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NUCLEAR CRITICALITY SAFETY REPORT

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Criticality Safety Review of Less Than 30" Cylinders During Transportation in the UX-30 Overpack

NCSR Approval

Nuclear Criticality Safety Organization

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1. INTRODUCTION

The East Tennessee Technology Park (ETTP) currently stores numerous UF_6 cylinders that are less than 30" in diameter. Several different models of less than 30" cylinders exist, including 12" cylinders (12A, modified 12A, and 12B), 8" cylinders (8A), 5" cylinders (5A), and smaller sample cylinders (1S, 2S, FAB3 and SAM). The ^{235}U mass and enrichment in the less than 30" cylinders varies widely, from less than 1% to 89% enriched, and from less than 1 gram to several kilograms. With the exception of the FAB3 and SAM cylinders, all of the less than 30" cylinders are recognized in ANSI N14.1-2001[1] as standard UF_6 cylinders. However, none of the cylinders addressed in this analysis are known to be fully compliant with the criteria provided in ANSI N14.1-2001, and the cylinders can therefore not be transported as ANSI N14.1-2001 compliant cylinders.

The less than 30" cylinders will be transported in the licensed UX-30 package, following approval of an amendment to the UX-30 Certificate of Compliance (CoC). One or more less than 30" cylinders will be placed inside a specially designed ASME pressure vessel (referred to as the "30 ECV"), which is then placed inside the UX-30 package for transport. The UX-30 will be licensed to transport one 30 ECV containing one or more less than 30" cylinders. The total quantity of ^{235}U will be limited based on the highest ^{235}U enrichment in any individual cylinder packaged in the 30 ECV.

The loaded UX-30 packages will be transported via exclusive use conveyance from the ETTP site in Oak Ridge, Tennessee to the Portsmouth Gaseous Diffusion Plant in Portsmouth, Ohio. Each exclusive use conveyance will transport up to five (5) loaded UX-30 packages.

This criticality safety review analyzes transportation of the less than 30" cylinders (packaged in the 30 ECV) in the UX-30 package, and determines the Criticality Safety Index (CSI) for the shipments. Because the 30 ECV containing one or more less than 30" cylinders is a non-standard UX-30 packaging configuration, the analysis herein assumes that water in-leakage to the 30 ECV is credible, and takes no credit for maintaining the less than 30" cylinder integrity (i.e., the 30 ECV is assumed to be the primary UF_6 container, which will be shown to be conservative from a criticality safety standpoint).

The U.S. regulations governing the packaging and transportation of fissile radioactive materials are contained in 10CFR71[2]. Under these regulations, packages with a CSI less than or equal to 50 may be shipped by a carrier in a non-exclusive use conveyance provided the sum of the CSIs for all packages on the conveyance is limited to less than or equal to 50, or shipped in an exclusive use conveyance provided the sum of the CSIs for all packages on the conveyance is limited to less than or equal to 100. Packages with a CSI greater than 50 must be shipped in an exclusive use conveyance with the sum of the CSIs for all packages on the conveyance limited to less than or equal to 100.

2. ANALYSIS METHODOLOGY

The total quantity of ^{235}U in a 30 ECV will be limited based on the ^{235}U enrichment. Three enrichment ranges are allowed, as shown below.

Maximum Enrichment in the 30 ECV	^{235}U Mass Limit
5%	1600 grams
15%	1000 grams
100%	800 grams

Since the ^{235}U mass and enrichment in the cylinders is typically determined by NDA measurements, it is important to note that measurement uncertainties must be appropriately incorporated into the assigned mass and enrichment values during loading of the cylinders.

For each enrichment range, a contents model is developed. The contents model is used to determine the most reactive geometry and moderation conditions inside the 30 ECV. This contents model is then used within the single unit models to demonstrate subcriticality of a single UX-30 package. Infinite array models for the UX-30 package containing a 30 ECV for each enrichment range are then used to demonstrate subcriticality under normal conditions of transport and hypothetical accident conditions.

All calculations in this analysis were performed using the CSAS25 control program of the SCALE-4.4 computer system. The CSAS25 module performs three dimensional nuclear criticality calculations using three programs, BONAMI-S, NITAWL-II, and KENO V.a. BONAMI-S and NITAWL-II are cross section processing codes used to determine resonance self-shielding of cross sections. KENO V.a calculates k_{eff} for three dimensional geometries using a Monte Carlo based computation. All calculations used the 238 group ENDF/B-V cross section library, with a minimum of 600 neutron generations and 500 neutrons per generation. The first 50 neutron generations were skipped, leaving 275,000 neutron histories per calculation.

The SCALE-4.4 code has been verified and validated (V&V) against benchmark experiments similar to the materials modeled. Installation verification is documented in Reference 3. The KENO V.a version of SCALE-4.4 has been verified using Intel X86 Family 15 Model 2 Stepping 9 processors at speeds of 2659 MHz or 2792 MHz. Verification was performed on PCs using Microsoft Windows 2000 Professional Version 5.0.2195 Service Pack 4 Build 2195 and 5.1.2195 Service Pack 4 Build 2195 as the operating systems.

The validation is documented in Reference 4 and was performed to meet the requirements of ANSI/ANS-8.1-1998. An area of applicability comparison is required to justify that the benchmark experiments selected to determine the bias and bias uncertainty of a criticality code are sufficiently similar to the system evaluated in the criticality safety analysis. This comparison is provided in Table 1 below. Bias and bias

uncertainty, when combined with a minimum subcritical margin (MSM), provide the upper subcritical limit for the analysis.

The fissile material form (UO_2F_2), reflector material (water), and moderating material (water and polyethylene) of the systems evaluated are clearly within the AOA. Enrichment is well within the AOA for the 5% enriched and 100% enriched calculations, but outside the AOA for LEU experiments for the 15% enriched calculations. The H/X ratio (i.e., the ratio of hydrogen atoms to ^{235}U atoms in the fuel) went beyond both the lower end and upper end of the AOA for the 5% enriched calculations, 15% enriched calculations, and 100% enriched calculations. However, the most reactive configurations for the 5% enriched calculations and 15% enriched calculations were well within the AOA (H/X of 593 and 725.5, respectively). For the 100% enriched calculations, the most reactive configurations were only slightly outside the AOA (H/X of 700 to 800). The S/X ratios (i.e., the ratio of light scattering elements [C, N, O and F] to ^{235}U atoms in the fuel) were outside the AOA at the lower end of the H/X range for the 5% enriched calculations and outside the AOA at both the lower end and upper end of the H/X range for the 15% enriched calculations and the 100% enriched calculations. For the 5% enriched calculations and 15% enriched calculations the S/X ratios were well within the AOA for the most reactive configurations (S/X ratios of 376 and 389.3 for the 5% enriched calculations and 15% enriched calculations, respectively). For the 100% enriched calculations, the most reactive configurations were slightly outside the AOA (S/X of 404 to 454). The average energy group (AEG) was also just slightly outside the AOA at the lower end of the H/X range for the 15% enriched calculations and the upper end of the H/X range for the 100% enriched calculations, but well within the AOA for the most reactive configurations (AEG of 218 and 220 for the 15% enriched and 100% enriched calculations, respectively). The average energy group was within the AOA throughout the entire H/X range for the 5% enriched calculations.

Based on the discussion above, the 5% enriched calculations are deemed to be within the AOA and a MSM of 0.03 may be appropriate, but a MSM of 0.05 is used consistent with NRC guidance. A subcritical value of 0.932 was selected for the 5% enriched calculations based on the validation. The 15% enriched calculations and 100% enriched calculations were outside the AOA in a few areas (including enrichment for the 15% enriched calculations and geometry for the 100% enriched calculations). The validation did not indicate a trend with respect to H/X, S/X or AEG. An additional MSM of 0.02 (for a total MSM of 0.05) was therefore applied to these cases to extend the AOA. The subcritical value for the 15% enriched calculations is therefore 0.932, while for the 100% enriched calculations the subcritical value is 0.943.

Table 1. SCALE 4.4a Validation Results

	LEU Experiments	HEU Experiments	5% Calculation Cases	15% Calculation Cases	100% Calculation Cases
Fissile Material Form	UF_4, UO_2F_2 Solutions and Compounds	UO_2F_2 Solutions	UO_2F_2 Solutions	UO_2F_2 Solutions	HEU UO_2F_2 Solutions
Reflector	Polyethylene, Paraffin, Water, or Unreflected	Water	Water, poly-ethylene	Water, poly-ethylene	Water, poly-ethylene
Moderating Material	Paraffin, water	Water	Water	Water	Water
Enrichment (wt% ^{235}U)	1-6	84-100	5	15	100
H/X Ratio	130-1700	30-533	99-2804	33-4587	5-5763
S/X Ratio	190-1725	20-280	128-1482	43-2321	6-2867
Average Energy Group	190-220	185-221	190-220	182-221	185-222
Geometry	Cylinders, slabs, spheres and arrays	Spheres	Cylinders, cylinder arrays	Cylinders	Cylinders, cylinder arrays
K_{eff}, bias and bias uncertainty	0.982	0.993	0.982	0.982	0.993
MSM	0.03	0.03	0.03	0.03	0.03
Additional MSM for extension of AOA	N/A	N/A	0.02	0.02	0.02
k_{sub}	0.952	0.963	0.932	0.932	0.943

3. LESS THAN 30" CYLINDER ANALYSIS

3.1 30 ECV DESCRIPTION

(NOTE: In the descriptions that follow, all dimensions are nominal. Manufacturing tolerances are given on the referenced drawings as ± 0.125" or less. These small tolerances have an insignificant effect on reactivity for individual packages of such large dimensions. For arrays of packages, manufacturing tolerances are compensated by assuming that the packages are in contact in a triangular pitch with significantly reduced outside dimensions, which in reality is not credible.)

The 30 ECV is an ASME pressure vessel specifically designed to be placed inside the UX-30 over pack. The construction of the 30 ECV is shown in drawings C-067-005311-004[5], C-067-005311-006[6], and C-067-005311-008[7]. It is a 20" outside diameter by 0.5" thick (for an inside diameter of 19") by 74" long carbon steel cylinder with a 2" thick, 30" OD welded top flange (for a total inside length of 76"). A 30" outside diameter by 2" thick plate is bolted to the top flange, while a 30" outside diameter by 2" thick plate is welded to the bottom of the carbon steel cylinder. A thin polyolefin "tape" (ingredients of polyethylene and a polyacrylate copolymer used as an acrylic adhesive) is applied to the inside surface of the cylinder to aid in sliding the insert (described below) in and out of the 30 ECV. High density foam (8-10 lbs./ft^3) is placed around the outside of the carbon steel cylinder at a thickness of 5" to occupy the space between the top and bottom plates. A thin (0.125" thick maximum) outer hard shell coating (protective paint or plastic) is rolled or sprayed onto the foam. The foam is a rigid, closed-cell polyurethane foam. While a specific chemical composition is not given, all polyurethanes contain C, H, O, N, and CH_2 (see Attachment C).

The UF_6 cylinders to be transported are placed in a steel/foam insert (see Reference 6) which is then loaded into the 30 ECV. The insert is constructed of steel and the same high density, rigid, closed-cell polyurethane foam described above. The insert is comprised of a lower half and a top half. The lower half is a 2" thick by 74.375" long foam hemicylinder with an inside radius of 7" and inside length of 70.25", surrounded by a 0.25" thick steel casing outside of the foam. One end is capped with a 0.5" thick by 18.5" diameter half-circular steel plate, and the other end is capped with a 0.75" thick by 18.5" diameter half-circular steel plate. Three nylon strips, each 0.1875" thick by 2" wide by 72" long, are adhered to the outside of the steel casing at approximately the 150°, 180°, and 210° positions, to aid in sliding the fully assembled steel/foam insert in and out of the 30 ECV. The top half of the steel/foam insert is a 2.125" thick by 75.375" long foam hemicylinder with an inside radius of 7" and inside length of 70.25", surrounded by an 11 gauge steel shell (approximately 0.12" thick) around the circumference and on both ends of the foam. All exposed foam surfaces are thinly coated with protective paint or plastic (thickness of 0.125" maximum).

The steel/foam insert is loaded with one or more less than 30" UF_6 cylinders and a low density packing material (e.g., polyethylene bubble wrap or fluoropolymer sheets that can be balled up and stuffed as dunnage) to protect the cylinders during transport. A simplified diagram of the 30 ECV is shown in Figure 1.

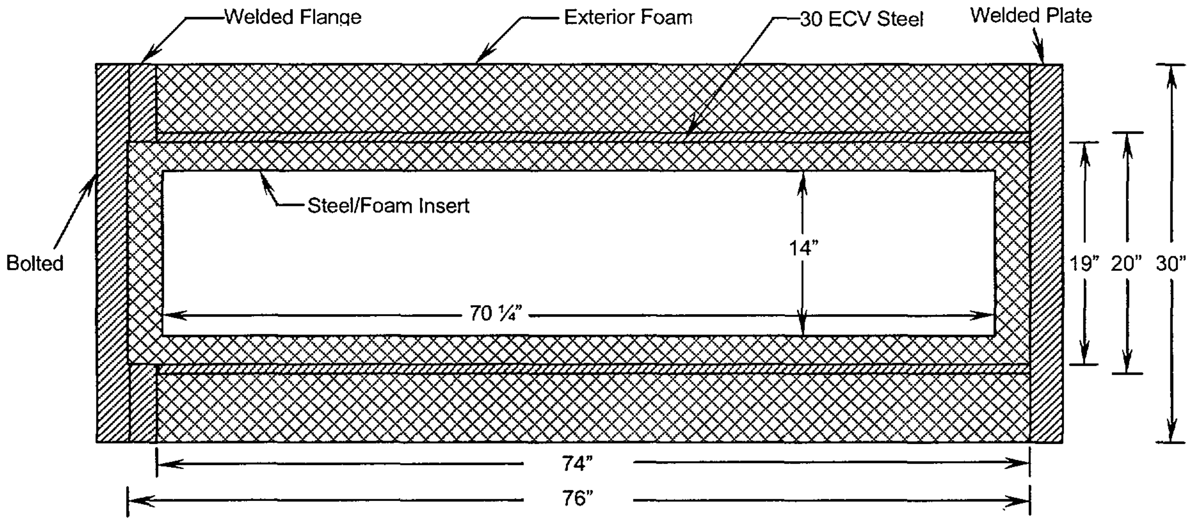

Figure 1: Simplified 30 ECV Diagram

3.2 UX-30 DESCRIPTION

The UX-30 is shown in drawing C-110-B-57922-0002[8], and is a large cylindrical vessel made of foam and thin gauge stainless steel. It has an outside diameter of 43.5", inside diameter of approximately 30.75", outside length of 96", and inside length of approximately 83". The outside foam surfaces are protected by 12 gauge stainless steel, and the inside foam surfaces are protected by minimum 14 gauge stainless steel. The chemical composition of the foam is 50-70% carbon, 14-34% oxygen, 4-12% nitrogen, 4-10% hydrogen, 0-2% phosphorus, less than 1% silicon, less than 1800 ppm chlorine, and less than 1% other constituents. The foam density is 8-10 lbs/ft^3. A simplified diagram of the UX-30 is shown in Figure 2.

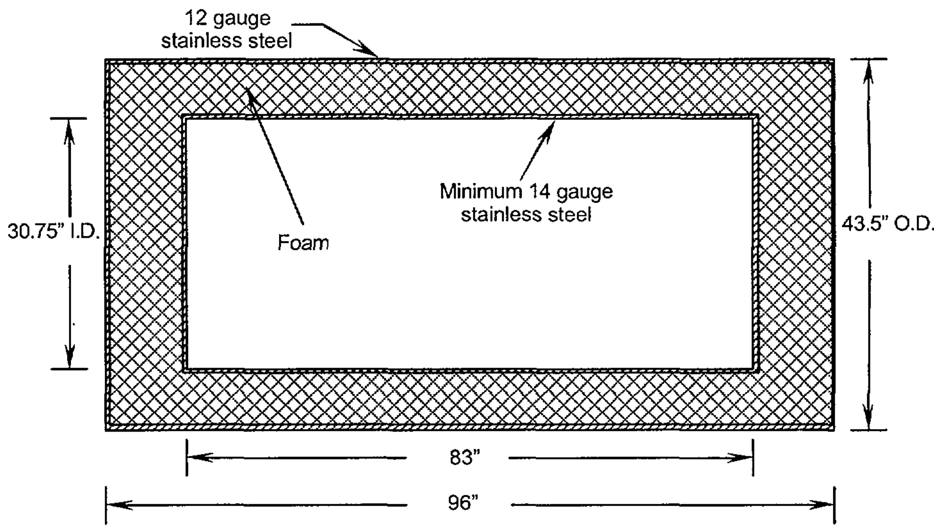

Figure 2: Simplified UX-30 Diagram

3.3 CONTENTS MODEL

The contents of the licensed UX-30 package under this amendment will be a 30 ECV containing any combination of less than 30" UF_6 cylinders and the associated packing materials, limited to a total ^{235}U mass based on the highest ^{235}U enrichment in any of the individual cylinders loaded in the 30 ECV. The 30 ECV will be allowed to contain a maximum of 800 grams ^{235}U at enrichments up to 100%, a maximum of 1000 grams ^{235}U at enrichments up to 15%, and a maximum of 1600 grams ^{235}U at enrichments up to 5%.

In order to determine the most reactive, realistic material geometry and an optimum moderation range within the 30 ECV, criticality calculations were performed. These calculations modeled the 30 ECV as a cylindrical container of polyethylene and steel construction, containing a UO_2F_2/water mixture at varying H/U ratios, with the remaining container volume occupied by void space. The polyethylene region has an inside diameter of 14", inside length of 70.25", outside diameter of 18.5", outside length of 76", and a density of approximately 12.5 lbs./ft^3. The polyethylene region is surrounded by carbon steel at a radial thickness of 0.25" (for an outside diameter of 19"), with 1" thick carbon steel caps on each end (for an outside length of 78"). The 30 ECV model is then surrounded by 12"of full density water.

The UO_2F_2-water mixture bounds the actual configuration of fissionable material in the event of water inleakage. The contents model takes no credit for the steel cylinders that are present in the interior of the 30 ECV, which act as a neutron absorber and diluent. Given the limited volume of the individual cylinders as compared to the volume of the 30 ECV, more reactive conditions are not attainable if the fissionable material remains in the individual cylinders. Also, since the configuration of individual cylinders that can

physically fit inside the 30 ECV is limited, there is no potential that the interaction of water-moderated cylinders inside the 30 ECV can be more reactive than the contents model.

The polyethylene bounds the 30 ECV steel/foam insert described in Section 3.1 for the contents model. The foam used in the construction of the 30 ECV contains nitrogen and oxygen, has a lower hydrogen to carbon ratio, and is less dense (8-10 lbs/ft^3) than the polyethylene used in the contents model. The polyethylene in the contents model will therefore provide better neutron reflection than the actual foam (variations in the polyethylene density is considered in the array calculations of Section 3.5). The polyethylene will also bound the thin coating present on the inside surfaces of the foam for similar reasons. Also, the steel used to contain the lower half and top half of the insert (ASTM A36 carbon steel) is not included in the model. While steel can act as an effective reflector, neglecting these relatively thin layers of steel in the contents model will not have a significant impact (the fissile material is reflected by the polyethylene and full density water). In the subsequent array models, neglecting the steel is also conservative due to the replacement of a higher density, more neutron-absorbing material (carbon steel) with a lower density, less neutron-absorbing material (polyethylene).

The steel of the 30 ECV (SA-516 Grade 70 carbon steel) is modeled at half the actual thickness (both radially and on the top and bottom heads), and also does not include the entire diameter of the top and bottom heads. Again, neglecting a portion of the steel will not have a significant impact in the contents model, and is conservative in the subsequent array models due to the replacement of a higher density, more neutron-absorbing material (carbon steel) with a lower density, less neutron-absorbing material (polyethylene, as described later in the single unit and array models). The foam that is present around the outside of the 30 ECV is also replaced by the full density water reflector. This is conservative for the contents model since the foam is much less dense (8-10 lbs/ft^3) than full density water (62 lbs/ft^3), and the increased hydrogen content in the full density water will bound the reflecting/ properties of the hydrogen and carbon in the lower density foam.

Two material geometry conditions were compared, one based on a vertically oriented 30 ECV and the other based on a horizontally oriented 30 ECV. The modeled material geometries are shown in Figure 3 and Figure 4 below.

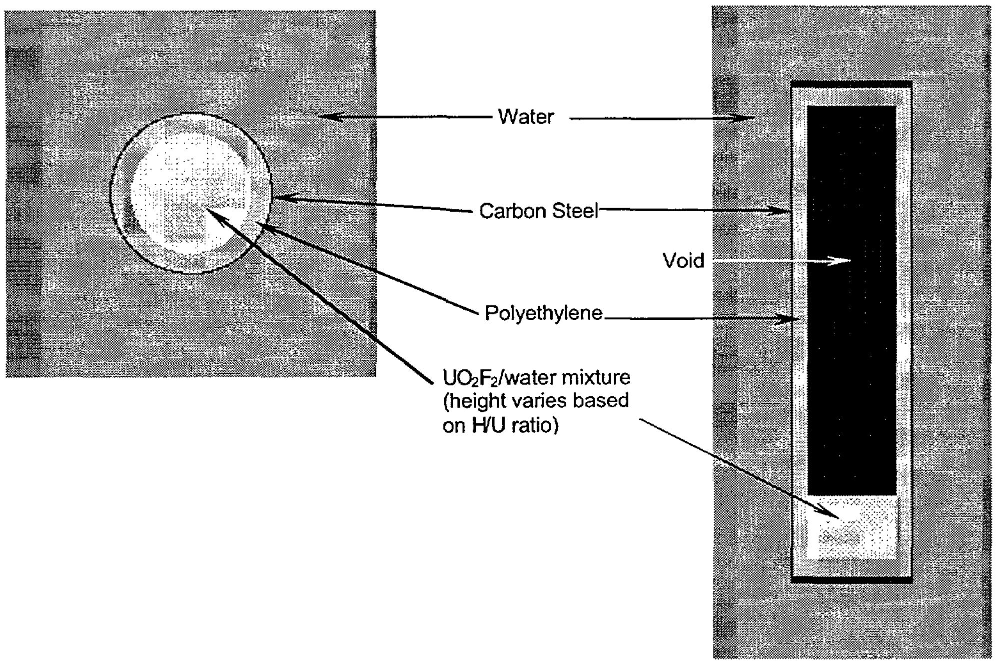

Figure 3: Vertically Oriented 30 ECV Contents Model

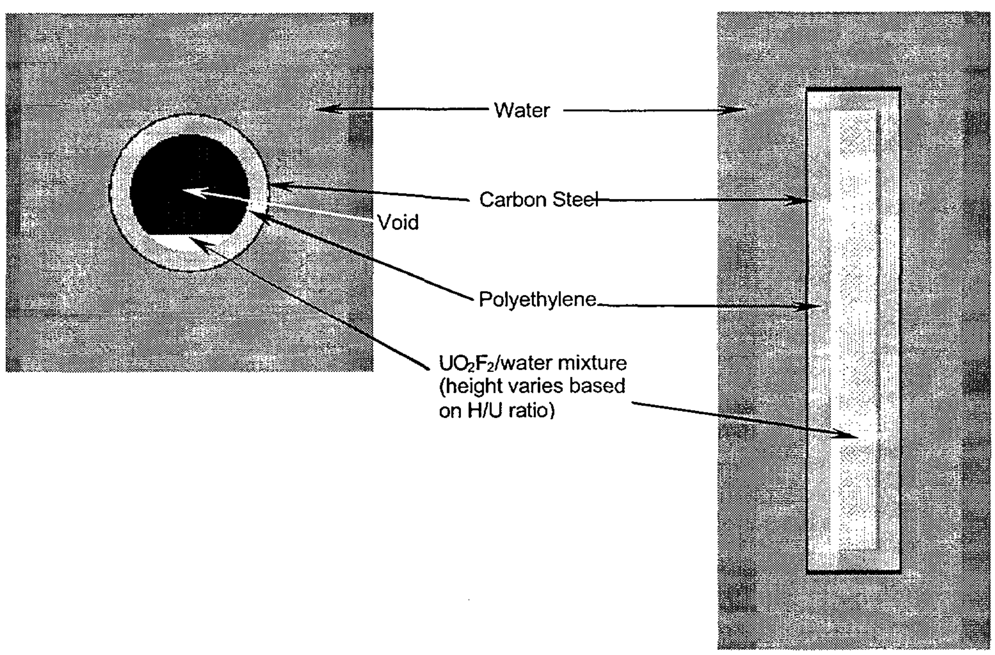

Figure 4: Horizontally Oriented 30 ECV Contents Model

Figure 3 represents the material configuration expected in a vertically oriented 30 ECV containing a liquid mixture of UO_2F_2 and water, as would occur upon water in-leakage to the 30 ECV ($UF_6 + 2H_2O \Rightarrow UO_2F_2 + 4HF$). Figure 4 represents the material configuration expected in a horizontally oriented cylinder containing a liquid mixture of UO_2F_2 and water (again under water in-leakage conditions). These material configurations are considered bounding of all other configurations (e.g., cylinders tilted between horizontal and vertical orientation) since they place the fissile material in more ideal geometries with increased neutron interaction between multiple cylinders when placed in an array. As previously discussed, the configurations are also considered bounding of the normal condition of transport in which the fissile material remains inside of the individual UF_6 cylinders within the 30 ECV. Splitting the same amount of material into smaller volume UF_6 cylinders decreases the amount of moderation that can be added to the material, and increases the neutron leakage from the fissile material regions (by creating more surface area from which the neutrons can escape).

The results of the calculations at each enrichment and mass limit are given in Tables 2 through 4 and shown graphically in Figures 5 through 7. Each enrichment, mass and geometry was analyzed at various H/U ratios (i.e., varying internal moderation) to determine the most reactive geometry. The last H/U value shown is that corresponding to a full inner cylinder.

Table 2: Contents Model Calculation Results for 5% Enriched (UO_2F_2/Water Mixture, 1600 grams of 5 wt % ^{235}U in a 30 ECV)

Case	Material Geometry	H/U	H/X	S/X	UO_2F_2 Density (g/cc)	H_2O Density (g/cc)	Fissile Material Height (cm)	K_{eff}	σ	K_{eff} + 2σ	K_{sub}	Average Energy Group
5p_contents_vertical_hu5	Vertical	5	98.8	128.5	3.7867	0.5539	11.0125	0.5054	0.0015	0.5084	0.932	190.2
5p_contents_vertical_hu10	Vertical	10	197.6	177.9	2.4348	0.7123	17.1267	0.7301	0.0016	0.7333	0.932	204.8
5p_contents_vertical_hu15	Vertical	15	296.4	227.3	1.7943	0.7874	23.2409	0.8372	0.0020	0.8412	0.932	210.2
5p_contents_vertical_hu20	Vertical	20	395.2	276.7	1.4206	0.8312	29.3551	0.8899	0.0020	0.8939	0.932	213.1
5p_contents_vertical_hu25	Vertical	25	494.0	326.2	1.1757	0.8599	35.4693	0.9115	0.0018	0.9151	0.932	214.8
5p_contents_vertical_hu30	**Vertical**	**30**	**592.8**	**375.6**	**1.0028**	**0.8801**	**41.5835**	**0.9159**	**0.0017**	**0.9193**	**0.932**	**215.9**
5p_contents_vertical_hu35	Vertical	35	691.6	425.0	0.8743	0.8952	47.6977	0.9099	0.0016	0.9131	0.932	216.7
5p_contents_vertical_hu40	Vertical	40	790.4	474.4	0.7749	0.9068	53.8119	0.8959	0.0013	0.8985	0.932	217.3
5p_contents_vertical_hu45	Vertical	45	889.2	523.8	0.6959	0.9161	59.9261	0.8834	0.0016	0.8866	0.932	217.8
5p_contents_vertical_hu50	Vertical	50	988.0	573.3	0.6314	0.9237	66.0403	0.8643	0.0014	0.8671	0.932	218.2
5p_contents_vertical_hu80	Vertical	80	1580.8	869.9	0.4059	0.9501	102.7256	0.7535	0.0013	0.7561	0.932	219.5
5p_contents_vertical_hufull	Vertical	142	2804.2	1,481.8	0.2337	0.9703	178.4350	0.5776	0.0008	0.5792	0.932	220.4
5p_contents_horizontal_hu5	Horizontal	5	98.8	128.5	3.7867	0.5539	3.9946	0.2196	0.0009	0.2214	0.932	193.3
5p_contents_horizontal_hu10	Horizontal	10	197.6	177.9	2.4348	0.7123	5.4091	0.2928	0.0011	0.2950	0.932	203.2
5p_contents_horizontal_hu50	Horizontal	50	988.0	573.3	0.6314	0.9237	14.1266	0.5854	0.0013	0.5880	0.932	217.6
5p_contents_horizontal_hu80	Horizontal	80	1580.8	869.9	0.4059	0.9501	19.8993	0.6143	0.0011	0.6165	0.932	219.2
5p_contents_horizontal_hufull	Horizontal	142	2804.2	1481.8	0.2337	0.9703	35.5600	0.5789	0.0008	0.5805	0.932	220.4

Table 3: Contents Model Calculation Results for 15% Enriched (UO_2F_2/Water Mixture, 1000 grams of 15 wt % ^{235}U in a 30 ECV)

Case	Material Geometry	H/U	H/X	S/X	UO_2F_2 Density (g/cc)	H_2O Density (g/cc)	Fissile Material Height (cm)	K_{eff}	σ	$K_{eff} + 2\sigma$	K_{sub}	Average Energy Group
15p_contents_vertical_hu5	Vertical	5	33.0	42.9	3.7830	0.5539	2.2972	0.1923	0.0010	0.1943	0.932	181.7
15p_contents_vertical_hu10	Vertical	10	66.0	59.4	2.4324	0.7123	3.5726	0.2627	0.0011	0.2649	0.932	191.3
15p_contents_vertical_hu50	Vertical	50	329.8	191.3	0.6308	0.9237	13.7760	0.7547	0.0018	0.7583	0.932	214.1
15p_contents_vertical_hu100	Vertical	100	659.5	356.2	0.3276	0.9592	26.5302	0.8886	0.0018	0.8922	0.932	218.1
15p_contents_vertical_hu110	**Vertical**	**110**	**725.5**	**389.3**	**0.2988**	**0.9626**	**29.0810**	**0.8944**	**0.0015**	**0.8974**	**0.932**	**218.5**
15p_contents_vertical_hu120	Vertical	120	791.4	422.3	0.2747	0.9654	31.6319	0.8915	0.0015	0.8945	0.932	218.8
15p_contents_vertical_hu130	Vertical	130	857.4	455.3	0.2542	0.9678	34.1827	0.8866	0.0015	0.8896	0.932	219.0
15p_contents_vertical_hu140	Vertical	140	923.3	488.2	0.2366	0.9699	36.7336	0.8827	0.0016	0.8859	0.932	219.2
15p_contents_vertical_hu150	Vertical	150	989.3	521.3	0.2212	0.9717	39.2844	0.8733	0.0015	0.8763	0.932	219.4
15p_contents_vertical_hu160	Vertical	160	1055.2	554.3	0.2077	0.9733	41.8353	0.8655	0.0017	0.8689	0.932	219.6
15p_contents_vertical_hu170	Vertical	170	1121.2	587.2	0.1958	0.9747	44.3861	0.8535	0.0017	0.8569	0.932	219.7
15p_contents_vertical_hu180	Vertical	180	1187.1	620.3	0.1851	0.9759	46.9369	0.8439	0.0014	0.8467	0.932	219.9
15p_contents_vertical_hu190	Vertical	190	1253.1	653.2	0.1756	0.9771	49.4878	0.8348	0.0015	0.8378	0.932	220.0
15p_contents_vertical_hu200	Vertical	200	1319.0	686.2	0.1670	0.9781	52.0386	0.8222	0.0016	0.8254	0.932	220.1
15p_contents_vertical_hu300	Vertical	300	1978.5	1,015.7	0.1121	0.9845	77.5470	0.7106	0.0011	0.7128	0.932	220.7
15p_contents_vertical_hu400	Vertical	400	2638.0	1,346.4	0.0843	0.9878	103.0555	0.6186	0.0009	0.6204	0.932	221.0
15p_contents_vertical_hu500	Vertical	500	3297.5	1,675.7	0.0676	0.9897	128.5639	0.5436	0.0008	0.5452	0.932	221.2
15p_contents_vertical_hufull	Vertical	696	4586.9	2,321.1	0.0487	0.9920	178.4350	0.4413	0.0007	0.4427	0.932	221.4
15p_contents_horizontal_hu5	Horizontal	5	33.0	42.9	3.7828	0.5539	1.3835	0.1210	0.0007	0.1224	0.932	192.8
15p_contents_horizontal_hu10	Horizontal	10	66.0	59.4	2.4324	0.7123	1.8623	0.1400	0.0008	0.1416	0.932	199.0
15p_contents_horizontal_hu50	*Horizontal*	*50*	*329.8*	*191.3*	*0.6308*	*0.9237*	*4.6564*	*0.2674*	*0.0012*	*0.2698*	*0.932*	*213.1*
15p_contents_horizontal_hu100	Horizontal	100	659.5	356.2	0.3276	0.9592	7.3308	0.3822	0.0013	0.3848	0.932	217.2
15p_contents_horizontal_hu500	Horizontal	500	3297.5	1675.7	0.0676	0.9897	24.0725	0.4855	0.0008	0.4871	0.932	221.2
15p_contents_horizontal_hufull	Horizontal	696	4586.9	2321.1	0.0487	0.9920	35.5600	0.4403	0.0007	0.4417	0.932	221.4

Table 4: Contents Model Calculation Results for 100% Enriched (UO_2F_2/Water Mixture, 800 grams of 100 wt % ^{235}U in a 30 ECV)

Case	Material Geometry	H/U	H/X	S/X	UO_2F_2 Density (g/cc)	H_2O Density (g/cc)	Fissile Material Height (cm)	K_{eff}	σ	K_{eff} + 2σ	K_{sub}	Average Energy Group
100p_contents_vertical_hu5	Vertical	5	5	6.5	3.7516	0.5539	0.2787	0.1237	0.0008	0.1253	0.943	188.4
100p_contents_vertical_hu10	Vertical	10	10	9.0	2.4123	0.7123	0.4334	0.1297	0.0008	0.1313	0.943	190.2
100p_contents_vertical_hu50	Vertical	50	50	29.0	0.6256	0.9237	1.6711	0.1832	0.0009	0.1850	0.943	197.3
100p_contents_vertical_hu100	Vertical	100	100	54.0	0.3248	0.9592	3.2182	0.2863	0.0014	0.2891	0.943	204.0
100p_contents_vertical_hu500	Vertical	500	500	254.2	0.0670	0.9897	15.5951	0.8250	0.0021	0.8292	0.943	217.7
100p_contents_vertical_hu600	Vertical	600	600	304.3	0.0559	0.9910	18.6893	0.8606	0.0018	0.8642	0.943	218.5
100p_contents_vertical_hu700	Vertical	700	700	354.1	0.0480	0.9920	21.7836	0.8777	0.0017	0.8811	0.943	219.0
100p_contents_vertical_hu800	**Vertical**	**800**	**800**	**404.4**	**0.0420**	**0.9927**	**24.8778**	**0.8836**	**0.0016**	**0.8868**	**0.943**	**219.4**
100p_contents_vertical_hu900	Vertical	900	900	453.9	0.0374	0.9932	27.9720	0.8817	0.0017	0.8851	0.943	219.7
100p_contents_vertical_hu1000	Vertical	1000	1000	503.5	0.0337	0.9937	31.0663	0.8753	0.0014	0.8781	0.943	220.0
100p_contents_vertical_hu1100	Vertical	1100	1100	554.3	0.0306	0.9940	34.1605	0.8648	0.0016	0.8680	0.943	220.2
100p_contents_vertical_hu1200	Vertical	1200	1200	603.4	0.0281	0.9943	37.2547	0.8491	0.0016	0.8523	0.943	220.3
100p_contents_vertical_hu1300	Vertical	1300	1300	654.5	0.0259	0.9946	40.3490	0.8347	0.0015	0.8377	0.943	220.5
100p_contents_vertical_hu1400	Vertical	1400	1400	703.2	0.0241	0.9948	43.4432	0.8174	0.0013	0.8200	0.943	220.6
100p_contents_vertical_hu1500	Vertical	1500	1500	753.1	0.0225	0.9950	46.5374	0.8039	0.0011	0.8061	0.943	220.7
100p_contents_vertical_hu2000	Vertical	2000	2000	1,002.0	0.0169	0.9957	62.0086	0.7199	0.0012	0.7223	0.943	221.1
100p_contents_vertical_hu3000	Vertical	3000	3000	1,510.9	0.0112	0.9963	92.9509	0.5842	0.0010	0.5862	0.943	221.4
100p_contents_vertical_hu4000	Vertical	4000	4000	2,014.0	0.0084	0.9967	123.8932	0.4899	0.0007	0.4913	0.943	221.6
100p_contents_vertical_hufull	Vertical	5763	5763	2,866.5	0.0059	0.9970	178.4350	0.3813	0.0006	0.3825	0.943	221.8
100p_contents_horizontal_hu5	Horizontal	5	5	6.5	3.7516	0.5539	0.3370	0.0768	0.0006	0.0780	0.943	185.3
100p_contents_horizontal_hu10	Horizontal	10	10	9.0	2.4123	0.7123	0.4526	0.0822	0.0006	0.0834	0.943	191.3
100p_contents_horizontal_hu50	Horizontal	50	50	29.0	0.6256	0.9237	1.1173	0.1074	0.0008	0.1090	0.943	204.2
100p_contents_horizontal_hu100	Horizontal	100	100	54.0	0.3248	0.9592	1.7356	0.1327	0.0007	0.1341	0.943	208.7
100p_contents_horizontal_hu500	Horizontal	500	500	254.2	0.0670	0.9897	5.0708	0.2840	0.0011	0.2862	0.943	217.0
100p_contents_horizontal_hu1000	Horizontal	1000	1000	503.5	0.0337	0.9937	8.1905	0.3897	0.0011	0.3919	0.943	219.4
100p_contents_horizontal_hu2000	Horizontal	2000	2000	1002.0	0.0169	0.9957	13.4789	0.4563	0.0011	0.4585	0.943	220.8
100p_contents_horizontal_hu3000	Horizontal	3000	3000	1510.9	0.0112	0.9963	18.3645	0.4497	0.0009	0.4515	0.943	221.3
100p_contents_horizontal_hu4000	Horizontal	4000	4000	2014.0	0.0084	0.9967	23.2973	0.4264	0.0008	0.4280	0.943	221.5
100p_contents_horizontal_hufull	Horizontal	5763	5763	2866.5	0.0059	0.9970	35.5600	0.3815	0.0006	0.3827	0.943	221.8

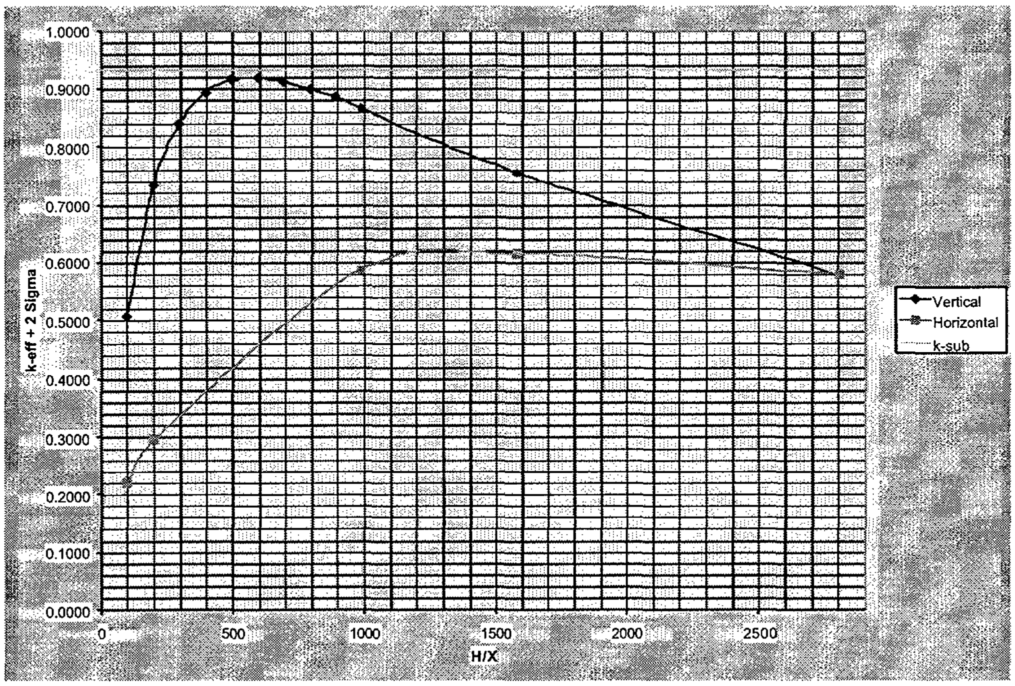

Figure 5: Contents Model Calculation Results for 5% Enriched (UO_2F_2/Water Mixture, 1600 grams of 5 wt % ^{235}U in a 30 ECV)

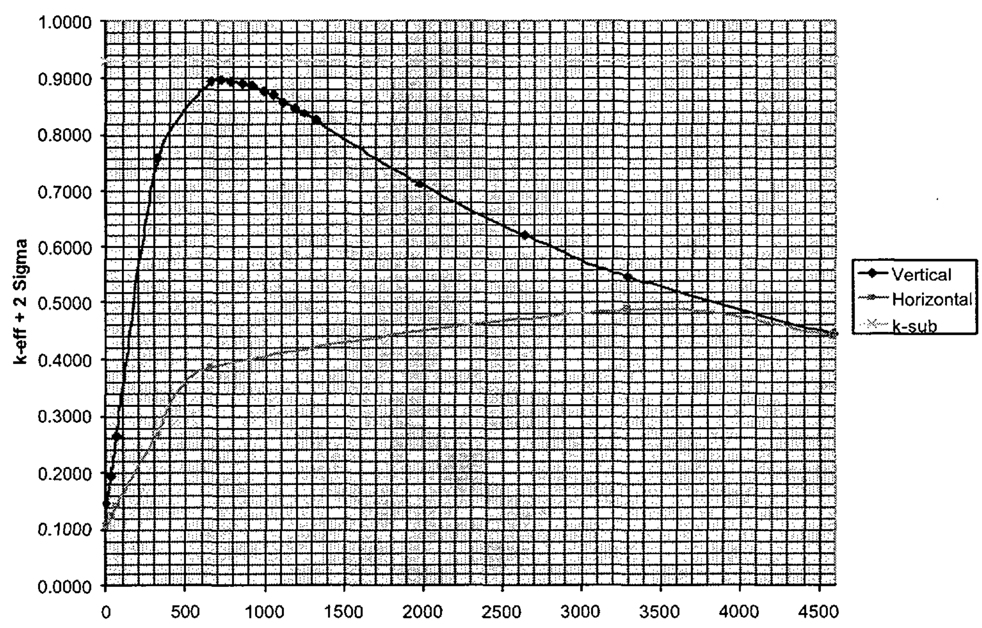

Figure 6: Contents Model Calculation Results for 15% Enriched (UO_2F_2/Water Mixture, 1000 grams of 15 wt % ^{235}U in a 30 ECV)

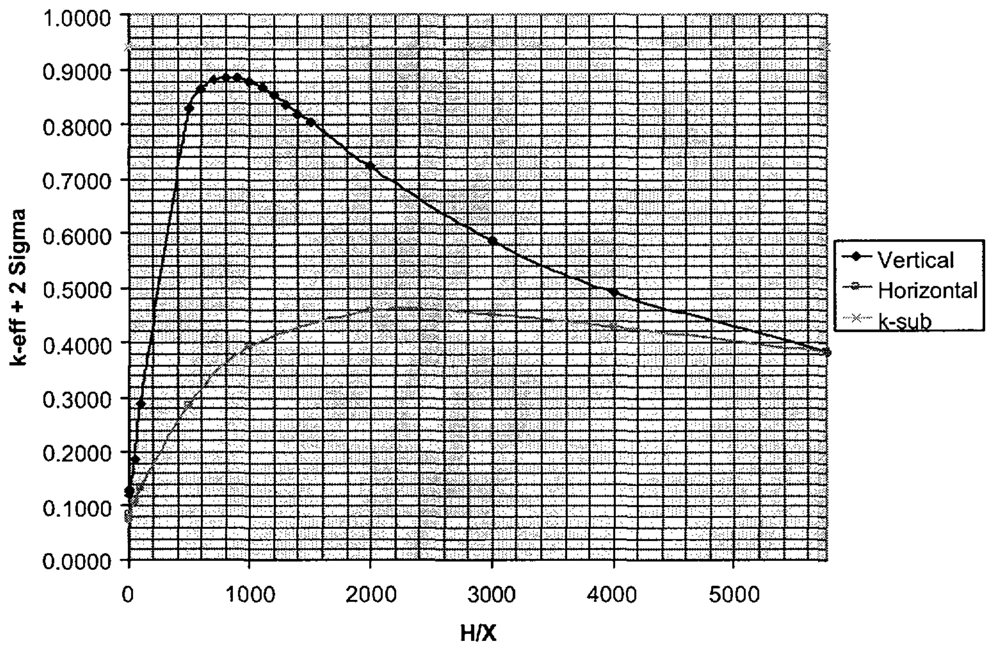

Figure 7: Contents Model Calculation Results for 100% Enriched (UO_2F_2/Water Mixture, 800 grams of 100 wt % ^{235}U in a 30 ECV)

The results shown in Figures 5 through 7 clearly indicate that the vertically oriented 30 ECV results in the most reactive material configuration, particularly at optimum H/U ratios, regardless of the ^{235}U enrichment/mass combinations modeled. These results can also be used to determine the optimum moderation conditions for each ^{235}U enrichment/mass combination modeled. Optimum moderation occurs for the 5% enriched calculations at an H/U ratio of ~30 (H/X = 593), for the 15% enriched calculations at an H/U ratio of ~110 (H/X = 725), and for the 100% enriched calculations at an H/U ratio of ~800 (H/X = 800).

As previously mentioned (and shown in Figure 3), the remaining space in the 30 ECV (i.e., above the UO_2F_2/water mixture) was modeled as void in the vertically oriented configuration. However, water in-leakage into the 30 ECV would, potentially, not only result in internal moderation of the fissile material (as accounted for in the modeled UO_2F_2/water mixtures), but also reflection of the material by water filling the remaining space above the UO_2F_2/water mixture in the 30 ECV. To demonstrate subcriticality under these conditions, the optimum moderation conditions in a range around the optimum previously calculated for each ^{235}U enrichment/mass combination above were run with varying density water in the remaining 30 ECV space. Water at 25%, 50%, 75% and full density was modeled. The results of these cases are shown in Tables 5 though 7 and Figures 8 through 10 below.

Table 5: Contents Model Calculation Results for Varying Water Density in the 30 ECV (UO_2F_2/Water Mixtures near Optimum H/U, 1600 grams of 5 wt%)

Case	^{235}U wt. %	^{235}U Mass (g)	H/U	H/X	S/X	30 ECV Internal Water Density	K_{eff}	σ	K_{eff} + 2σ	K_{sub}	Average Energy Group
5p_contents_vertical_hu20	5	1600	20	395.2	276.7	Void	0.8899	0.0020	0.8939	0.932	213.1
5p_contents_vertical_hu20_25	5	1600	20	395.2	276.7	25%	0.9027	0.0017	0.9061	0.932	213.3
5p_contents_vertical_hu20_50	5	1600	20	395.2	276.7	50%	0.9129	0.0016	0.9161	0.932	213.3
5p_contents_vertical_hu20_75	5	1600	20	395.2	276.7	75%	0.9135	0.0015	0.9165	0.932	213.4
5p_contents_vertical_hu20_100	5	1600	20	395.2	276.7	100%	0.9182	0.0018	0.9218	0.932	213.4
5p_contents_vertical_hu25	5	1600	25	494.0	326.2	Void	0.9115	0.0018	0.9151	0.932	214.8
5p_contents_vertical_hu25_25	5	1600	25	494.0	326.2	25%	0.9231	0.0017	0.9265	0.932	214.9
5p_contents_vertical_hu25_50	5	1600	25	494.0	326.2	50%	0.9280	0.0016	0.9312	0.932	214.9
5p_contents_vertical_hu25_75	5	1600	25	494.0	326.2	75%	0.9278	0.0016	0.9310	0.932	214.9
5p_contents_vertical_hu25_100	5	1600	25	494.0	326.2	100%	0.9257	0.0016	0.9289	0.932	214.9
5p_contents_vertical_hu30	5	1600	30	592.8	375.6	Void	0.9159	0.0017	0.9193	0.952	215.9
5p_contents_vertical_hu30_25	5	1600	30	592.8	375.6	25%	0.9220	0.0018	0.9256	0.952	216.0
5p_contents_vertical_hu30_50	5	1600	30	592.8	375.6	50%	0.9238	0.0017	0.9272	0.952	216.0
5p_contents_vertical_hu30_75	5	1600	30	592.8	375.6	75%	0.9254	0.0018	0.9290	0.952	216.0
5p_contents_vertical_hu30_100	5	1600	30	592.8	375.6	100%	0.9281	0.0015	0.9311	0.952	216.0
5p_contents_vertical_hu35	5	1600	35	691.6	425.0	Void	0.9099	0.0016	0.9131	0.932	216.7
5p_contents_vertical_hu35_25	5	1600	35	691.6	425.0	25%	0.9115	0.0016	0.9147	0.932	216.8
5p_contents_vertical_hu35_50	5	1600	35	691.6	425.0	50%	0.9151	0.002	0.9191	0.932	216.8
5p_contents_vertical_hu35_75	5	1600	35	691.6	425.0	75%	0.9142	0.0016	0.9174	0.932	216.8
5p_contents_vertical_hu35_100	5	1600	35	691.6	425.0	100%	0.9167	0.0016	0.9199	0.932	216.8
5p_contents_vertical_hu40	5	1600	40	790.4	474.4	Void	0.8959	0.0013	0.8985	0.932	217.3
5p_contents_vertical_hu40_25	5	1600	40	790.4	474.4	25%	0.9010	0.0016	0.9042	0.932	217.4
5p_contents_vertical_hu40_50	5	1600	40	790.4	474.4	50%	0.9013	0.0016	0.9045	0.932	217.4
5p_contents_vertical_hu40_75	5	1600	40	790.4	474.4	75%	0.9029	0.0016	0.9061	0.932	217.4
5p_contents_vertical_hu40_100	5	1600	40	790.4	474.4	100%	0.9046	0.0016	0.9078	0.932	217.4

Table 6: Contents Model Calculation Results for Varying Water Density in the 30 ECV (UO_2F_2/Water Mixtures near Optimum H/U, 1000 grams of 15 wt%)

Case	^{235}U wt. %	^{235}U Mass (g)	H/U	H/X	S/X	30 ECV Internal Water Density	K_{eff}	σ	K_{eff} + 2σ	K_{sub}	Average Energy Group
15p_contents_vertical_hu90	15	1000	90	593.6	323.2	Void	0.8848	0.0018	0.8884	0.932	217.6
15p_contents_vertical_hu90_25	15	1000	90	593.6	323.2	25%	0.9026	0.0016	0.9058	0.932	217.7
15p_contents_vertical_hu90_50	15	1000	90	593.6	323.2	50%	0.9112	0.0019	0.9150	0.932	217.8
15p_contents_vertical_hu90_75	15	1000	90	593.6	323.2	75%	0.9144	0.0016	0.9176	0.932	217.8
15p_contents_vertical_hu90_100	15	1000	90	593.6	323.2	100%	0.9208	0.0017	0.9242	0.932	217.8
15p_contents_vertical_hu100	15	1000	100	659.5	356.2	Void	0.8886	0.0018	0.8922	0.932	218.1
15p_contents_vertical_hu100_25	15	1000	100	659.5	356.2	25%	0.9050	0.0017	0.9084	0.932	218.2
15p_contents_vertical_hu100_50	15	1000	100	659.5	356.2	50%	0.9127	0.0018	0.9163	0.932	218.2
15p_contents_vertical_hu100_75	15	1000	100	659.5	356.2	75%	0.9177	0.0017	0.9211	0.932	218.2
15p_contents_vertical_hu100_100	15	1000	100	659.5	356.2	100%	0.9172	0.0017	0.9206	0.932	218.2
15p_contents_vertical_hu110	15	1000	110	725.5	389.3	Void	0.8944	0.0015	0.8974	0.932	218.5
15p_contents_vertical_hu110_25	15	1000	110	725.5	389.3	25%	0.9037	0.0018	0.9073	0.932	218.5
15p_contents_vertical_hu110_50	15	1000	110	725.5	389.3	50%	0.9124	0.0015	0.9154	0.932	218.6
15p_contents_vertical_hu110_75	15	1000	110	725.5	389.3	75%	0.9147	0.0020	0.9187	0.932	218.6
15p_contents_vertical_hu110_100	15	1000	110	725.5	389.3	100%	0.9163	0.0017	0.9197	0.932	218.6
15p_contents_vertical_hu120	15	1000	120	791.4	422.3	Void	0.8915	0.0015	0.8945	0.932	218.8
15p_contents_vertical_hu120_25	15	1000	120	791.4	422.3	25%	0.9014	0.0016	0.9046	0.932	218.8
15p_contents_vertical_hu120_50	15	1000	120	791.4	422.3	50%	0.9061	0.0017	0.9095	0.932	218.8
15p_contents_vertical_hu120_75	15	1000	120	791.4	422.3	75%	0.9109	0.0016	0.9141	0.932	218.8
15p_contents_vertical_hu120_100	15	1000	120	791.4	422.3	100%	0.9113	0.0017	0.9147	0.932	218.9
15p_contents_vertical_hu130	15	1000	130	857.4	455.3	Void	0.8866	0.0015	0.8896	0.932	219.0
15p_contents_vertical_hu130_25	15	1000	130	857.4	455.3	25%	0.8992	0.0017	0.9026	0.932	219.1
15p_contents_vertical_hu130_50	15	1000	130	857.4	455.3	50%	0.8992	0.0017	0.9026	0.932	219.1
15p_contents_vertical_hu130_75	15	1000	130	857.4	455.3	75%	0.9019	0.0014	0.9047	0.932	219.1
15p_contents_vertical_hu130_100	15	1000	130	857.4	455.3	100%	0.9050	0.0016	0.9082	0.932	219.1

Table 7: Contents Model Calculation Results for Varying Water Density in the 30 ECV (UO_2F_2/Water Mixtures near Optimum H/U, 800 grams of 100 wt%)

Case	^{235}U wt. %	^{235}U Mass (g)	H/U	H/X	S/X	30 ECV Internal Water Density	K_{eff}	σ	K_{eff} + 2σ	K_{sub}	Average Energy Group
100p_contents_vertical_hu600	100	800	600	600	304.3	Void	0.8606	0.0018	0.8642	0.943	218.5
100p_contents_vertical_hu600_25	100	800	600	600	304.3	25%	0.8889	0.0018	0.8925	0.943	218.6
100p_contents_vertical_hu600_50	100	800	600	600	304.3	50%	0.9049	0.0018	0.9085	0.943	218.7
100p_contents_vertical_hu600_75	100	800	600	600	304.3	75%	0.9119	0.0020	0.9159	0.943	218.7
100p_contents_vertical_hu600_100	100	800	600	600	304.3	100%	0.9153	0.0020	0.9193	0.943	218.7
100p_contents_vertical_hu700	100	800	700	700	354.1	Void	0.8777	0.0017	0.8811	0.943	219.0
100p_contents_vertical_hu700_25	100	800	700	700	354.1	25%	0.9028	0.0020	0.9068	0.943	219.1
100p_contents_vertical_hu700_50	100	800	700	700	354.1	50%	0.9126	0.0018	0.9162	0.943	219.1
100p_contents_vertical_hu700_75	100	800	700	700	354.1	75%	0.9180	0.0016	0.9212	0.943	219.2
100p_contents_vertical_hu700_100	100	800	700	700	354.1	100%	0.9176	0.0017	0.9210	0.943	219.2
100p_contents_vertical_hu800	100	800	800	800	404.4	Void	0.8836	0.0016	0.8868	0.943	219.4
100p_contents_vertical_hu800_25	100	800	800	800	404.4	25%	0.9025	0.0017	0.9059	0.943	219.5
100p_contents_vertical_hu800_50	100	800	800	800	404.4	50%	0.9052	0.0017	0.9086	0.943	219.5
100p_contents_vertical_hu800_75	100	800	800	800	404.4	75%	0.9082	0.0015	0.9112	0.943	219.5
100p_contents_vertical_hu800_100	100	800	800	800	404.4	100%	0.9165	0.0017	0.9199	0.943	219.5
100p_contents_vertical_hu900	100	800	900	900	453.9	Void	0.8817	0.0017	0.8851	0.943	219.7
100p_contents_vertical_hu900_25	100	800	900	900	453.9	25%	0.8940	0.0015	0.8970	0.943	219.8
100p_contents_vertical_hu900_50	100	800	900	900	453.9	50%	0.9018	0.0018	0.9054	0.943	219.8
100p_contents_vertical_hu900_75	100	800	900	900	453.9	75%	0.9067	0.0015	0.9097	0.943	219.8
100p_contents_vertical_hu900_100	100	800	900	900	453.9	100%	0.9061	0.0017	0.9095	0.943	219.8
100p_contents_vertical_hu1000	100	800	1000	1000	503.5	Void	0.8753	0.0014	0.8781	0.943	220.0
100p_contents_vertical_hu1000_25	100	800	1000	1000	503.5	25%	0.8828	0.0018	0.8864	0.943	220.0
100p_contents_vertical_hu1000_50	100	800	1000	1000	503.5	50%	0.8911	0.0016	0.8943	0.943	220.0
100p_contents_vertical_hu1000_75	100	800	1000	1000	503.5	75%	0.8908	0.0017	0.8942	0.943	220.0
100p_contents_vertical_hu1000_100	100	800	1000	1000	503.5	100%	0.8911	0.0015	0.8941	0.943	220.0

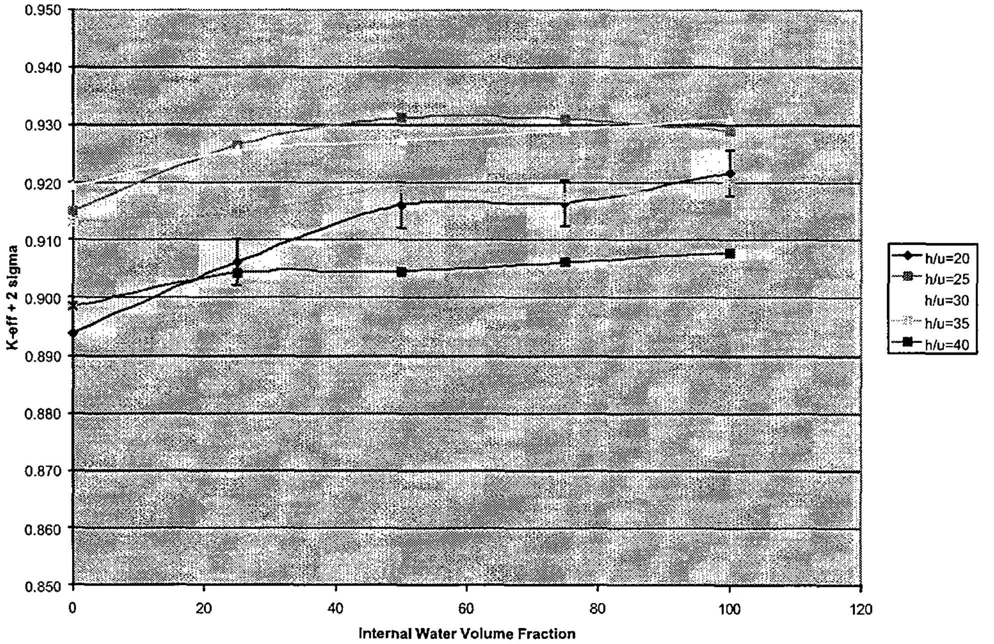

Figure 8 Contents Model Calculation Results for Varying Water Density in the 30 ECV
(UO_2F_2/Water Mixtures at 5% Enriched)

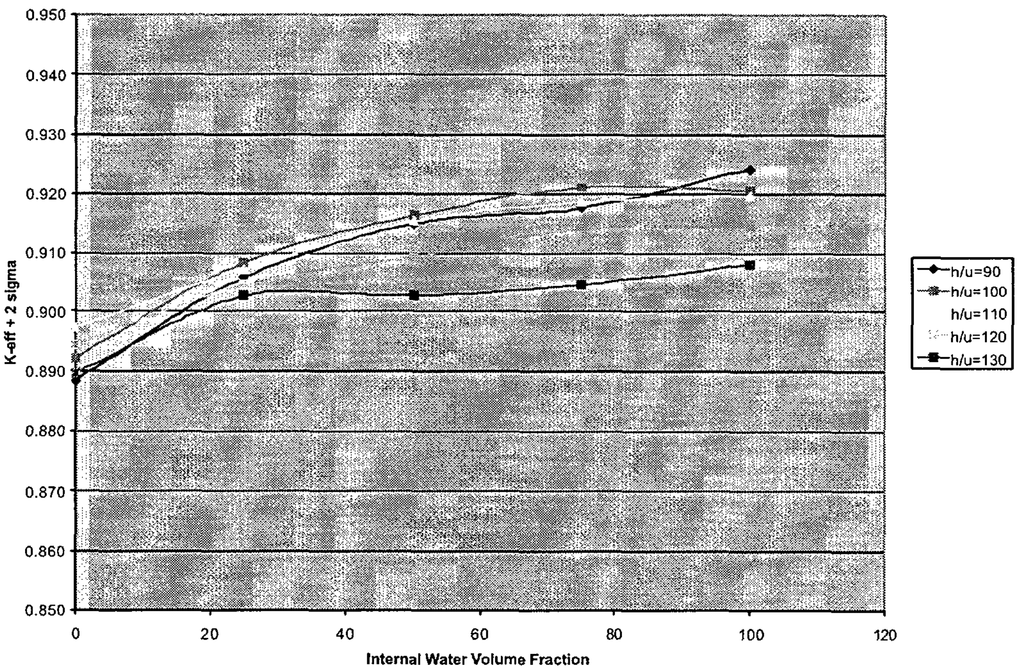

Figure 9 Contents Model Calculation Results for Varying Water Density in the 30 ECV
(UO_2F_2/Water Mixtures at 15% Enriched)

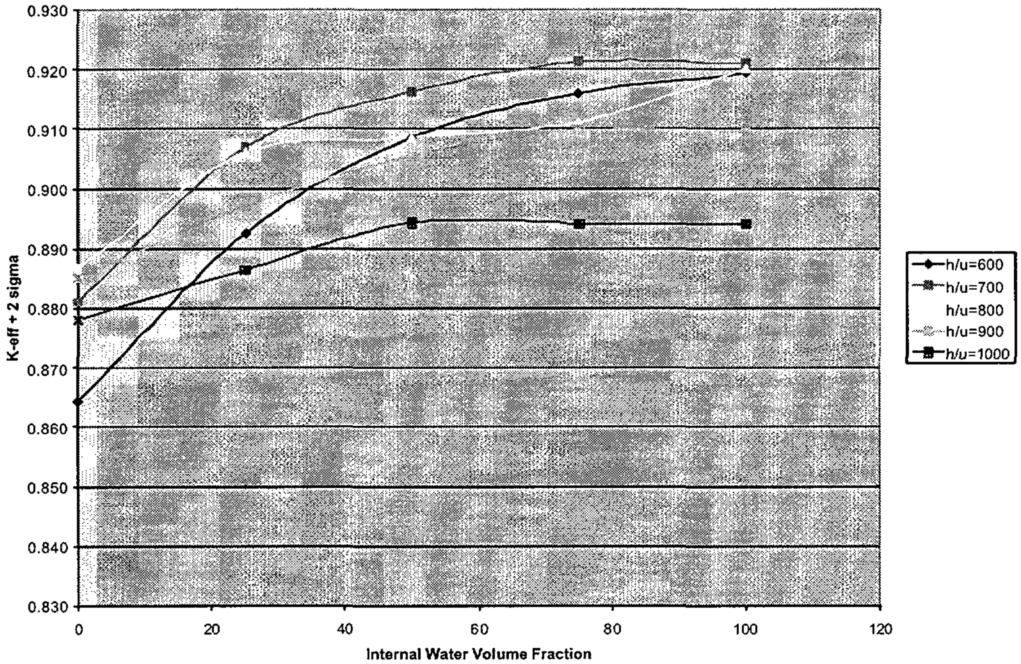

Figure 10 Contents Model Calculation Results for Varying Water Density in the 30 ECV (UO_2F_2/Water Mixtures at 100% Enriched)

The results presented in Tables 5 through 7 and Figures 8 through 10 indicate that the 30 ECV is most reactive (and still subcritical) with full density water in the remaining vessel space above the UO_2F_2/water mixture. Although water at less than full density appears in some cases (e.g., 5 wt%) to result in a slightly higher k_{eff}, the differences are not statistically significant (i.e., the k_{eff}'s are within two standard deviations of each other). The optimum moderation conditions for 5 wt % and 15 wt% are not statistically different with increases in water density (i.e., H/U ratios of ~30 and ~110, respectively). For 100% wt %, optimum moderation appears to shift slightly to an H/U ratio of ~700 with increasing water density.

3.4 SINGLE UNIT MODELS

For the single unit models, the 30 ECV was modeled identical to the contents model described in Section 3.3, with the exception of the 12" water reflection. Instead of the 12" water reflection, 5.5" thick polyethylene at a density of approximately 12.5 lbs/ft^3 is modeled around the outside of the modeled 19-inch OD of the 30 ECV (to bound the high density foam, same as the foam in the 30 ECV steel/foam insert). The UX-30 is modeled as tight fitting foam around the 30 ECV at an outside diameter of 40" and outside length of 90". This represents a 3.5" diameter reduction over the entire length of the UX-30, and a 6" length reduction. Reducing the diameter of the UX-30 by 3.5" and

the length by 6" bounds the localized damage to the UX-30 resulting from the hypothetical accident drop tests[9]. The modeled composition of the UX-30 foam is 70% carbon, 15% oxygen, 5% nitrogen, and 10% hydrogen at a density of 10 lbs/ft^3, which bounds the actual foam composition (given in Section 3.2) by maximizing the carbon and hydrogen content as well as the density of the foam (demonstrated by calculations further below).

The fissile material within the 30 ECV was modeled in the vertical orientation (more conservative than the normal horizontal orientation) at the optimum H/U ratio determined in Section 3.3 for each enrichment (H/U ratios of 30, 110, and 700 for 5% enriched, 15% enriched, and 100% enriched, respectively). The remaining 30 ECV volume was filled with full density water (determined to be the most reactive contents in Section 3.3). Full density water at a thickness of 12" was modeled around the outside of the UX-30. The single unit model is shown in Figure 11.

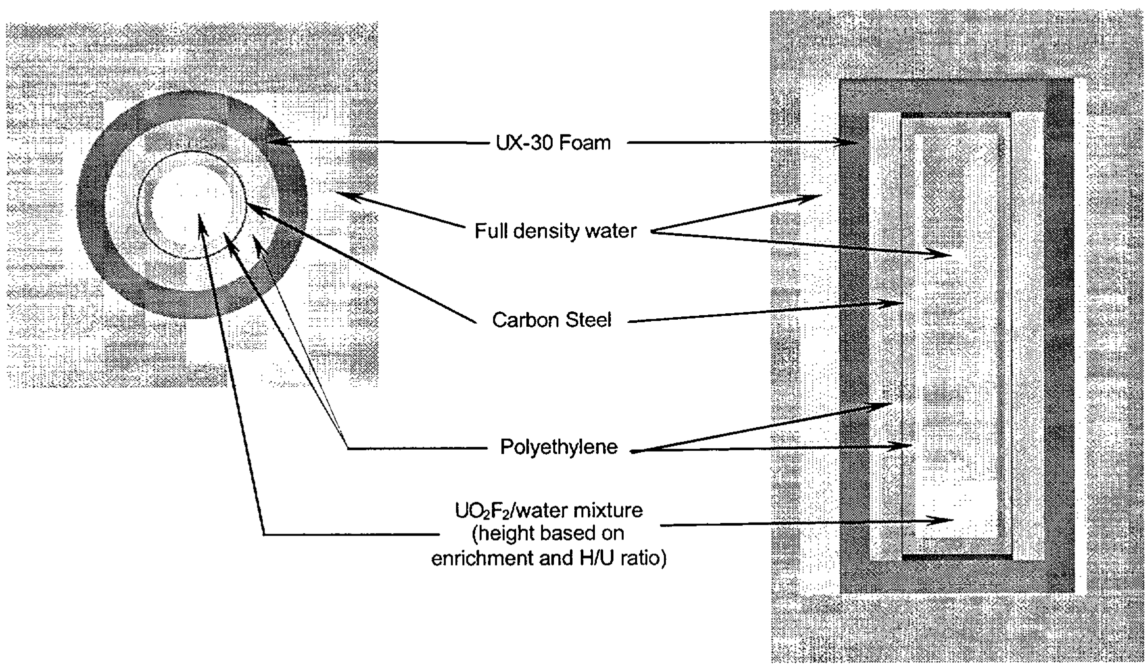

Figure 11: Single Unit Model

Results of the single unit models are given in Table 8. The single unit models result in lower reactivity as compared to the contents models due to the lower density reflection provided by the 30 ECV exterior foam and foam of the UX-30 (compared to the full density water reflection in the contents models). All cases were subcritical.

Table 8: Single Unit Model Calculation Results
(UO_2F_2/Water Mixtures at Optimum H/U for each enrichment)

Case	^{235}U wt. %	^{235}U Mass (g)	H/U	H/X	S/X	30 ECV Internal Water Density	K_{eff}	σ	K_{eff} + 2σ	K_{sub}	Average Energy Group
5p_singleunit	5	1600	30	592.8	375.6	100%	0.9194	0.0016	0.9226	0.932	215.9
15p_singleunit	15	1000	110	725.5	389.3	100%	0.9100	0.0015	0.9130	0.932	218.5
100p_singleunit	100	800	700	700	354.1	100%	0.9145	0.0017	0.9179	0.943	219.1

Variations in the composition of the UX-30 foam were next modeled. The foam was modeled with 50% carbon and 4% hydrogen (the lowest carbon and hydrogen content as described in Section 3.2), and again with 60% carbon and 7% hydrogen (middle of the carbon and hydrogen content range). These results are shown in Table 9. The results indicate that varying the UX-30 composition has no statistically significant effect on system reactivity within the given carbon and hydrogen content range. All remaining cases will be ran with the maximum carbon and hydrogen content.

Table 9: Single Unit Model Calculation Results for Varying UX-30 Foam Carbon and Hydrogen Content
(UO_2F_2/Water Mixtures at Optimum H/U for each enrichment)

Case	UX-30 Foam Composition	^{235}U wt. %	^{235}U Mass (g)	H/U	H/X	S/X	K_{eff}	σ	K_{eff} + 2σ	K_{sub}	Average Energy Group
5p_singleunit_ux30foamlow	50% C, 4% H, 34% O, 12% N	5	1600	30	592.8	375.6	0.9203	0.0017	0.9237	0.932	216
5p_singleunit_ux30foammid	60% C, 7% H, 25% O, 8% N	5	1600	30	592.8	375.6	0.9177	0.0019	0.9215	0.932	216
15p_singleunit_ux30foamlow	50% C, 4% H, 34% O, 12% N	15	1000	110	725.5	389.3	0.9072	0.0019	0.9110	0.932	218
15p_singleunit_ux30foammid	60% C, 7% H, 25% O, 8% N	15	1000	110	725.5	389.3	0.9114	0.0017	0.9148	0.932	218
100p_singleunit_ux30foamlow	50% C, 4% H, 34% O, 12% N	100	800	700	700	354.1	0.9122	0.0018	0.9158	0.943	219
100p_singleunit_ux30foammid	60% C, 7% H, 25% O, 8% N	100	800	700	700	354.1	0.9127	0.0019	0.9165	0.943	219

The single unit model results demonstrate that a single UX-30 package (containing a 30 ECV with one or more less than 30" cylinders limited in ^{235}U mass based on the highest ^{235}U enrichment in any individual cylinder) will remain subcritical under all normal conditions of transport and hypothetical accident conditions.

Prior testing of the UX-30 indicates that the package will absorb most of the force of impact from hypothetical accident drops, and the 30 ECV is therefore not expected to sustain significant damage under hypothetical accident conditions. The hypothetical accident fire test documented in the UX-30 SAR[10] indicates that the maximum temperature inside the UX-30 is less than 200 degrees F. The foam used in construction of the 30 ECV is rated for a maximum service temperature of 250 degrees

F. Thus, the 30 ECV foam (both the exterior foam and the foam used in the steel/foam insert) will not be substantially damaged in a fire scenario.

3.5 INFINITE ARRAY MODELS

Infinite arrays of UX-30 packages each containing a 30 ECV were modeled at each ^{235}U enrichment/mass combination with the material in a vertically oriented configuration. The single unit model (without water reflection) described in Section 3.4 was used as the basic unit in the infinite array models. An infinite triangular pitched array was achieved by modeling four (4) half-single units in a triangular pitch and applying a mirror boundary condition to all six faces of , as shown in Figure 12.

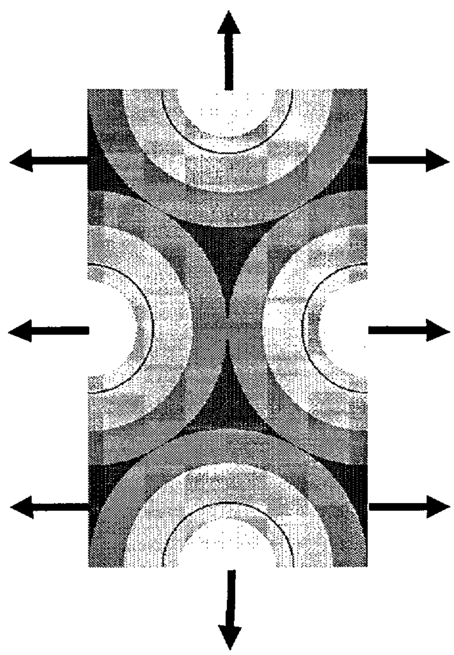

Figure 12: Infinite Array Model

Initially, the interstitial space between the individual UX-30 packages was modeled as void, while the remaining space above the UO_2F_2/water mixture in the 30 ECV was varied from void to full density water. Optimum moderation in the UO_2F_2/water mixture was modeled as determined in Section 3.2 (i.e., H/U = 30 for 5 wt %, H/U = 110 for 15 wt %, and H/U = 700 to 800 for 100 wt %). The results of these cases are given in Table 10, and indicate that, in general, the system is most reactive with full density water filling the remaining 30 ECV interior volume. Variation of the water density inside the 30 ECV will bound both the low density dunnage material placed inside the 30 ECV to protect the UF_6 cylinders under normal conditions of transport and water in-leakage under hypothetical accident conditions.

Table 10: Infinite Array Calculation Results for Varying Water Density in the 30 ECV (UO_2F_2/Water Mixtures at Optimum H/U for each enrichment)

Case	^{235}U wt. %	^{235}U Mass (g)	H/U	H/X	S/X	30 ECV Internal Water Density	K_{eff}	σ	$K_{eff} + 2\sigma$	K_{sub}	Average Energy Group
5p_infarraytp_void_void	5	1600	30	592.8	375.6	0%	0.9168	0.0015	0.9198	0.932	216
5p_infarraytp_void_25water	5	1600	30	592.8	375.6	25%	0.9218	0.0017	0.9252	0.932	216
5p_infarraytp_void_50water	5	1600	30	592.8	375.6	50%	0.9237	0.0017	0.9271	0.932	216
5p_infarraytp_void_75water	5	1600	30	592.8	375.6	75%	0.9263	0.0018	0.9299	0.932	216
5p_infarraytp_void_100water	5	1600	30	592.8	375.6	100%	0.9268	0.0017	0.9302	0.932	216
15p_infarraytp_void_void	15	1000	110	725.5	389.3	0%	0.8952	0.0015	0.8982	0.932	218
15p_infarraytp_void_25water	15	1000	110	725.5	389.3	25%	0.9047	0.0018	0.9083	0.932	218
15p_infarraytp_void_50water	15	1000	110	725.5	389.3	50%	0.9101	0.0018	0.9137	0.932	218
15p_infarraytp_void_75water	15	1000	110	725.5	389.3	75%	0.9159	0.0014	0.9187	0.932	218
15p_infarraytp_void_100water	15	1000	110	725.5	389.3	100%	0.9177	0.0016	0.9209	0.932	218
100p_infarraytp_hu700_void_void	100	800	700	700	354.1	0%	0.8814	0.0017	0.8848	0.943	219
100p_infarraytp_hu700_void_25water	100	800	700	700	354.1	25%	0.9007	0.0016	0.9039	0.943	219
100p_infarraytp_hu700_void_50water	100	800	700	700	354.1	50%	0.9110	0.0017	0.9144	0.943	219
100p_infarraytp_hu700_void_75water	100	800	700	700	354.1	75%	0.9193	0.0019	0.9231	0.943	219
100p_infarraytp_hu700_void_100water	100	800	700	700	354.1	100%	0.9155	0.0018	0.9191	0.943	219
100p_infarraytp_hu800_void_void	100	800	800	800	404.4	0%	0.8844	0.0020	0.8884	0.943	219
100p_infarraytp_hu800_void_25water	100	800	800	800	404.4	25%	0.9025	0.0019	0.9063	0.943	219
100p_infarraytp_hu800_void_50water	100	800	800	800	404.4	50%	0.9095	0.0015	0.9125	0.943	219
100p_infarraytp_hu800_void_75water	100	800	800	800	404.4	75%	0.9119	0.0017	0.9153	0.943	219
100p_infarraytp_hu800_void_100water	100	800	800	800	404.4	100%	0.9169	0.0017	0.9203	0.943	219

The polyethylene in the 30 ECV and the foam in the UX-30 were modeled at 12.5 lb/ft^3 (0.2 g/cc) and 10 lb/ft^3 (0.1602 g/cc), respectively, relative to their design values of 8 to 10 lb/ft^3. In an infinite array, the presence of neutron absorbers can have a significant effect on reactivity. The effects of the polyethylene and foam densities were evaluated by decreasing the density of both to ~6.25 lb/ft^3 (0.1 g/cc). The results of these calculations are shown in Table 11. In all cases, the results are lower than those in Table 10 that used the higher densities.

Table 11: Infinite Array Calculation Results for Varying Water Density in the 30 ECV (UO_2F_2/Water Mixtures at Optimum H/U for each enrichment with lower polyethyene/foam density)

Case	^{235}U wt. %	^{235}U Mass (g)	H/U	H/X	S/X	30 ECV Internal Water Density	K_{eff}	σ	K_{eff} + 2σ	K_{sub}	Average Energy Group
5p_infarraytp_low_void_void	5	1600	30	592.8	375.6	0%	0.9106	0.0020	0.9146	0.932	215.8
5p_infarraytp_low_void_25water	5	1600	30	592.8	375.6	25%	0.9146	0.0016	0.9178	0.932	215.8
5p_infarraytp_low_void_50water	5	1600	30	592.8	375.6	50%	0.9187	0.0016	0.9219	0.932	215.9
5p_infarraytp_low_void_75water	5	1600	30	592.8	375.6	75%	0.9212	0.0015	0.9242	0.932	215.9
5p_infarraytp_low_void_100water	5	1600	30	592.8	375.6	100%	0.9211	0.0017	0.9245	0.932	215.9
15p_infarraytp_low_void_void	15	1000	110	725.5	389.3	0%	0.8865	0.0016	0.8997	0.932	218.3
15p_infarraytp_low_void_25water	15	1000	110	725.5	389.3	25%	0.8995	0.0015	0.9025	0.932	218.4
15p_infarraytp_low_void_50water	15	1000	110	725.5	389.3	50%	0.9038	0.0017	0.9072	0.932	218.4
15p_infarraytp_low_void_75water	15	1000	110	725.5	389.3	75%	0.9083	0.0015	0.9133	0.932	218.5
15p_infarraytp_low_void_100water	15	1000	110	725.5	389.3	100%	0.9086	0.0017	0.9120	0.932	218.5
100p_infarraytp_low_void_void	100	800	800	800	404.4	0%	0.8782	0.0015	0.8812	0.943	219.3
100p_infarraytp_low_void_25water	100	800	800	800	404.4	25%	0.8965	0.0019	0.9003	0.943	219.4
100p_infarray tp_low_void_50water	100	800	800	800	404.4	50%	0.8991	0.0018	0.9027	0.943	219.4
100p_infarraytp_low_void_75water	100	800	800	800	404.4	75%	0.9032	0.0019	0.9070	0.943	219.4
100p_infarraytp_low_void_100water	100	800	800	800	404.4	100%	0.9089	0.0017	0.9123	0.943	219.5

Next, the interstitial water density between the UX-30 packages was varied from 25% water density to full density water. Table 12 gives the results of these calculations. As can be seen from the results, there is no statistically significant difference in k_{eff} due to varying interstitial water density. Due to the large size of the UX-30 packages and the already optimally moderated conditions, changing the interstitial water density has little effect on the system.

Table 12: Infinite Array Calculation Results for Varying Interstitial Water Density (UO_2F_2/Water Mixtures at Optimum H/U for each enrichment)

Case	^{235}U wt. %	^{235}U Mass (g)	H/U	H/X	S/X	Interstitial Water Density	K_{eff}	σ	K_{eff} + 2σ	K_{sub}	Average Energy Group
5p_infarraytp_25water_100water	5	1600	30	592.8	375.6	25%	0.9262	0.0016	0.9294	0.932	216
5p_infarraytp_50water_100water	5	1600	30	592.8	375.6	50%	0.9224	0.0016	0.9256	0.932	216
5p_infarraytp_75water_100water	5	1600	30	592.8	375.6	75%	0.9233	0.0015	0.9263	0.932	216
5p_infarraytp_100water_100water	5	1600	30	592.8	375.6	100%	0.9271	0.0017	0.9305	0.932	216
15p_infarraytp_25water_100water	15	1000	110	725.5	389.3	25%	0.9137	0.0015	0.9167	0.932	218
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

The final set of calculations modeled 5% by volume full density water absorbed into all foam regions (UX-30 foam, internal 30 ECV foam, and external 30 ECV foam). All of the foams are rigid, closed-cell foam which will absorb very little water (see, for example, Specification ES-M-170 in Chapter 8 of the UX-30 SAR). The modeled condition of 5% by volume water absorbed into the foam will bound normal absorption as well as hypothetical accident conditions in which water enters cracks and other voids in the foam. As previously discussed, prior testing of the UX-30 indicates that it will survive hypothetical accident conditions and provide substantial protection of the 30 ECV. Modeling 5% by volume water absorbed into the foam provides better reflection conditions (by increasing the density and hydrogen content throughout the entire foam regions) than any realistic scenario in which water enters cracks and voids in the foam, which will only result in small areas of localized reflection.

The results of these calculations are shown in Table 13. All cases result in $k_{eff} + 2\sigma < k_{sub}$, demonstrating subcriticality of the infinite array of UX-30 packages.

Table 13: Infinite Array Calculation Results for 5% by Volume Water Absorbed into Foam (UO_2F_2/Water Mixtures at Optimum H/U for each enrichment)

Case	^{235}U wt. %	^{235}U Mass (g)	H/U	H/X	S/X	K_{eff}	σ	K_{eff} + 2σ	K_{sub}	Average Energy Group
5p_infarraytp_foamwater5	5	1600	30	592.8	375.6	0.9281	0.0016	0.9313	0.932	216
15p_infarraytp_foamwater5	15	1000	110	725.5	389.3	0.9182	0.0017	0.9216	0.932	218
100p_infarraytp_foamwater5	100	800	800	800	404.4	0.9183	0.0017	0.9217	0.943	219

The infinite array models described above bound all normal conditions of transport and hypothetical accident conditions by incorporating the following conservatism:

1. The UX-30 is modeled at reduced diameter and reduced length. The reduced diameter and length decreases fissile material spacing and increases neutron interaction between the units, and provides a bounding condition for UX-30 damage due to impact.

2. Significant amounts of steel have been eliminated from the model, and replaced with better moderating materials (polyethylene or foam). Steel used in the construction of the 30 ECV steel/foam insert is not present in the model. Only half of the 30 ECV wall thickness, and half the 30 ECV top and bottom head thickness at reduced diameter, is modeled. Finally, the steel shell of the UX-30 (on both the interior and exterior foam surfaces) is not included.

3. The material is modeled in the most reactive credible geometry (i.e., vertical orientation), as previously determined in Section 3.3.

4. The modeled material geometry represents an infinite array of vertically oriented packages in which the fissile material is at the bottom of one layer of cylinders, and levitated to the top of the next layer of cylinders. This causes the material in every

two layers of cylinders to be adjacent, thereby maximizing neutron interaction between the material in the two adjacent cylinder layers.

5. All of the less than 30" cylinders are assumed to breached and the fissile material is modeled as UO_2F_2 homogeneously mixed with water, with no consideration of the cylinder steel construction. While the formation of UO_2F_2 is expected upon water in-leakage, modeling all of the material as a homogeneous mixture of UO_2F_2 and water is conservative since UO_2F_2 is more reactive than UF_6 and the steel of the less than 30" cylinders would act as a neutron absorber and diluent.

6. The fissile material is modeled at either end of the 30 ECV even though the material would be expected as an annular ring around the inside surfaces of the internal cylinders under normal conditions of transport, and the low density dunnage material would not credibly allow all of the material to collect at one end of the 30 ECV even under hypothetical accident conditions.

These bounding infinite array calculations demonstrate that UX-30 packages, each containing a 30 ECV with one or more less than 30" UF_6 cylinders at the allowed enrichment/mass combinations, are subcritical under all normal conditions of transport and hypothetical accident conditions. Based on 10CFR71.59(b), the derived value "N" is effectively equal to infinity, which results in a CSI of 0.

4. SUMMARY

Normal conditions of transport and hypothetical accident conditions have been demonstrated subcritical by k_{eff} calculations for infinite arrays of UX-30 packages containing a 30 ECV with one or more less than 30" UF_6 cylinders at various ^{235}U enrichment/mass combinations. All calculation results were shown to be subcritical with $k_{eff} + 2\sigma$ values less than the applicable upper subcritical limits established in Section 2. The enrichment/mass combinations allowed in the UX-30 are shown below.

^{235}U Enrichment Limit	^{235}U Mass Limit	CSI
5%	1600 grams	0
15%	1000 grams	0
100%	800 grams	0

Measurement uncertainties in the enrichment and mass values must be considered when determining the loading of individual UF_6 cylinders into the packages.

The 30 ECV ASME pressure vessel (including the steel/foam insert and exterior foam, with dimensions as shown in References 5, 6 and 7), and the UX-30 over pack (with dimensions as shown in Reference 8) are credited as design features in this analysis. Dimensional tolerances have been discussed and will not significantly affect reactivity of the packages. Other manufacturing tolerances (e.g., composition of foam) have been addressed in the calculations, and shown to not have a significant impact.

Since an infinite array of cylinders has been shown subcritical under all normal conditions of transport and hypothetical accident conditions, the value "N" as specified

in 10CFR71.59 is effectively equal to infinity, and the CSI is zero (0) in accordance with that regulation. Based on this CSI, UX-30 packages, each containing a 30 ECV with one or more less than 30" UF_6 cylinders limited to a total ^{235}U mass based on the highest ^{235}U enrichment in any loaded cylinder per the table above, may be shipped in a nonexclusive use conveyance as allowed by 10CFR71.59.

5. REFERENCES

1. American National Standard for Nuclear Materials, ANSI N14.1-2001, *Uranium Hexafluoride – Packaging for Transport*, February 1, 2001

2. Code of Federal Regulations, Title 10, Part 71, *Packaging and Transportation of Radioactive Material*

3. NCSR-MS-0000000-0035, Rev. 0, *SCALE 4.4a Verification Report*, June 2004

4. NCSR-MS-0000000-0036, Rev. 0, *Validation Of Scale Version 4.4a and the 238-Group Endf/B-V Cross Section Library For U-235*, July 2004

5. Drawing C-067-005311-004, Rev. 0, *30 ECV Cylinder with Foam*

6. Drawing C-067-005311-006, Rev. 0, *30 ECV Foam Insert* (3 sheets)

7. Drawing C-067-005311-008, Rev. 0, *30 ECV Cylinder*

8. Drawing C-110-B-57922-0002, Rev. 2, Sheet 2 of 3, *UX-30 Overpack*

9. UX-30 Consolidated SAR, Rev. 0, Appendix 2.10.4, *Hypothetical Accident Drop Testing*, February 1999

10. UX-30 Consolidated SAR, Rev. 0, Appendix 3.6.3, *Hypothetical Accident Fire Test*, February 1999

Attachment A

SCALE Mixture and Geometry Calculations

Material Mixture

	100% Cases	15% Cases	5% Cases
U-235 Mass (g)	800	1000	1600
Enrichment (wt fraction ^{235}U)	1.00	0.15	0.05
mol. wt. U_enrich (g/mole)	235.043924	237.5948608	237.898616
af_u^{235}	1.0	0.151627953	0.050607268
af_u^{238}	0.0	0.848372047	0.949392732
mol. wt. UO_2F_2 (g/mole)	305.03953	307.5904668	307.894222
wt fraction U in UO_2F_2	0.77053595	0.772438962	0.772663464

Constants

avogadro's number (molecules-cm^2/mole-barn)	0.60221367
mol. wt natural uranium (g/mole)	238.0289
mol. wt. U-235 (g/mole)	235.043924
mol. wt. U-238 (g/mole)	238.050785
mol wt. H (g/mole)	1.0079
mol wt. O (g/mole)	15.9994
mol wt. F (g/mole)	18.998403
mol. wt. H_2O (g/mole)	18.0152
density UO_2F_2 (g/cm^3)	6.37
density H_2O (g/cm^3)	0.9982
specific vol. UO_2F_2-$2H_2O$	72.2809
specific vol. H_2O	9.0287

30ECV

modeled IR	17.7800	cm
modeled IL	178.4350	cm
modeled volume (V)	177212.1241	cm^3

The formula used for uranium density is given in ORNL/TM-12292, *Estimated Critical Conditions for UO_2F_2-H_2O Systems in Fully Water-Reflected Spherical Geometry*, W. C. Jordan and J. C. Turner, December 1992.

$$\rho_u = \frac{M_u}{V_{UO_2F_2-2H_2O} + \left(\frac{H}{U} - 4\right) * \frac{V_{H_2O}}{2}} \quad \text{(for H/U} \geq 4\text{)}$$

$$\rho_u = 4.96 - 0.32 * \left(\frac{H}{U}\right) \quad \text{(for H/U} < 4\text{)}$$

The angle theta in the "Horizontally Oriented 30ECV Contents Model" material configuration was derived using the "goal seek" function in Microsoft Excel with the H/U ratio set at the desired value.

Vertically Oriented 30ECV Contents Model:

100% Cases:

H/U Ratio	H/X Ratio	U Density	UO2F2 Density	H2O Density	Total Mixture Density	Volume for given mass (cm3)	Material Height (cm)	U-235	U-238	H	O	F	U-235 Density
0.088	0.088	4.9318E+00	6.4005	0.0166	6.4172E+00	162.2113	0.1633	1.2636E-02	0.0000E+00	1.1120E-03	2.5828E-02	2.5272E-02	4.9318E+00
5.0	5.0	2.8907E+00	3.7516	0.5539	4.3055E+00	276.7469	0.2787	7.4064E-03	0.0000E+00	3.7032E-02	3.3329E-02	1.4813E-02	2.8907E+00
10.0	10.0	1.8587E+00	2.4123	0.7123	3.1246E+00	430.3982	0.4334	4.7623E-03	0.0000E+00	4.7623E-02	3.3336E-02	9.5247E-03	1.8587E+00
50.0	50.0	4.8204E-01	0.6256	0.9237	1.5493E+00	1659.6084	1.6711	1.2351E-03	0.0000E+00	6.1753E-02	3.3346E-02	2.4701E-03	4.8204E-01
100.0	100.0	2.5030E-01	0.3248	0.9592	1.2841E+00	3196.1212	3.2182	6.4131E-04	0.0000E+00	6.4131E-02	3.3348E-02	1.2826E-03	2.5030E-01
500.0	500.0	5.1652E-02	0.0670	0.9897	1.0568E+00	15488.2237	15.5951	1.3234E-04	0.0000E+00	6.6170E-02	3.3350E-02	2.6468E-04	5.1652E-02
600.0	600.0	4.3101E-02	0.0559	0.9910	1.0470E+00	18561.2493	18.6893	1.1043E-04	0.0000E+00	6.6258E-02	3.3350E-02	2.2086E-04	4.3101E-02
700.0	700.0	3.6978E-02	0.0480	0.9920	1.0400E+00	21634.2750	21.7836	9.4743E-05	0.0000E+00	6.6320E-02	3.3350E-02	1.8949E-04	3.6978E-02
800.0	800.0	3.2379E-02	0.0420	0.9927	1.0347E+00	24707.3006	24.8778	8.2960E-05	0.0000E+00	6.6368E-02	3.3350E-02	1.6592E-04	3.2379E-02
900.0	900.0	2.8797E-02	0.0374	0.9932	1.0306E+00	27780.3262	27.9720	7.3783E-05	0.0000E+00	6.6404E-02	3.3350E-02	1.4757E-04	2.8797E-02
1000.0	1000.0	2.5929E-02	0.0337	0.9937	1.0273E+00	30853.3518	31.0663	6.6434E-05	0.0000E+00	6.6434E-02	3.3350E-02	1.3287E-04	2.5929E-02
1100.0	1100.0	2.3580E-02	0.0306	0.9940	1.0246E+00	33926.3774	34.1605	6.0416E-05	0.0000E+00	6.6458E-02	3.3350E-02	1.2083E-04	2.3580E-02
1200.0	1200.0	2.1622E-02	0.0281	0.9943	1.0224E+00	36999.4031	37.2547	5.5398E-05	0.0000E+00	6.6478E-02	3.3350E-02	1.1080E-04	2.1622E-02
1300.0	1300.0	1.9964E-02	0.0259	0.9946	1.0205E+00	40072.4287	40.3490	5.1150E-05	0.0000E+00	6.6495E-02	3.3350E-02	1.0230E-04	1.9964E-02
1400.0	1400.0	1.8542E-02	0.0241	0.9948	1.0189E+00	43145.4543	43.4432	4.7507E-05	0.0000E+00	6.6510E-02	3.3350E-02	9.5014E-05	1.8542E-02
1500.0	1500.0	1.7309E-02	0.0225	0.9950	1.0175E+00	46218.4799	46.5374	4.4348E-05	0.0000E+00	6.6522E-02	3.3350E-02	8.8696E-05	1.7309E-02
2000.0	2000.0	1.2990E-02	0.0169	0.9957	1.0125E+00	61583.6080	62.0086	3.3283E-05	0.0000E+00	6.6567E-02	3.3350E-02	6.6567E-05	1.2990E-02
3000.0	3000.0	8.6661E-03	0.0112	0.9963	1.0076E+00	92313.8642	92.9509	2.2204E-05	0.0000E+00	6.6611E-02	3.3350E-02	4.4407E-05	8.6661E-03
4000.0	4000.0	6.5017E-03	0.0084	0.9967	1.0051E+00	123044.1204	123.8932	1.6658E-05	0.0000E+00	6.6633E-02	3.3350E-02	3.3317E-05	6.5017E-03
5762.7	5762.7	4.5144E-03	0.0059	0.9970	1.0028E+00	177212.1241	178.4350	1.1566E-05	0.0000E+00	6.6654E-02	3.3350E-02	2.3133E-05	4.5144E-03

15% Cases:

H/U Ratio	H/X Ratio	U Density	UO2F2 Density	H2O Density	Total Mixture Density	Volume for given mass (cm3)	Material Height (cm)	U-235	U-238	H	O	F	U-235 Density
0.088	0.6	4.9318E+00	6.3848	0.0165	6.4012E+00	1351.7605	1.3611	1.8954E-03	1.0605E-02	1.1000E-03	2.5551E-02	2.5001E-02	7.3978E-01
5.0	33.0	2.9221E+00	3.7830	0.5539	4.3369E+00	2281.4635	2.2972	1.1230E-03	6.2834E-03	3.7032E-02	3.3329E-02	1.4813E-02	4.3832E-01
10.0	66.0	1.8789E+00	2.4324	0.7123	3.1448E+00	3548.1435	3.5726	7.2211E-04	4.0402E-03	4.7623E-02	3.3336E-02	9.5247E-03	2.8184E-01
50.0	329.8	4.8727E-01	0.6308	0.9237	1.5545E+00	13681.5838	13.7760	1.8727E-04	1.0478E-03	6.1753E-02	3.3346E-02	2.4701E-03	7.3091E-02
100.0	659.5	2.5302E-01	0.3276	0.9592	1.2868E+00	26348.3842	26.5302	9.7241E-05	5.4407E-04	6.4131E-02	3.3348E-02	1.2826E-03	3.7953E-02
110.0	725.5	2.3083E-01	0.2988	0.9626	1.2614E+00	28881.7442	29.0810	8.8711E-05	4.9635E-04	6.4356E-02	3.3348E-02	1.1701E-03	3.4624E-02
120.0	791.4	2.1221E-01	0.2747	0.9654	1.2402E+00	31415.1043	31.6319	8.1557E-05	4.5632E-04	6.4545E-02	3.3348E-02	1.0758E-03	3.1832E-02
130.0	857.4	1.9638E-01	0.2542	0.9678	1.2221E+00	33948.4644	34.1827	7.5471E-05	4.2227E-04	6.4706E-02	3.3349E-02	9.9548E-04	2.9456E-02
140.0	923.3	1.8274E-01	0.2366	0.9699	1.2065E+00	36481.8244	36.7336	7.0230E-05	3.9295E-04	6.4845E-02	3.3349E-02	9.2635E-04	2.7411E-02
150.0	989.3	1.7087E-01	0.2212	0.9717	1.1929E+00	39015.1845	39.2844	6.5670E-05	3.6743E-04	6.4965E-02	3.3349E-02	8.6620E-04	2.5631E-02
160.0	1055.2	1.6045E-01	0.2077	0.9733	1.1810E+00	41548.5446	41.8353	6.1666E-05	3.4503E-04	6.5071E-02	3.3349E-02	8.1339E-04	2.4068E-02
170.0	1121.2	1.5123E-01	0.1958	0.9747	1.1705E+00	44081.9046	44.3861	5.8122E-05	3.2520E-04	6.5164E-02	3.3349E-02	7.6664E-04	2.2685E-02
180.0	1187.1	1.4301E-01	0.1851	0.9759	1.1611E+00	46615.2647	46.9369	5.4963E-05	3.0753E-04	6.5248E-02	3.3349E-02	7.2498E-04	2.1452E-02
190.0	1253.1	1.3564E-01	0.1756	0.9771	1.1527E+00	49148.6248	49.4878	5.2130E-05	2.9167E-04	6.5323E-02	3.3349E-02	6.8761E-04	2.0346E-02
200.0	1319.0	1.2899E-01	0.1670	0.9781	1.1451E+00	51681.9849	52.0386	4.9575E-05	2.7738E-04	6.5390E-02	3.3349E-02	6.5390E-04	1.9349E-02
300.0	1978.5	8.6563E-02	0.1121	0.9845	1.0966E+00	77015.5856	77.5470	3.3268E-05	1.8614E-04	6.5821E-02	3.3349E-02	4.3881E-04	1.2984E-02
400.0	2638.0	6.5136E-02	0.0843	0.9878	1.0721E+00	102349.1863	103.0555	2.5033E-05	1.4006E-04	6.6039E-02	3.3349E-02	3.3019E-04	9.7705E-03
500.0	3297.5	5.2213E-02	0.0676	0.9897	1.0573E+00	127682.7870	128.5639	2.0066E-05	1.1227E-04	6.6170E-02	3.3350E-02	2.6468E-04	7.8319E-03
695.5	4586.9	3.7620E-02	0.0487	0.9920	1.0407E+00	177212.1241	178.4350	1.4458E-05	8.0894E-05	6.6318E-02	3.3350E-02	1.9070E-04	5.6430E-03

5% Cases:

H/U Ratio	H/X Ratio	U Density	UO2F2 Density	H2O Density	Total Mixture Density	Volume for given mass (cm3)	Material Height (cm)	U-235	U-238	H	O	F	U-235 Density
0.088	1.7	4.9318E+00	6.3829	0.0164	6.3993E+00	6488.4506	6.5332	6.3180E-04	1.1853E-02	1.0986E-03	2.5518E-02	2.4969E-02	2.4659E-01
5.0	98.8	2.9258E+00	3.7867	0.5539	4.3406E+00	10937.0422	11.0125	3.7482E-04	7.0316E-03	3.7032E-02	3.3329E-02	1.4813E-02	1.4629E-01
10.0	197.6	1.8813E+00	2.4348	0.7123	3.1472E+00	17009.3432	17.1267	2.4101E-04	4.5213E-03	4.7623E-02	3.3336E-02	9.5247E-03	9.4066E-02
15.0	296.4	1.3864E+00	1.7943	0.7874	2.5817E+00	23081.6442	23.2409	1.7760E-04	3.3319E-03	5.2642E-02	3.3340E-02	7.0189E-03	6.9319E-02
20.0	395.2	1.0976E+00	1.4206	0.8312	2.2518E+00	29153.9451	29.3551	1.4061E-04	2.6379E-03	5.5570E-02	3.3342E-02	5.5570E-03	5.4881E-02
25.0	494.0	9.0841E-01	1.1757	0.8599	2.0356E+00	35226.2461	35.4693	1.1637E-04	2.1832E-03	5.7489E-02	3.3343E-02	4.5991E-03	4.5421E-02
30.0	592.8	7.7485E-01	1.0028	0.8801	1.8830E+00	41298.5471	41.5835	9.9263E-05	1.8622E-03	5.8843E-02	3.3344E-02	3.9229E-03	3.8742E-02
35.0	691.6	6.7552E-01	0.8743	0.8952	1.7695E+00	47370.8481	47.6977	8.6539E-05	1.6235E-03	5.9850E-02	3.3345E-02	3.4200E-03	3.3776E-02
40.0	790.4	5.9877E-01	0.7749	0.9068	1.6818E+00	53443.1491	53.8119	7.6706E-05	1.4390E-03	6.0628E-02	3.3346E-02	3.0314E-03	2.9938E-02
45.0	889.2	5.3768E-01	0.6959	0.9161	1.6120E+00	59515.4501	59.9261	6.8880E-05	1.2922E-03	6.1248E-02	3.3346E-02	2.7221E-03	2.6884E-02
50.0	988.0	4.8790E-01	0.6314	0.9237	1.5551E+00	65587.7510	66.0403	6.2503E-05	1.1726E-03	6.1753E-02	3.3346E-02	2.4701E-03	2.4395E-02
80.0	1580.8	3.1366E-01	0.4059	0.9501	1.3560E+00	102021.5570	102.7256	4.0182E-05	7.5381E-04	6.3519E-02	3.3348E-02	1.5880E-03	1.5683E-02
141.9	2804.2	1.8057E-01	0.2337	0.9703	1.2040E+00	177212.1241	178.4350	2.3133E-05	4.3397E-04	6.4869E-02	3.3349E-02	9.1421E-04	9.0287E-03

Horizontally Oriented 30ECV Contents Model:

100% Cases:

Angle theta (in degrees)	Angle theta (in Radians)	Chord (cm)	Mixture Cross Sectional Area (cm2)	U Density	H/U Ratio	H/X Ratio	UO2F2 Density	H2O Density	Total Mixture Density	U-235 Density	Volume for given mass (cm3)
17.2	0.2996	-17.5809	0.7050	6.3593E+00	0.088	0.088	8.2531	0.0215	8.2745E+00	6.3593E+00	125.80041
22.3	0.3900	-17.4430	1.5510	2.8907E+00	5.0	5.0	3.7516	0.5539	4.3055E+00	2.8907E+00	276.74803
25.9	0.4523	-17.3274	2.4121	1.8587E+00	10.0	10.0	2.4123	0.7123	3.1246E+00	1.8587E+00	430.39991
40.8	0.7128	-16.6627	9.3009	4.8204E-01	50.0	50.0	0.6256	0.9237	1.5493E+00	4.8204E-01	1659.61469
51.1	0.8911	-16.0444	17.9120	2.5030E-01	100.0	100.0	0.3248	0.9592	1.2841E+00	2.5030E-01	3196.13259
88.7	1.5489	-12.7092	86.8004	5.1652E-02	500.0	500.0	0.0670	0.9897	1.0568E+00	5.1652E-02	15488.22373
114.7	2.0023	-9.5895	172.9109	2.5929E-02	1000.0	1000.0	0.0337	0.9937	1.0273E+00	2.5929E-02	30853.35182
152.0	2.6529	-4.3011	345.1318	1.2990E-02	2000.0	2000.0	0.0169	0.9957	1.0125E+00	1.2990E-02	61583.58519
183.8	3.2073	0.5845	517.3529	8.6661E-03	3000.0	3000.0	0.0112	0.9963	1.0076E+00	8.6661E-03	92313.86420
216.2	3.7726	5.5173	689.5739	6.5017E-03	4000.0	4000.0	0.0084	0.9967	1.0051E+00	6.5017E-03	123044.12038
360.0	6.2832	17.7800	993.1467	4.5144E-03	5762.7	5762.7	0.0059	0.9970	1.0028E+00	4.5144E-03	177212.12410

15% Cases:

Angle theta (in degrees)	Angle theta (in Radians)	Chord (cm)	Mixture Cross Sectional Area (cm2)	U Density	H/U Ratio	H/X Ratio	UO2F2 Density	H2O Density	Total Mixture Density	U-235 Density	Volume for given mass (cm3)
34.8	0.6080	-16.9648	5.8123	6.4281E+00	0.088	0.6	8.3218	0.0215	8.3433E+00	9.6422E-01	1037.11206
45.5	0.7942	-16.3965	12.7864	2.9220E+00	5.0	33.0	3.7828	0.5539	4.3368E+00	4.3830E-01	2281.53646
52.9	0.9236	-15.9177	19.8854	1.8789E+00	10.0	66.0	2.4324	0.7123	3.1447E+00	2.8183E-01	3548.25156
84.9	1.4811	-13.1236	76.6755	4.8727E-01	50.0	329.8	0.6308	0.9237	1.5545E+00	7.3091E-02	13681.58402
108.0	1.8852	-10.4492	147.6638	2.5302E-01	100.0	659.5	0.3276	0.9592	1.2868E+00	3.7953E-02	26348.38462
221.5	3.8651	6.2925	715.5700	5.2213E-02	500.0	3297.5	0.0676	0.9897	1.0573E+00	7.8319E-03	127682.73960
360.0	6.2832	17.7800	993.1467	3.7620E-02	695.5	4586.9	0.0487	0.9920	1.0407E+00	5.6430E-03	177212.12410

5% Cases:

Angle theta (in degrees)	Angle theta (in Radians)	Chord (cm)	Mixture Cross Sectional Area (cm2)	U Density	H/U Ratio	H/X Ratio	UO2F2 Density	H2O Density	Total Mixture Density	U-235 Density	Volume for given mass (cm3)
59.4	1.0373	-15.4417	27.8624	6.4365E+00	0.088	1.7	8.3303	0.0214	8.3518E+00	3.2183E-01	4971.62138
78.3	1.3671	-13.7854	61.2942	2.9258E+00	5.0	98.8	3.7867	0.5539	4.3406E+00	1.4629E-01	10937.03559
91.8	1.6026	-12.3709	95.3288	1.8812E+00	10.0	197.6	2.4348	0.7123	3.1471E+00	9.4062E-02	17009.99506
156.3	2.7277	-3.6534	367.5784	4.8789E-01	50.0	988.0	0.6314	0.9237	1.5551E+00	2.4394E-02	65588.84300
193.7	3.3806	2.1193	571.7585	3.1366E-01	80.0	1580.8	0.4059	0.9501	1.3560E+00	1.5683E-02	102021.73405
360.0	6.2832	17.7800	993.1467	1.8057E-01	141.9	2804.2	0.2337	0.9703	1.2040E+00	9.0287E-03	177212.12410

Attachment B

SCALE Input Deck Samples

100p contents vertical hu800.inp

```
=csas25   parm=size=1500000
UX-30 containing ASME Pressure Vessel
238groupndf5  infhommedium
uo2f2        1  den=0.0420  1.0 293 92235 100 92238 0 end
h2o          1  den=0.9927  1.0 293 end
carbonsteel 2 1.0 293 end
orconcrete  3 1.0 293 end
h2o         4 1.0 293 end
h2o         5 3.4e-5 293 end
'Foam
c            6  den=0.1602 0.600 end
o            6  den=0.1602 0.240 end
n            6  den=0.1602 0.080 end
h            6  den=0.1602 0.070 end
p            6  den=0.1602 0.010 end
h2o         7 1.0 293 end
poly(h2o)   8 den=0.2 end
end comp

read parm
 tba=20 gen=600 npg=500 nsk=50 run=yes nub=yes
end parm

read geom

com='UX-30 Overpack with ASME Pressure Vessel'

global
unit 1

 com='UO2F2 and water'
 cylinder 1 1 17.7800  24.8778   0.0000

 com='void space above UO2F2 and Water'
 cylinder 0 1 17.7800 178.4350   0.0000

 com='Foam (modeled as polyethylene) inside ASME Pressure Vessel'
 cylinder 8 1 23.4950 185.7375 -7.3025

 com='Steel ASME pressure vessel'
 cylinder 2 1 24.1300 188.2775 -9.8425

 cuboid 4 1 2p54.6100 2p54.6100 218.7575 -40.3225

end geom


end data
end
```

100p contents horizontal hu100.inp

```
=csas25   parm=size=1500000
UX-30 containing ASME Pressure Vessel
238groupndf5  infhommedium
uo2f2       1  den=0.3248  1.0 293 92235 100 92238 0 end
h2o         1  den=0.9592  1.0 293 end
carbonsteel 2 1.0 293 end
orconcrete  3 1.0 293 end
h2o         4 1.0 293 end
h2o         5 3.4e-5 293 end
'UX-30 Foam
c           6  den=0.1602 0.700 end
o           6  den=0.1602 0.140 end
n           6  den=0.1602 0.080 end
h           6  den=0.1602 0.100 end
p           6  den=0.1602 0.010 end
h2o         7 1.0 293 end
poly(h2o)   8 den=0.2 end
end comp

read parm
 tba=20 gen=600 npg=500 nsk=50 run=yes nub=yes
end parm

read geom

com='UX-30 Overpack with ASME Pressure Vessel'

global
unit 1

 com='UO2F2 and water'
 yhemicyl-z 1 1 17.7800 2p89.2175   chord -16.0444

 com='void space above UO2F2 and Water'
 ycylinder 0 1 17.7800 2p89.2175

 com='Foam (modeled as polyethylene) inside ASME Pressure Vessel'
 ycylinder 8 1 23.4950 2p96.5200

 com='Steel ASME pressure vessel'
 ycylinder 2 1 24.1300 2p99.0600

 cuboid 4 1 2p54.6100 2p129.5400 2p54.6100

end geom


end data
end
```

15p contents vertical hu110.inp

```
=csas25   parm=size=1500000
UX-30 containing ASME Pressure Vessel
238groupndf5  infhommedium
uo2f2        1  den=0.2988  1.0 293 92235 15 92238 85 end
h2o          1  den=0.9626  1.0 293 end
carbonsteel 2 1.0 293 end
orconcrete  3 1.0 293 end
h2o         4 1.0 293 end
h2o         5 3.4e-5 293 end
'Foam
c            6  den=0.1602 0.600 end
o            6  den=0.1602 0.240 end
n            6  den=0.1602 0.080 end
h            6  den=0.1602 0.070 end
p            6  den=0.1602 0.010 end
h2o         7 1.0 293 end
poly(h2o)   8 den=0.2 end
end comp

read parm
 tba=20 gen=600 npg=500 nsk=50 run=yes nub=yes
end parm

read geom

com='UX-30 Overpack with ASME Pressure Vessel'

global
unit 1

 com='UO2F2 and water'
 cylinder 1 1 17.7800  29.0810   0.0000

 com='void space above UO2F2 and Water'
 cylinder 0 1 17.7800 178.4350   0.0000

 com='Foam (modeled as polyethylene) inside ASME Pressure Vessel'
 cylinder 8 1 23.4950 185.7375 -7.3025

 com='Steel ASME pressure vessel'
 cylinder 2 1 24.1300 188.2775 -9.8425

 cuboid 4 1 2p54.6100 2p54.6100 218.7575 -40.3225

end geom


end data
end
```

15p_contents_horizontal_hu50.inp

```
=csas25   parm=size=1500000
UX-30 containing ASME Pressure Vessel
238groupndf5  infhommedium
uo2f2        1  den=0.6308  1.0 293 92235 15 92238 85 end
h2o          1  den=0.9237  1.0 293 end
carbonsteel 2 1.0 293 end
orconcrete  3 1.0 293 end
h2o         4 1.0 293 end
h2o         5 3.4e-5 293 end
'UX-30 Foam
c            6  den=0.1602 0.700 end
o            6  den=0.1602 0.140 end
n            6  den=0.1602 0.080 end
h            6  den=0.1602 0.100 end
p            6  den=0.1602 0.010 end
h2o         7 1.0 293 end
poly(h2o)   8 den=0.2 end
end comp

read parm
 tba=20 gen=600 npg=500 nsk=50 run=yes nub=yes
end parm

read geom

com='UX-30 Overpack with ASME Pressure Vessel'

global
unit 1

 com='UO2F2 and water'
 yhemicyl-z 1 1 17.7800 2p89.2175   chord -13.1236

 com='void space above UO2F2 and Water'
 ycylinder 0 1 17.7800 2p89.2175

 com='Foam (modeled as polyethylene) inside ASME Pressure Vessel'
 ycylinder 8 1 23.4950 2p96.5200

 com='Steel ASME pressure vessel'
 ycylinder 2 1 24.1300 2p99.0600

 cuboid 4 1 2p54.6100 2p129.5400 2p54.6100

end geom


end data
end
```

5p_contents_vertical_hu30.inp

```
=csas25   parm=size=1500000
UX-30 containing ASME Pressure Vessel
238groupndf5  infhommedium
uo2f2        1  den=1.0028  1.0 293 92235 5 92238 95 end
h2o          1  den=0.8801  1.0 293 end
carbonsteel 2 1.0 293 end
orconcrete  3 1.0 293 end
h2o         4 1.0 293 end
h2o         5 3.4e-5 293 end
'Foam
c            6  den=0.1602 0.600 end
o            6  den=0.1602 0.240 end
n            6  den=0.1602 0.080 end
h            6  den=0.1602 0.070 end
p            6  den=0.1602 0.010 end
h2o         7 1.0 293 end
poly(h2o)   8 den=0.2 end
end comp

read parm
 tba=20 gen=600 npg=500 nsk=50 run=yes nub=yes
end parm

read geom

com='UX-30 Overpack with ASME Pressure Vessel'

global
unit 1

 com='UO2F2 and water'
 cylinder 1 1 17.7800  41.5835   0.0000

 com='void space above UO2F2 and Water'
 cylinder 0 1 17.7800 178.4350   0.0000

 com='Foam (modeled as polyethylene) inside ASME Pressure Vessel'
 cylinder 8 1 23.4950 185.7375 -7.3025

 com='Steel ASME pressure vessel'
 cylinder 2 1 24.1300 188.2775 -9.8425

 cuboid 4 1 2p54.6100 2p54.6100 218.7575 -40.3225

end geom


end data
end
```

5p_contents_horizontal_hu50.inp

```
=csas25   parm=size=1500000
UX-30 containing ASME Pressure Vessel
238groupndf5  infhommedium
uo2f2        1  den=0.6314  1.0 293 92235 5 92238 95 end
h2o          1  den=0.9237  1.0 293 end
carbonsteel 2 1.0 293 end
orconcrete  3 1.0 293 end
h2o         4 1.0 293 end
h2o         5 3.4e-5 293 end
'UX-30 Foam
c            6  den=0.1602 0.700 end
o            6  den=0.1602 0.140 end
n            6  den=0.1602 0.080 end
h            6  den=0.1602 0.100 end
p            6  den=0.1602 0.010 end
h2o         7 1.0 293 end
poly(h2o)   8 den=0.2 end
end comp

read parm
 tba=20 gen=600 npg=500 nsk=50 run=yes nub=yes
end parm

read geom

com='UX-30 Overpack with ASME Pressure Vessel'

global
unit 1

 com='UO2F2 and water'
 yhemicyl-z 1 1 17.7800 2p89.2175   chord -3.6534

 com='void space above UO2F2 and Water'
 ycylinder 0 1 17.7800 2p89.2175

 com='Foam (modeled as polyethylene) inside ASME Pressure Vessel'
 ycylinder 8 1 23.4950 2p96.5200

 com='Steel ASME pressure vessel'
 ycylinder 2 1 24.1300 2p99.0600

 cuboid 4 1 2p54.6100 2p129.5400 2p54.6100

end geom


end data
end
```

100p_singleunit.inp

```
=csas25    parm=size=1500000
UX-30 containing ASME Pressure Vessel
238groupndf5  infhommedium
uo2f2        1  den=0.0420  1.0 293 92235 100 92238 0 end
h2o          1  den=0.9927  1.0 293 end
carbonsteel 2 1.0 293 end
orconcrete  3 1.0 293 end
h2o         4 1.0 293 end
h2o         5 1.0 293 end
'Foam
c            6  den=0.1602 0.70 end
o            6  den=0.1602 0.15 end
n            6  den=0.1602 0.05 end
h            6  den=0.1602 0.10 end
h2o         7 1.0 293 end
poly(h2o)   8 den=0.2 end
end comp

read parm
 tba=20 gen=600 npg=500 nsk=50 run=yes nub=yes
end parm

read geom

com='UX-30 Overpack with ASME Pressure Vessel'

global
unit 1

 com='UO2F2 and water'
 cylinder 1 1 17.7800  24.8778   0.0000

 com='water above UO2F2 and Water'
 cylinder 5 1 17.7800 178.4350   0.0000

 com='Foam (modeled as polyethylene) inside ASME Pressure Vessel'
 cylinder 8 1 23.4950 185.7375 -7.3025

 com='Steel ASME pressure vessel'
 cylinder 2 1 24.1300 188.2775 -9.8425

 com='Foam (modeled as polyethylene) outside ASME Pressure Vessel'
 cylinder 8 1 38.1000 188.2775 -9.8425

 com='UX-30 Foam'
 cylinder 6 1 50.8000 203.5175 -25.0825

 com='surrounding cuboid'
 cuboid 5 1 4p81.2800 233.9975 -55.5625


end geom

end data
end
```

100p_infarraytp_void_50water.inp

```
=csas25    parm=size=1500000
UX-30 containing ASME Pressure Vessel
238groupndf5  infhommedium
uo2f2        1  den=0.0420  1.0 293 92235 100 92238 0 end
h2o          1  den=0.9927  1.0 293 end
carbonsteel 2 1.0 293 end
orconcrete  3 1.0 293 end
h2o         4 1.0 293 end
h2o         5 0.5 293 end
'Foam
c            6  den=0.1602 0.70 end
o            6  den=0.1602 0.15 end
n            6  den=0.1602 0.05 end
h            6  den=0.1602 0.10 end
h2o         7 1.0 293 end
poly(h2o)   8 den=0.2 end
end comp

read parm
 tba=20 gen=600 npg=500 nsk=50 run=yes nub=yes
end parm

read geom

com='UX-30 Overpack with ASME Pressure Vessel'

unit 1

 com='UO2F2 and water'
 zhemicyl+x 1 1 17.7800  24.8778   0.0000

 com='water above UO2F2 and Water'
 zhemicyl+x 5 1 17.7800 178.4350   0.0000

 com='Foam (modeled as polyethylene) inside ASME Pressure Vessel'
 zhemicyl+x 8 1 23.4950 185.7375 -7.3025

 com='Steel ASME pressure vessel'
 zhemicyl+x 2 1 24.1300 188.2775 -9.8425

 com='Foam (modeled as polyethylene) outside ASME Pressure Vessel'
 zhemicyl+x 8 1 38.1000 188.2775 -9.8425

 com='UX-30 Foam'
 zhemicyl+x 6 1 50.8000 203.5175 -25.0825

unit 2

 com='UO2F2 and water'
 zhemicyl-x 1 1 17.7800  24.8778   0.0000

 com='water above UO2F2 and Water'
 zhemicyl-x 5 1 17.7800 178.4350   0.0000

 com='Foam (modeled as polyethylene) inside ASME Pressure Vessel'
```

```
 zhemicyl-x 8 1 23.4950 185.7375 -7.3025

 com='Steel ASME pressure vessel'
 zhemicyl-x 2 1 24.1300 188.2775 -9.8425

 com='Foam (modeled as polyethylene) outside ASME Pressure Vessel'
 zhemicyl-x 8 1 38.1000 188.2775 -9.8425

 com='UX-30 Foam'
 zhemicyl-x 6 1 50.8000 203.5175 -25.0825

unit 3

 com='UO2F2 and water'
 zhemicyl+y 1 1 17.7800  24.8778   0.0000

 com='water above UO2F2 and Water'
 zhemicyl+y 5 1 17.7800 178.4350   0.0000

 com='Foam (modeled as polyethylene) inside ASME Pressure Vessel'
 zhemicyl+y 8 1 23.4950 185.7375 -7.3025

 com='Steel ASME pressure vessel'
 zhemicyl+y 2 1 24.1300 188.2775 -9.8425

 com='Foam (modeled as polyethylene) outside ASME Pressure Vessel'
 zhemicyl+y 8 1 38.1000 188.2775 -9.8425

 com='UX-30 Foam'
 zhemicyl+y 6 1 50.8000 203.5175 -25.0825

unit 4

 com='UO2F2 and water'
 zhemicyl-y 1 1 17.7800  24.8778   0.0000

 com='water above UO2F2 and Water'
 zhemicyl-y 5 1 17.7800 178.4350   0.0000

 com='Foam (modeled as polyethylene) inside ASME Pressure Vessel'
 zhemicyl-y 8 1 23.4950 185.7375 -7.3025

 com='Steel ASME pressure vessel'
 zhemicyl-y 2 1 24.1300 188.2775 -9.8425

 com='Foam (modeled as polyethylene) outside ASME Pressure Vessel'
 zhemicyl-y 8 1 38.1000 188.2775 -9.8425

 com='UX-30 Foam'
 zhemicyl-y 6 1 50.8000 203.5175 -25.0825

global
unit 5

 cuboid 0 1 50.8000 -50.8000 87.9883 -87.9883 203.5176 -25.0826
 hole 1 -50.8000   0.0000 0.0000
```

```
 hole 2  50.8000    0.0000 0.0000
 hole 3   0.0000 -87.9883 0.0000
 hole 4   0.0000  87.9883 0.0000

end geom

read bounds
all=mirror
end bounds

end data
end
```