	237.0	5.7499	1.00162E-02	7.91281E-01	1.01796E-02	1.88523E-01	4.607
4.0	316.0	5.0447	9.72141E-03	7.67991E-01	1.31734E-02	2.09114E-01	3.923
5.0	395.0	4.5218	9.44346E-03	7.46034E-01	1.59959E-02	2.28527E-01	3.416
6.0	474.0	4.1186	9.18097E-03	7.25297E-01	1.86615E-02	2.46861E-01	3.025
7.0	553.0	3.7982	8.93268E-03	7.05681E-01	2.11830E-02	2.64203E-01	2.714
8.0	632.0	3.5376	8.69746E-03	6.87099E-01	2.35716E-02	2.80632E-01	2.461
9.0	711.0	3.3213	8.47431E-03	6.69470E-01	2.58377E-02	2.96218E-01	2.252
10.0	790.0	3.1391	8.26232E-03	6.52723E-01	2.79904E-02	3.11024E-01	2.075
11.0	869.0	2.9833	8.06068E-03	6.36794E-01	3.00381E-02	3.25107E-01	1.924
12.0	948.0	2.8487	7.86865E-03	6.21624E-01	3.19881E-02	3.38520E-01	1.793
13.0	1027.0	2.7312	7.68556E-03	6.07159E-01	3.38475E-02	3.51308E-01	1.679
14.0	1106.0	2.6278	7.51079E-03	5.93353E-01	3.56222E-02	3.63514E-01	1.579
15.0	1185.0	2.5360	7.34380E-03	5.80160E-01	3.73181E-02	3.75178E-01	1.490

5.2. Optimum 1.25% ²³⁵U Enriched UO₂ Solution

The optimum solution density was determined by using the solution densities and component weight fractions for a range of H/U ratios in a fully reflected sphere of UO₂ solution representing and infinite medium. The results of this calculation are listed in Table 5.2-1 and shown graphically in Figure 5.2-1. The optimum reactivity was found to occur at a H/U ratio of 5.0.

Table 5.2-1 1.25% Enriched UO_2 Solution Infinite Medium Reactivity Versus H/U Ratio

H/U	k-inf	Input file
1	0.872	inf001
2	0.993	inf002
3	1.036	inf003
4	1.069	inf004
5	1.075	inf005
6	1.069	inf006
7	1.062	inf007
8	1.057	inf008
9	1.034	inf009
10	1.024	inf010

Figure 5.2.1. 1.25% Enriched UO_2 Solution Infinite Medium Reactivity Versus H/U Ratio

5.3. Criticality Safety Limit And MCNP Code Calculational Bias

The criticality safety limit was established as 0.95 for the project. The calculations in this study were performed by the MCNP code (Breismeister, 1993). The MCNP code has a 95% confidence interval (C.I.) calculational bias and a measurement bias that has been determined (Schmittroth, F., and R. H. Ruben, 1996) to be the following:

$$K_{\text{calc}} + 0.0004 + [0.010^2 + (1.645 \sigma_{\text{calc}})^2]^{1/2} < k_{\text{limit}}$$

where k_{calc} and σ_{calc} represent the calculated value for k_{eff} and its standard deviation respectively. The limit, k_{limit} , is an established limiting value (0.95). The multiplier of 1.645 was obtained from tables of the normal distribution. This multiplier ensures that 95% of the MCNP population is bounded by the limit and assumes that there is no uncertainty in the standard deviation, σ_{calc} .

5.4. 1.25% ²³⁵U Enriched UO₂ Solution Safe Slab Thickness

The safe slab thickness was determined by modeling a one foot square slab of UO₂ solution with fully reflective sides and concrete reflected top and bottom surfaces. The solution density corresponded to the optimum H/U ratio of 5.0 that was determined in section 5.2. The results of these calculations are listed in Tables 5.4-1 and 5.4-2, and are shown graphically in Figure 5.4-1. The safe slab thickness, that corresponds to the reactivity equal to the criticality safety limit was determined to be 26.6 cm (10.5 inches).

Table 5.4-1 1.25% Enriched UO₂ Solution Slab Thickness Versus Reactivity

Slab Thickness		Reactivity		95% C.I.		Input
(cm)	(in)	k-eff	Sigma	+ bias		File
22	8.66	0.909	0.0020	0.920		slab001
23	9.06	0.918	0.0020	0.929		slab002
24	9.45	0.921	0.0017	0.932		slab003
25	9.84	0.926	0.0020	0.937		slab004
26	10.24	0.936	0.0018	0.947		slab005
27	10.63	0.942	0.0019	0.953		slab006
28	11.02	0.946	0.0019	0.957		slab007
29	11.42	0.954	0.0018	0.965		slab008
30	11.81	0.960	0.0017	0.971		slab009a
31	12.20	0.959	0.0016	0.970		slab010
32	12.60	0.966	0.0018	0.977		slab011

Figure 5.4-1. 1.25% Enriched UO₂ Solution Reflected Slab Thickness At Optimum H/U Ratio Versus Reactivity

Table 5.4-2 1.25% Enriched UO₂ Solution Safe Slab Thickness

Slab Thickness (cm)	Slab Thickness (in)	95% C.I. + bias
26.68	10.50	0.950

5.5 1.25% ²³⁵U Enriched UO₂ Solution Safe Cylinder Diameters

The safe cylinder diameter was determined for the cases of a single cylinder, and double parallel cylinders of UO₂ solution. The safe diameters of these cases were determined by modeling the UO₂ solution as a cylinder of with fully reflective ends and a water reflected outside surface. The solution density corresponded to the optimum H/U ratio of 5.0 that was determined in section 5.2. The results of these calculations are discussed in Sections 5.5.1 for the single cylinder, and sections 5.5.2 and for double parallel cylinders with no spacing control, and a spacing control of at least six inches, respectively.

5.5.1. 1.25% ²³⁵U Enriched UO₂ Solution Single Cylinder Safe Diameter And Reactivity Versus Uranium Density

The results of the single cylinder of 1.25% ²³⁵U enriched UO₂ solution reactivity and radius are listed in Tables 5.5-1 and 5.5-2, and are shown graphically in Figure 5.5-1. The safe cylinder diameter that corresponds to the reactivity equal to the criticality safety limit was determined in Table 5.5-2 to be 59.8 cm (23.5 inches).

The relationship of reactivity and solution density, as the density relates to the H/U ratio, for a reflected cylinder at the safe diameter of 59.8 cm is listed in Table 5.5-3 and shown graphically in Figure 5.5-2.

Table 5.5-1 1.25% Enriched UO₂ Solution Infinite Single Cylinder Radius Versus Reactivity

Tank Radius (cm)	Radius (in)	Reactivity		95% C.I. + bias	Input File
		k-eff	Sigma		
30	23.62	0.940	0.00069	0.950	cylr001
31	24.41	0.945	0.00078	0.955	cylr002
32	25.20	0.949	0.00072	0.960	cylr003
33	25.98	0.955	0.00069	0.966	cylr004
34	26.77	0.959	0.00065	0.970	cylr005
35	27.56	0.965	0.00073	0.976	cylr006
36	28.35	0.970	0.00069	0.980	cylr007
37	29.13	0.975	0.00065	0.986	cylr008
38	29.92	0.978	0.00077	0.989	cylr009
39	30.71	0.981	0.00068	0.991	cylr010
40	31.50	0.985	0.00068	0.996	cylr011

Figure 5.5-1 1.25% Enriched UO₂ Solution Single Tank Inner Radius Versus Reactivity

5.5.2 1.25% ^{235}U Enriched UO_2 Solution Double Cylinder Safe Diameter With No Separation Control

The double cylinder of 1.25% ^{235}U enriched UO_2 solution was modeled with a cylinder in contact with a reflective boundary on one side. The results of reactivity and radius are listed in Tables 5.5-3 and 5.5-4, and are shown graphically in Figure 5.5-3. The safe cylinder diameter that corresponds to the reactivity equal to the criticality safety limit was determined in Table 5.5-4 to be 52.5 cm (20.6 inches).

Figure 5.5-2 1.25% Enriched UO_2 Solution. Reactivity Versus Solution Density For Single Safe Diameter Cylinder

Table 5.5-2. 1.25% Enriched UO_2 Solution Safe Single Cylinder Diameter

Diameter		95% C.I
(cm)	(in)	+ bias
59.80	23.54	0.950

5.5.3 1.25% ^{235}U Enriched UO_2 Solution Double Cylinder Safe Diameter With Six Inch Separation Control

The double cylinder of 1.25% ^{235}U enriched UO_2 solution was modeled with a cylinder three inches from a reflective boundary on one side. This model represented two parallel cylinders with a separation distance of six inches between surfaces. The results of reactivity and radius are listed in Tables 5.5-5 and 5.5-6, and are shown graphically in Figure 5.5-4. The safe cylinder diameter that corresponds to the reactivity equal to the criticality safety limit was determined in Table 5.5-6 to be 60.1 cm (23.8 inches). Due to shielding of the water between the cylinders, this diameter is greater than the safe diameter for a single cylinder in Section 5.5.1. Therefore, the single cylinder safe diameter of 59.8 cm (23.5 inches) was also given to this situation.

**Table 5.5-3. 1.25% Enriched Uranium Oxide
Solution, Double Tanks In Contact. MCNP Calculations Of
Reactivity Versus Diameter**

Tank Radius		Reactivity		95% C.L.	Input
(cm)	(in)	k-eff	Sigma	+ bias	File
32	25.20	0.969	0.00071	0.979	dyI001
31	24.41	0.965	0.00084	0.975	dyI002
30	23.62	0.960	0.00070	0.971	dyI003
29	22.83	0.956	0.00081	0.967	dyI004
28	22.05	0.950	0.00083	0.960	dyI005
27	21.26	0.945	0.00077	0.955	dyI006
26	20.47	0.938	0.00081	0.948	dyI007
25	19.69	0.930	0.00078	0.941	dyI008
24	18.90	0.922	0.00082	0.933	dyI009
23	18.11	0.916	0.00086	0.927	dyI010
22	17.32	0.907	0.00077	0.917	dyI011
21	16.54	0.896	0.00086	0.907	dyI012
20	15.75	0.887	0.00078	0.897	dyI013
19	14.96	0.877	0.00088	0.887	dyI014
18	14.17	0.863	0.00080	0.873	dyI015
17	13.39	0.849	0.00095	0.860	dyI016
16	12.60	0.835	0.00094	0.846	dyI017
15	11.81	0.820	0.00109	0.830	dyI018

Figure 5.5-3 1.25% UO₂ Solution Double Tank Radii Versus Reactivity With No Separation Control

Table 5.5-4. 1.25% Enriched Uranium Oxide Solution Safe Tank Diameter With No Separation

Diameter (cm)	Diameter (in)	95% C.I.
		+ bias
52.54	20.69	0.950

Table 5.5-4. 1.25% Enriched UO₂ Solution Safe Single Cylinder Solution Density Versus Reactivity

H/U Ratio	Density (g/cm ³)	Reactivity k-eff	Sigma	95% C.I. + bias	Input File
4	5.0447	0.931	0.00066	0.941	cylr102
5	4.5218	0.938	0.00075	0.949	cylr103
6	4.1186	0.936	0.00069	0.946	cylr104
7	3.7982	0.932	0.00075	0.942	cylr105
8	3.5376	0.921	0.00078	0.932	cylr106
9	3.3213	0.911	0.00068	0.922	cylr107
10	3.1391	0.900	0.00060	0.910	cylr108
11	2.9833	0.887	0.00056	0.898	cylr109
12	2.8487	0.876	0.00061	0.886	cylr110
13	2.7312	0.860	0.00069	0.871	cylr112
14	2.6278	0.848	0.00057	0.859	cylr113
15	2.5360	0.834	0.00060	0.845	cylr114

Table 5.5-5. 1.25% Enriched Uranium Oxide Solution, Double Tanks With Six Inch Separation. MCNP Calculations Of Reactivity Versus Diameter

Tank Radius (cm)	(in)	Reactivity k-eff	Sigma	95% C.I. + bias	Input File
32	25.20	0.952	0.00075	0.962	dyl101
31	24.41	0.945	0.00072	0.955	dyl102
30	23.62	0.940	0.00076	0.951	dyl103
29	22.83	0.933	0.00080	0.944	dyl104
28	22.05	0.924	0.00065	0.934	dyl105
27	21.26	0.919	0.00075	0.929	dyl106
26	20.47	0.911	0.00075	0.922	dyl107
25	19.69	0.901	0.00065	0.911	dyl108
24	18.90	0.892	0.00071	0.902	dyl109
23	18.11	0.881	0.00072	0.891	dyl110
22	17.32	0.871	0.00088	0.881	dyl111
21	16.54	0.858	0.00072	0.869	dyl112
20	15.75	0.846	0.00082	0.857	dyl113
19	14.96	0.831	0.00074	0.842	dyl114
18	14.17	0.815	0.00078	0.826	dyl115
17	13.39	0.797	0.00080	0.808	dyl116
16	12.60	0.778	0.00075	0.788	dyl117
15	11.81	0.759	0.00088	0.769	dyl118

Table 5.5-6. 1.25% Enriched Uranium Oxide Solution Safe Double Tank Diameter With Six Inch Separation

Diameter		95% C.I. +bias
(cm)	(in)	
60.08	23.65	0.950

Figure 5.5-4 1.25% Enriched UO_2 Solution Double Cylinder Radii Versus Reactivity With Six Inch Separation

5.6 1.25% ²³⁵U Enriched UO₂ Solution Minimum Safe Mass

The Minimum safe mass was determined by modeling a water reflected sphere of UO₂ solution over a range of H/U ratios or solution densities and sphere radii. The solution density and its components corresponded to values listed in Table 5.1-1 above. The radius of the sphere was first determined that corresponded to the criticality safety limit for each H/U ratio. The results of these calculations are listed in Tables 5.6-1 through 5.5-9, and are shown graphically in Figures 5.6-1 through 5.6-9.

A summary of the Sphere radii corresponding to the criticality safety limit and the corresponding safe mass of uranium for various H/U ratios is listed in Table 5.6-10 and shown graphically in Figure 5.6-10. The minimum safe mass of 1.25% ²³⁵U enriched uranium in homogeneous UO₂ solution was determined to be 614.9 kg.

Table 5.6-1 1.25% Enriched UO₂ Solution Water Reflected Sphere Radius Versus Reactivity At An H/U Ratio Of 3.0

Radius (cm)	Diameter (in)	Reactivity k-eff	Sigma	95% C.I. + bias	Input File
40	31.50	0.90058	0.00203	0.9115	sphr101
41	32.28	0.90937	0.00181	0.9202	sphr102
42	33.07	0.91546	0.00186	0.9263	sphr103
43	33.86	0.92127	0.00234	0.9324	sphr104
44	34.65	0.92511	0.00225	0.9362	sphr105
45	35.43	0.92689	0.00180	0.9377	sphr106
46	36.22	0.93230	0.00201	0.9432	sphr107
47	37.01	0.93398	0.00223	0.9450	sphr108
48	37.80	0.93558	0.00212	0.9466	sphr109
49	38.58	0.94567	0.00221	0.9567	sphr110
50	39.37	0.94523	0.00146	0.9559	sphr111

Table 5.6-2 1.25% Enriched UO₂ Solution Water Reflected Sphere Radius Versus Reactivity At An H/U Ratio Of 4.0

Radius (cm)	Diameter (in)	Reactivity k-eff	Sigma	95% C.I. + bias	Input File
40	31.50	0.92751	0.00210	0.9385	sphr201
41	32.28	0.93076	0.00226	0.9418	sphr202
42	33.07	0.93856	0.00197	0.9495	sphr203
43	33.86	0.94025	0.00190	0.9511	sphr204
44	34.65	0.94806	0.00202	0.9590	sphr205
45	35.43	0.94965	0.00197	0.9606	sphr206
46	36.22	0.94839	0.00186	0.9592	sphr207
47	37.01	0.95757	0.00182	0.9684	sphr208
48	37.80	0.96008	0.00185	0.9709	sphr209
49	38.58	0.96533	0.00208	0.9763	sphr210
50	39.37	0.96972	0.00199	0.9806	sphr211

Table 5.6-3 1.25% Enriched UO₂ Solution Water Reflected Sphere Radius Versus Reactivity At An H/U Ratio Of 5.0

Radius (cm)	Diameter (in)	Reactivity k-eff	Sigma	95% C.I. + bias	Input File
35	27.56	0.89427	0.00204	0.9052	sphr001
36	28.35	0.90873	0.00185	0.9196	sphr002
37	29.13	0.91304	0.00184	0.9239	sphr003
38	29.92	0.92136	0.00195	0.9323	sphr004
39	30.71	0.92728	0.00193	0.9382	sphr005
40	31.50	0.93367	0.00189	0.9445	sphr006
41	32.28	0.94046	0.00176	0.9513	sphr007
42	33.07	0.94683	0.00207	0.9578	sphr008
43	33.86	0.94756	0.00193	0.9585	sphr009
44	34.65	0.94795	0.00192	0.9588	sphr010
45	35.43	0.95647	0.00170	0.9673	sphr011

Table 5.6-4 1.25% Enriched UO₂ Solution Water Reflected Sphere Radius Versus Reactivity At An H/U Ratio Of 6.0

Radius (cm)	Diameter (in)	Reactivity k-eff	Sigma	95% C.I. + bias	Input File
40	31.50	0.93281	0.00199	0.9437	sphr301
41	32.28	0.93579	0.00184	0.9466	sphr302
42	33.07	0.94210	0.00199	0.9530	sphr303
43	33.86	0.94376	0.00208	0.9547	sphr304
44	34.65	0.95208	0.00182	0.9629	sphr305
45	35.43	0.95766	0.00193	0.9686	sphr306
46	36.22	0.95991	0.00181	0.9707	sphr307
47	37.01	0.96378	0.00181	0.9746	sphr308
48	37.80	0.96125	0.00191	0.9721	sphr309
49	38.58	0.97120	0.00184	0.9820	sphr310
50	39.37	0.96886	0.00198	0.9798	sphr311

Table 5.6-5 1.25% Enriched UO₂ Solution Water Reflected Sphere Radius Versus Reactivity At An H/U Ratio Of 7.0

Radius (cm)	Diameter (in)	Reactivity k-eff	Sigma	95% C.I. + bias	Input File
41	32.28	0.93139	0.00175	0.9422	sphr402
42	33.07	0.93596	0.00192	0.9468	sphr403
43	33.86	0.94398	0.00200	0.9549	sphr404
44	34.65	0.94241	0.00213	0.9534	sphr405
45	35.43	0.94811	0.00178	0.9589	sphr406
46	36.22	0.95547	0.00183	0.9663	sphr407
47	37.01	0.95713	0.00197	0.9680	sphr408
48	37.80	0.95874	0.00174	0.9695	sphr409
49	38.58	0.95994	0.00189	0.9708	sphr410
50	39.37	0.96908	0.00173	0.9799	sphr411

Table 5.6-6 1.25% Enriched UO₂ Solution Water Reflected Sphere Radius Versus Reactivity At An H/U Ratio Of 8.0

Radius (cm)	Diameter (in)	Reactivity k-eff	Sigma	95% C.I. + bias	Input File
40	31.50	0.91768	0.00180	0.9285	sphr501
41	32.28	0.92267	0.00178	0.9335	sphr502
42	33.07	0.92619	0.00196	0.9371	sphr503
43	33.86	0.93307	0.00173	0.9439	sphr504
44	34.65	0.94053	0.00148	0.9512	sphr505
45	35.43	0.94254	0.00196	0.9534	sphr506
46	36.22	0.94006	0.00179	0.9509	sphr507
47	37.01	0.94909	0.00178	0.9599	sphr508
48	37.80	0.95047	0.00178	0.9613	sphr509
49	38.58	0.95298	0.00190	0.9639	sphr510
50	39.37	0.95736	0.00195	0.9683	sphr511

Table 5.6-7 1.25% Enriched UO₂ Solution Water Reflected Sphere Radius Versus Reactivity At An H/U Ratio Of 9.0

Radius (cm)	Diameter (in)	Reactivity k-eff	Sigma	95% C.I. + bias	Input File
40	31.50	0.90540	0.00151	0.9161	sphr601
41	32.28	0.91156	0.00205	0.9225	sphr602
42	33.07	0.92056	0.00176	0.9314	sphr603
43	33.86	0.91788	0.00165	0.9286	sphr604
44	34.65	0.92562	0.00209	0.9366	sphr605
45	35.43	0.92721	0.00183	0.9381	sphr606
46	36.22	0.93340	0.00170	0.9442	sphr607
47	37.01	0.93237	0.00157	0.9431	sphr608
48	37.80	0.94299	0.00189	0.9539	sphr609
49	38.58	0.94264	0.00172	0.9534	sphr610
50	39.37	0.94413	0.00188	0.9550	sphr611

Table 5.6-8 1.25% Enriched UO₂ Solution Water Reflected Sphere Radius Versus Reactivity At An H/U Ratio Of 10.0

Radius (cm)	Diameter (in)	Reactivity k-eff	Sigma	95% C.I. + bias	Input File
40	31.50	0.89076	0.00186	0.9016	sphr701
41	32.28	0.89963	0.00178	0.9104	sphr702
42	33.07	0.90474	0.00183	0.9156	sphr703
43	33.86	0.90859	0.00158	0.9193	sphr704
44	34.65	0.91127	0.00164	0.9220	sphr705
45	35.43	0.91403	0.00160	0.9248	sphr706
46	36.22	0.92027	0.00158	0.9310	sphr707
47	37.01	0.92492	0.00179	0.9357	sphr708
48	37.80	0.92360	0.00181	0.9344	sphr709
49	38.58	0.93225	0.00172	0.9430	sphr710
50	39.37	0.93117	0.00160	0.9419	sphr711
51	40.16	0.94033	0.00185	0.9512	sphr712
52	40.94	0.94175	0.00150	0.9524	sphr713
53	41.73	0.94094	0.00186	0.9518	sphr714
54	42.52	0.94343	0.00147	0.9541	sphr715
55	43.31	0.95046	0.00168	0.9612	sphr716
56	44.09	0.95136	0.00154	0.9621	sphr717
57	44.88	0.95514	0.00167	0.9659	sphr718
58	45.67	0.95534	0.00165	0.9661	sphr719
59	46.46	0.95745	0.00157	0.9682	sphr720
60	47.24	0.96137	0.00178	0.9722	sphr721

Table 5.6-9 1.25% Enriched UO₂ Solution Water Reflected Sphere Radius Versus Reactivity At An H/U Ratio Of 11.0

Radius (cm)	Diameter (in)	Reactivity k-eff	Sigma	95% C.I. + bias	Input File
40	31.50	0.88175	0.00156	0.8925	sphr801
41	32.28	0.89149	0.00191	0.9024	sphr802
42	33.07	0.89084	0.00167	0.9016	sphr803
43	33.86	0.90261	0.00175	0.9134	sphr804
44	34.65	0.90214	0.00171	0.9129	sphr805
45	35.43	0.90577	0.00165	0.9165	sphr806
46	36.22	0.90201	0.00183	0.9129	sphr807
47	37.01	0.91128	0.00193	0.9222	sphr808
48	37.80	0.91677	0.00164	0.9275	sphr809
49	38.58	0.91404	0.00187	0.9249	sphr810
50	39.37	0.92237	0.00177	0.9332	sphr811
52	40.94	0.92975	0.00185	0.9406	sphr812
54	42.52	0.92990	0.00184	0.9407	sphr813
56	44.09	0.94124	0.00150	0.9519	sphr814
58	45.67	0.94517	0.00162	0.9559	sphr815
60	47.24	0.94647	0.00164	0.9572	sphr816
62	48.82	0.94697	0.00152	0.9577	sphr817
64	50.39	0.95126	0.00182	0.9621	sphr818
66	51.97	0.95593	0.00170	0.9667	sphr819
68	53.54	0.95925	0.00176	0.9701	sphr820
70	55.12	0.95997	0.00180	0.9708	sphr821

Table 5.6-10 1.25% Enriched UO₂ Solution Water Reflected Sphere, Summary Of Safe Radius And Uranium Mass At Various H/U Ratios

H/U	Radius (cm)	Diameter (in)	Uranium Mass		volume (cm³)	uranium	
			U-235 (kg)	Total U (kg)		density (g/cm³)	
3.00	48.16	37.93	21.6	1727.9	468036	4.607	
4.00	42.37	33.36	12.2	972.3	318657	3.923	
5.00	40.83	32.15	9.2	735.9	285161	3.416	
6.00	41.68	32.82	8.4	673.7	303202	3.025	
7.00	42.48	33.45	7.8	622.7	321023	2.714	
8.00	44.34	34.92	7.8	625.5	365251	2.461	
9.00	47.73	37.58	8.7	695.3	455499	2.252	
10.00	51.81	40.80	10.0	799.0	582603	2.075	
11.00	56.54	44.52	11.7	939.1	757017	1.924	
minimum	7.51	43.41	34.18	7.7	614.9	342633	2.579

**Figure 5.6-2 1.25% Enriched UO₂ Solution Reflected Sphere
Radius Versus Reactivity At An H/U Ratio Of
4.0**

**Figure 5.6-3 1.25% Enriched UO_2 Solution Reflected Sphere
Radius Versus Reactivity At An H/U Ratio Of
5.0**

**Figure 5.6-4 1.25% Enriched UO_2 Solution Reflected Sphere
Radius Versus Reactivity At An H/U Ratio Of
6.0**

**Figure 5.6-5 1.25% Enriched UO₂ Solution Reflected Sphere
Radius Versus Reactivity At An H/U Ratio Of
7.0**

Figure 5.6-6 1.25% Enriched UO_2 Solution Reflected Sphere Radius Versus Reactivity At An H/U Ratio Of 8.0

**Figure 5.6-7 1.25% Enriched UO₂ Solution Reflected Sphere
Radius Versus Reactivity At An H/U Ratio Of
9.0**

**Figure 5.6-8 1.25% Enriched UO_2 Solution Reflected Sphere
Radius Versus Reactivity At An H/U Ratio Of
10.0**

**Figure 5.6-9 1.25% Enriched UO_2 Solution Reflected Sphere
Radius Versus Reactivity At An H/U Ratio Of
11.0**

**Figure 5.6-10 1.25% Enriched UO_2 Solution Reflected Sphere
Uranium Safe Mass Versus H/U Ratio**

5.7 Optimum UO_2 and Resin Solution Mixture

Ion exchange resin contains appreciable hydrogen and thus acts as a neutron moderator. The solution mixtures of UO_2 , water, and ion exchange resins in the ion exchange module was evaluated to determine the most reactive mixture combination for further design calculations. The resin atom densities corresponded to NRW-37 nuclear grade mixed resin that will be used in the ion exchange vessels. The density of UO_2 , water, and resin were assumed to be 10.96, 1.0, and 0.92 gram per cm^3 , respectively. A representative set of material mass fractions and solution densities for various H/U ratios and resin volume fractions are listed in Table 5.7-1. The MCNP results for a range of resin fractions and H/U ratios is given in Table 5.7-2. The maximum reactivity values were shown graphically in Figure 5.7-1. The results of this study show that the highest reactivity occurs for a mixture that does not contain resin.

Table 5.7-1. Mass Fractions Of UO₂ Water And Resin Solutions At 1.25 Wt % ²³⁵U Enrichment

H/U	Volume Fraction resin	water	Solution Density (g/cm ³)	Mass Fractions				
				U-235	U-238	O	H	C
1	10	0.1944	8.0203	1.0625E-02	8.3939E-01	1.3580E-01	3.5995E-03	1.0583E-02
2	10	0.3434	6.5360	1.0285E-02	8.1249E-01	1.5727E-01	6.9683E-03	1.2986E-02
3	10	0.4404	5.5693	9.9652E-03	7.8725E-01	1.7741E-01	1.0128E-02	1.5240E-02
4	10	0.5087	4.8897	9.6651E-03	7.6354E-01	1.9634E-01	1.3097E-02	1.7359E-02
5	10	0.5593	4.3858	9.3824E-03	7.4121E-01	2.1416E-01	1.5893E-02	1.9353E-02
6	10	0.5983	3.9972	9.1159E-03	7.2015E-01	2.3097E-01	1.8529E-02	2.1234E-02
7	10	0.6293	3.6885	8.8640E-03	7.0026E-01	2.4685E-01	2.1020E-02	2.3011E-02
8	10	0.6545	3.4373	8.6257E-03	6.8143E-01	2.6187E-01	2.3377E-02	2.4693E-02
1	20	0.1210	7.7472	1.0585E-02	8.3621E-01	1.2771E-01	3.5859E-03	2.1912E-02
2	20	0.2644	6.3189	1.0237E-02	8.0871E-01	1.4726E-01	6.9359E-03	2.6865E-02
3	20	0.3578	5.3886	9.9108E-03	7.8296E-01	1.6556E-01	1.0073E-02	3.1502E-02
4	20	0.4234	4.7346	9.6050E-03	7.5880E-01	1.8273E-01	1.3016E-02	3.5854E-02
5	20	0.4721	4.2498	9.3175E-03	7.3608E-01	1.9887E-01	1.5783E-02	3.9945E-02
6	20	0.5097	3.8759	9.0467E-03	7.1469E-01	2.1408E-01	1.8389E-02	4.3798E-02
7	20	0.5395	3.5788	8.7912E-03	6.9450E-01	2.2843E-01	2.0847E-02	4.7433E-02
8	20	0.5637	3.3371	8.5497E-03	6.7543E-01	2.4198E-01	2.3171E-02	5.0869E-02
1	30	0.0476	7.4741	1.0542E-02	8.3279E-01	1.1903E-01	3.5712E-03	3.4069E-02
2	30	0.1854	6.1018	1.0185E-02	8.0465E-01	1.3653E-01	6.9011E-03	4.1731E-02
3	30	0.2751	5.2080	9.8527E-03	7.7836E-01	1.5288E-01	1.0013E-02	4.8893E-02
4	30	0.3382	4.5796	9.5409E-03	7.5373E-01	1.6820E-01	1.2929E-02	5.5601E-02
5	30	0.3850	4.1137	9.2482E-03	7.3061E-01	1.8258E-01	1.5665E-02	6.1898E-02
6	30	0.4210	3.7545	8.9730E-03	7.0887E-01	1.9610E-01	1.8239E-02	6.7820E-02
7	30	0.4497	3.4691	8.7137E-03	6.8838E-01	2.0884E-01	2.0664E-02	7.3400E-02
8	30	0.4730	3.2369	8.4690E-03	6.6905E-01	2.2087E-01	2.2952E-02	7.8666E-02
2	40	0.1064	5.8846	1.0130E-02	8.0030E-01	1.2501E-01	6.8638E-03	5.7694E-02
3	40	0.1924	5.0273	9.7903E-03	7.7343E-01	1.3929E-01	9.9500E-03	6.7533E-02
4	40	0.2529	4.4246	9.4723E-03	7.4831E-01	1.5265E-01	1.2836E-02	7.6732E-02
5	40	0.2978	3.9777	9.1743E-03	7.2477E-01	1.6517E-01	1.5540E-02	8.5352E-02
6	40	0.3324	3.6332	8.8944E-03	7.0266E-01	1.7692E-01	1.8079E-02	9.3447E-02
7	40	0.3599	3.3594	8.6312E-03	6.8186E-01	1.8798E-01	2.0468E-02	1.0106E-01

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8	40	0.3823	3.1366	8.3831E-03	6.6226E-01	1.9840E-01	2.2720E-02	1.0824E-01
2	50	0.0274	5.6675	1.0071E-02	7.9562E-01	1.1260E-01	6.8236E-03	7.4880E-02
3	50	0.1098	4.8467	9.7233E-03	7.6814E-01	1.2469E-01	9.8819E-03	8.7562E-02
4	50	0.1677	4.2696	9.3987E-03	7.4250E-01	1.3597E-01	1.2736E-02	9.9397E-02
5	50	0.2107	3.8417	9.0951E-03	7.1851E-01	1.4652E-01	1.5406E-02	1.1047E-01
6	50	0.2438	3.5118	8.8104E-03	6.9602E-01	1.5641E-01	1.7908E-02	1.2084E-01
7	50	0.2701	3.2497	8.5431E-03	6.7490E-01	1.6570E-01	2.0259E-02	1.3059E-01
8	50	0.2915	3.0364	8.2915E-03	6.5503E-01	1.7444E-01	2.2471E-02	1.3977E-01
3	60	0.0271	4.6661	9.6511E-03	7.6244E-01	1.0896E-01	9.8086E-03	1.0914E-01
4	60	0.0825	4.1146	9.3196E-03	7.3625E-01	1.1804E-01	1.2629E-02	1.2377E-01
5	60	0.1235	3.7057	9.0100E-03	7.1179E-01	1.2651E-01	1.5262E-02	1.3743E-01
6	60	0.1552	3.3905	8.7204E-03	6.8891E-01	1.3444E-01	1.7725E-02	1.5020E-01
7	60	0.1803	3.1400	8.4488E-03	6.6746E-01	1.4187E-01	2.0036E-02	1.6219E-01
8	60	0.2008	2.9362	8.1937E-03	6.4730E-01	1.4886E-01	2.2206E-02	1.7344E-01
5	70	0.0364	3.5697	8.9185E-03	7.0457E-01	1.0497E-01	1.5107E-02	1.6644E-01
6	70	0.0666	3.2691	8.6237E-03	6.8127E-01	1.1083E-01	1.7529E-02	1.8174E-01
7	70	0.0905	3.0303	8.3478E-03	6.5947E-01	1.1632E-01	1.9796E-02	1.9607E-01
8	70	0.1100	2.8360	8.0889E-03	6.3902E-01	1.2146E-01	2.1922E-02	2.0950E-01

Table 5.7-2. Reactivity Of Ion Exchange Module Versus Resin Volume And H/U Ratio. No Vessel Steel

File	Resin Volume %	H/U	keff	Sigma	95% C.I. +bias
E03	65	3.0	0.919	0.0020	0.930
E04	65	4.0	0.927	0.0020	0.938
E05	65	5.0	0.926	0.0020	0.937
E06	65	6.0	0.925	0.0017	0.935
E07	65	7.0	0.917	0.0019	0.928
E08	65	8.0	0.901	0.0017	0.912
C02	60	2.0	0.903	0.0020	0.914
C03	60	3.0	0.918	0.0020	0.929
C04	60	4.0	0.928	0.0019	0.939
C05	60	5.0	0.936	0.0017	0.946
C06	60	6.0	0.926	0.0020	0.937
C07	60	7.0	0.921	0.0017	0.931
C08	60	8.0	0.908	0.0015	0.919
D02	55	2.0	0.884	0.0021	0.895
D03	55	3.0	0.920	0.0019	0.931
D04	55	4.0	0.934	0.0019	0.945
D05	55	5.0	0.933	0.0017	0.943
D06	55	6.0	0.931	0.0019	0.942
D07	55	7.0	0.928	0.0020	0.938
D08	55	8.0	0.909	0.0019	0.920
B01	50	1.0	0.867	0.0019	0.878
B02	50	2.0	0.882	0.0019	0.893
B03	50	3.0	0.921	0.0020	0.932
B04	50	4.0	0.932	0.0019	0.943
B05	50	5.0	0.945	0.0016	0.955
B06	50	6.0	0.936	0.0017	0.947
B07	50	7.0	0.931	0.0016	0.941
B08	50	8.0	0.919	0.0017	0.929
F01	45	1.0	0.841	0.0019	0.851

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F02	45	2.0	0.882	0.0019	0.893
F03	45	3.0	0.924	0.0017	0.934
F04	45	4.0	0.939	0.0020	0.950
F05	45	5.0	0.940	0.0018	0.951
F06	45	6.0	0.937	0.0016	0.948
F07	45	7.0	0.932	0.0017	0.943
F08	45	8.0	0.915	0.0019	0.926
G01	40	1.0	0.819	0.0017	0.830
G02	40	2.0	0.887	0.0020	0.898
G03	40	3.0	0.929	0.0018	0.940
G04	40	4.0	0.937	0.0020	0.948
G05	40	5.0	0.945	0.0018	0.956
G06	40	6.0	0.937	0.0020	0.948
G07	40	7.0	0.931	0.0019	0.942
G08	40	8.0	0.920	0.0020	0.931
H01	35	1.0	0.784	0.0021	0.795
H02	35	2.0	0.891	0.0019	0.902
H03	35	3.0	0.932	0.0021	0.943
H04	35	4.0	0.945	0.0018	0.956
H05	35	5.0	0.947	0.0019	0.958
H06	35	6.0	0.940	0.0020	0.951
H07	35	7.0	0.937	0.0016	0.948
H08	35	8.0	0.925	0.0016	0.935
I01	30	1.0	0.756	0.0020	0.766
I02	30	2.0	0.901	0.0021	0.912
I03	30	3.0	0.935	0.0020	0.945
I04	30	4.0	0.953	0.0020	0.964
I05	30	5.0	0.952	0.0016	0.963
I06	30	6.0	0.948	0.0017	0.959
I07	30	7.0	0.934	0.0021	0.945
I08	30	8.0	0.928	0.0015	0.939
J01	25	1.0	0.728	0.0017	0.739
J02	25	2.0	0.899	0.0019	0.910
J03	25	3.0	0.938	0.0020	0.949
J04	25	4.0	0.954	0.0019	0.965
J05	25	5.0	0.954	0.0020	0.965

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J06	25	6.0	0.949	0.0019	0.960
J07	25	7.0	0.938	0.0019	0.949
J08	25	8.0	0.930	0.0019	0.941
K01	20	1.0	0.695	0.0016	0.706
K02	20	2.0	0.899	0.0020	0.910
K03	20	3.0	0.937	0.0019	0.947
K04	20	4.0	0.952	0.0017	0.963
K05	20	5.0	0.961	0.0019	0.972
K06	20	6.0	0.950	0.0021	0.961
K07	20	7.0	0.942	0.0019	0.953
K08	20	8.0	0.931	0.0019	0.941
L01	15	1.0	0.660	0.0015	0.671
L02	15	2.0	0.901	0.0019	0.912
L03	15	3.0	0.941	0.0023	0.952
L04	15	4.0	0.955	0.0022	0.966
L05	15	5.0	0.961	0.0018	0.972
L06	15	6.0	0.953	0.0018	0.964
L07	15	7.0	0.946	0.0021	0.957
L08	15	8.0	0.932	0.0017	0.943
M01	10	1.0	0.634	0.0015	0.644
M02	10	2.0	0.902	0.0022	0.913
M03	10	3.0	0.939	0.0022	0.950
M04	10	4.0	0.958	0.0020	0.969
M05	10	5.0	0.967	0.0020	0.978
M06	10	6.0	0.959	0.0019	0.970
M07	10	7.0	0.944	0.0021	0.955
M08	10	8.0	0.937	0.0017	0.948
N01	5	1.0	0.809	0.0020	0.820
N02	5	2.0	0.904	0.0019	0.914
N03	5	3.0	0.950	0.0020	0.961
N04	5	4.0	0.965	0.0021	0.976
N05	5	5.0	0.968	0.0019	0.978
N06	5	6.0	0.961	0.0020	0.972
N07	5	7.0	0.946	0.0018	0.957
N08	5	8.0	0.939	0.0018	0.950

HNF-SD-SNF-CSER-009 REV 0

A01	0	1.0	0.812	0.0016	0.823
A02	0	2.0	0.904	0.0022	0.915
A03	0	3.0	0.948	0.0019	0.959
A04	0	4.0	0.963	0.0021	0.974
A05	0	5.0	0.963	0.0018	0.974
A06	0	6.0	0.965	0.0018	0.975
A07	0	7.0	0.958	0.0020	0.969
A08	0	8.0	0.940	0.0015	0.951
A09	0	9.0	0.926	0.0017	0.937
A10	0	10.0	0.916	0.0017	0.926

Figure 5.7-1 Optimum Ion Exchange Module Reactivity Versus Resin Volume. No Vessel Steel.

5.8. Ion Exchange Module

The ion exchange module was evaluated to determine that the geometry is favorable for all combinations of UO_2 , water, and resin mixtures. The ion exchange vessels were modeled in three pairs in contact encased in concrete. The vessels were modeled with a maximum outer height of 107.32 cm (42.25 inches), an outer diameter of 40.64 cm (16 inches), and a wall thickness of 0.635 cm (0.25 inches). The vessel wall thickness was conservatively modeled as 2/3 of the nominal thickness of schedule 30 pipe. The vessels were surrounded by 30.5 cm (12 inches) of concrete which acts as an infinite medium reflector in the model.

The reactivity of the ion exchange module was determined for a range of H/U ratios of UO_2 at 1.25 wt% enriched ^{235}U with a resin volume of 0 %. This situation is the most limiting of the credible combinations. The results of this calculation is listed in Table 5.8-1, and is shown graphically in Figure 5.8-1. The maximum 95% C.I. reactivity of 0.916 occurred at a H/U ratio of 5.08. The reactivity of the ion exchange module is less than the criticality safety limit for all combinations of UO_2 , water, and resin mixtures. Therefore, the ion exchange module has been shown to be geometrically favorable.

Table 5.8-1. Reactivity Of Ion Exchange Module Versus H/U Ratio. Includes Vessel Steel

File	Resin Volume %	H/U	keff	95% C.I.	
				Sigma	+bias
Q02	0	2.0	0.840	0.0018	0.851
Q03	0	3.0	0.879	0.0019	0.890
Q04	0	4.0	0.904	0.0017	0.914
Q05	0	5.0	0.904	0.0018	0.915
Q06	0	6.0	0.902	0.0019	0.913
Q07	0	7.0	0.892	0.0017	0.903
Q08	0	8.0	0.879	0.0019	0.890

**Figure 5.8-1 Ion Exchange Module Reactivity Versus H/U Ratio
With No Resin. Vessel Steel Included.**

5.9. Filter With Resin Moderation

The filter was evaluated to determine the safe diameter for all combinations of UO_2 , water, and resin mixtures. The filter vessel was modeled as a cylinder surrounded by infinite water reflector beyond its radius, and reflective boundaries on each of its ends. A mixture with 5% resin volume was chosen as the limiting mixture as suggested in Figure 5.7-1. However, the results below showed that the mixture resulted in a lower reactivity and slightly greater vessel radius than the diameter of the receiver tank which was a similar calculation with no resin volume in Section 5.1. The results of this calculation with 5% resin volume is listed in Table 5.9-1 and shown graphically in Figure 5.9-1.

**Table 5.9-1. Filter Diameter MCNP Calculations.
1.25% Enriched Uranium Oxide
Solution, With 5% Resin Volume
Fraction.**

Radius (cm)	Input File	Reactivity		
		Mean	Sigma	95% C.I.
25	cylr201	0.897	0.00084	0.907
26	cylr202	0.907	0.00075	0.917
27	cylr203	0.914	0.00079	0.925
28	cylr204	0.922	0.00069	0.932
29	cylr205	0.930	0.00070	0.940
30	cylr206	0.937	0.00067	0.947
31	cylr207	0.942	0.00073	0.952
32	cylr208	0.948	0.00075	0.959
33	cylr209	0.954	0.00068	0.964
34	cylr210	0.958	0.00069	0.969
35	cylr211	0.963	0.00069	0.974

Figure 5.9-1. Filter Radius Versus Reactivity For A 1.25% Enriched Solution Of UO_2 With 5% Resin Volume Fraction.

The safe diameter from this calculation is shown in Table 5.9-2. However, the diameter was greater than the diameter determined in Section 5.5.1 for a similar calculation with no resin in the mixture. Therefore, the resin is not as good a moderator as water and the results of Section 5.5.1 will be used for filters or vessel that may contain resin.

Table 5.9-2. 1.25% Enriched Uranium Oxide, Water, and 5% Resin Volume Solution Safe Filter Radius and Diameter

Radius (cm)	Diameter (in)	95% C.L. + BIAS
30.49	24.01	0.95

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