THE NATION'S URANIUM PROCESSING FACILITY

UPF CALCULATION COVER SHEET

PROJECT	JOB NO.	CALC. NO.	SHEET
Uranium Processing Facility	25774	DAC-EN-801768-A100	1 of 132

SUBJECT Nuclear Criticality Safety Data Book

DISCIPLINE Nuclear Criticality Safety

UPF SYSTEM DESIGNATORS: (See ML-EG-801768-A001.)
All

CALCULATION STATUS DESIGNATION	PRELIMINARY	COMMITTED	CONFIRMED	SUPERCEDED	OBSOLETE
	☐	☐	☒	☐	☐

SMan COMPUTER PROGRAM ACRONYM/QL	Type	VERSION/RELEASE	COMPUTER TYPE	OPERATING SYSTEM
SCALE	☒ SCP ☐ Non-SCP	6.1	☐ IBM Compatible Desktop ☒ Remote Server	RedHat Linux

SOFTWARE RUN-TIME VALIDATION	Run-Time Validation Type?	SUCCESSFUL TEST COMPLETION
☒ YES ☐ NO See Appendix A	☐ AUTO ☒ MANUAL ☐ REMOTE	☒ YES ☐ NO

- **Scope**
  This Design Analysis and Calculation (DAC) support revisions to many Criticality Safety Process Studies (CSPSs) for the Uranium Processing Facility (UPF). It provides many of the data inputs typically used in Nuclear Criticality Safety (NCS) calculational DACs at UPF to model both normal and abnormal conditions of processes at UPF. Calculations and documentation were performed in accordance with APA-UPF-3DP-G04B-00037, Rev. 0.
- **What was done**
  This DAC collects many of the input parameter values, with references, used in NCS DACs into one place for easy reference. Section 2 contains the original input data used in this DAC. Section 6 discusses its pedigree, describes how the date is manipulated to place it in a form better suited for use in NCS calculation DACs and produces the resulting data to be used in NCS DACs. Section 7 contains a summary table of information and where in section 6 details of the data can be found. The only program used in this DAC is the Material Information Processor (MIP) in SCALE, version 6.1.1 to calculate atom densities and solutions densities of Uranyl Nitrate and Uranyl Fluoride solutions.
- **Why it was performed**
  This information will provide consistency between NCS DACs and efficiency in preparations and review of DACs, as frequently used data are provided in one reference source.
- **Results and conclusions**
  The data in section 6 include discussions on input data origin, how the data were manipulated, and the final results. The final results include physical constants, sizing specifications, and guidelines for reasonable engineering approximations. This DAC does not contain any NCS computer code results that are directly usable in CSPS evaluations.

QUALITY LEVEL	"Q" Quality	"RS" Risk Significant	"CC" Commercial Control
	☒	☐	☐

	PRINTED NAME	SIGNATURE	DATE
ORIGINATOR	D. F. Hollenbach	Daniel F. Hollenbach	11/15/16
CHECKER	R. G. Taylor	Robert G. Taylor	11/15/16
Sr. EGS/EGS	N/A		
APPROVER	K. H. Reynolds	Kevin H. Reynolds	11/16/16

RC-UPF DMC
11/16/16 10:32

This document has been reviewed by a Y-12 DC / UCNI-RO and has been determined to be UNCLASSIFIED and contains no UCNI. This review does not constitute clearance for Public Release.

Name: Scott Ha Date: 11/15/16

RECORD OF REVISIONS		
REV. NO.	**REASON FOR REVISION**	**LAST SHEET NO.**
0	Initial	79
1	Correct Errors, Add additional materials such as Glass tanks, furnace insulation, Isotopic Data for materials	132
2	Change classification from UCNI to Unclassified and correct a few minor typos.	132

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. OBJECTIVE/PURPOSE STATEMENT

The objective of this document is to support the revision of criticality safety process studies (CSPSs) for the Uranium Processing Facility (UPF) at the Y-12 National Security Complex (Y-12). This design analysis and calculation (DAC) document contains development and justification for generic inputs typically used in Nuclear Criticality Safety (NCS) DACs to model both normal and abnormal conditions of processes at UPF to support CSPSs. This will provide consistency between NCS DACs and efficiency in preparation and review of DACs, as frequently used data are provided in one reference source.

2. DESIGN INPUTS

This section contains physical constants such as atomic weights, material densities, and other material properties that are not calculated but inherent to the material. These are properties that were measured and are reported in the scientific literature or Y-12 internal documents. In all cases, the applicable references for these data are cited.

2.1 DESIGN INPUT SUMMARY

Table 2.1-1 summarizes the design inputs developed for use in typical NCS model calculational DACs.

Table 2.1-1. Design Input

Input Number	Description	Value	Units	Reference
2.1	Elemental atomic mass and densities, except uranium	As specified in Table 2.2-1	g/mole, specific gravity at 20°C, g/cm^3	Ref. 4.15, p. 95
2.2	Isotopic atomic mass and isotopic atom percent for natural elements	As specified in Table 2.2-2	g/mole atom %	Ref. 4.15, p. 92
2.3	Uranium enrichment (unless specified)	Highest	wt % or atom%	Ref. 4.31, Appendix B, item 5
2.4	Uranium density (natural, theoretical)	19.05	g/cm^3	Ref. 4.23, p. 137
2.5	Uranium compound densities (natural, theoretical) UO_2 UO_3 U_3O_8 UF_4	 10.97 ~7.3 8.38 6.7	g/cm^3	Ref. 4.2, p. 4-97
2.6	Uranium compound bulk density UO_2 UO_3 U_3O_8 UF_4	 4.0 – 6.63 3.44 – 4.3 2.4 – 4.3 3.0 – 3.5	g/cm^3	Ref. 4.4, Table 2
2.7	Hydrogen to uranium atomic ratio (H/U) for these flooded (wet) uranium oxides based on minimum powder density UO_3 powder U_3O_8 powder	 ≤ 10.4 ≤ 7.1	H/U atomic ratio	Ref. 4.4, Section 5.0 Recommendations
2.8	H/U for flooded (wet) UO_2 powder depends on maximum dry density	Varies	H/U atomic ratio	Ref. 4.4, Section 5.0 Recommendations
2.9	Hydration for "dry" material (H/U) UO_2 U_3O_8	 0.0 0.94	H/U atomic ratio	Ref. 4.4, Section 2.1.2
2.10	UF_4 not appreciably hygroscopic	0.05	% weight gain	Ref. 4.23, p. 373

Table 2.1-1. Design Input

Input Number	Description	Value	Units	Reference
2.11	UO_3 crystalline forms/phases, production methods, and hydration tendencies..	Various	Various	Ref. 4.23, p. 283-289 Ref. 4.24, p. 3-8 Ref. 4.25, p. 1-18 (See Section 3.2.1.3)
2.12	Avogadro's Constant (N_A)	$6.02214179 \times 10^{23}$	entities/mole	Ref. 4.15
2.13	UPF pipe specifications	See Table 2.6-3	N/A	Refs. 4.36–4.43
2.14	Water density	0.9998495 at 0.1°C 0.9999749 at 4°C 0.9982067 at 20°C	g/cm^3	Ref. 4.2, p. 6-7
2.15	Chemicals in liquid form	As specified in Table 2.3-2	As specified in Table 2.3-2	References listed in Table 2.3-2
2.16	Compound data – densities and compositions	As specified in Table 2.3-3	g/cm^3 atoms/molecule	Ref. 4.18, Table M8.2.4 Ref. 4.51 Ref. 4.52
2.17	Alloy and mixture data – densities and composition	As specified in Table 2.3-4	g/cm^3 wt %	Ref. 4.18, Table M8.2.5
2.18	C350 specification for 10% mixture with water	As specified in Table 2.3-7	wt % (% confidence)	Refs. 4.26, 4.27, 4.28
2.19	Default concrete composition and density - Magnuson's (mgconcrete)	As specified in Table 2.3-4	wt % g/cm^3	Ref. 4.18, Table M8.2.5
2.20	Calculations of slab reflection show for concrete thickness greater than 30-cm, Magnuson's concrete produced the highest overall system k_{eff} for eight different concrete mixtures.	Magnuson Concrete	N/A	Ref. 4.5, Fig. 2
2.21	Thickness considered effectively infinite for concrete reflection	45	cm	Ref. 4.5, Fig. 2
2.22	Full tight-fitting water reflection on a "single *fissile unit*" shall be shown to be subcritical	12	in.	Ref. 4.31, Appendix B, item 9
2.23	The *"fissile unit"* definition is a list of items, which includes single parts, single process containers, and most groups of portable items that are controlled as a single item under container handling requirements in the current Y-12 facilities	N/A	N/A	Ref. 4.31, Appendix A
2.24	Water thickness that is considered effectively infinite for water reflection	300	mm	Ref. 4.14, Section 2.8

Table 2.1-1. Design Input

Input Number	Description	Value	Units	Reference
2.25	Hydrocarbon and water thickness considered effectively saturated reflection (close-fitting); Water reflection graph	10 See Fig. 2.4-1	cm	Ref. 4.19, Page 42, Table XX and Fig. 21.
2.26	Graphed experimental data on neutron reflection effects from 1 to 6 human hands of various sizes around a small uranium sphere. Data presented in relation to equivalent thickness of contiguous water reflection around an item	Various	cm	Ref. 4.11, page 5, Fig. 7
2.27	Water reflection that would easily bound the potential reflection on an item from one set of operator hands	0.5	in.	Ref. 4.11, p. 6
2.28	Water density from sprinklers	Less than 0.0005	g/cm^3	Ref. 4.13, 4.54
2.29	Sprinkler water film thickness Non-horizontal surface Horizontal surface	 3.5 7	 mm mm	Ref. 4.12 and Ref. 4.46
2.30	Pipe dimensions	Outer diameter, wall thickness, and tolerance as specified in Table 2.6-1	in.	Ref. 4.7, Table X1.1, and Ref. 4.9, Table 1
2.31	Tube outer dimension tolerance	As specified in Table 2.6-2	in.	Ref. 4.8, Table 2
2.32	Standard person (operator) - water cuboid size Height Width Depth	 183 37.13 12.38	 cm cm cm	Ref. 4.1, p. 5
2.33	Gloveboxes, airlocks, hoods: Floor – 304 stainless steel	7	ga	Ref. 4.45, criterion DC-3-1106.1.22
2.34	Thickness of 7 ga. steel	3/16 0.1875	in. in.	Ref. 4.34, p. 585
2.35	Gloveboxes, airlocks, hoods: Lexan MR-10 window thickness, nominal	3/8	in.	Ref. 4.45, criterion DC-3-1106.1.61
2.36	Effectiveness of various reflectors on uranium spheres	Various	Various	Ref. 4.32, Figs. 44 and 46
2.37	Glovebox spacing from walls, minimum Glovebox and other equipment spacing from floor, minimum	35 35	in. in.	Ref. 4.35, criteria: DC-2-302.7.3 DC-2-302.7.2
2.38	Manual lifting weight for operations in gloveboxes	15	lb	Ref. 4.45, criterion DC-3-1106.1.10
2.39	Concrete floor thickness, typical	15	in.	Ref. 4.73 – 4.84

Table 2.1-1. Design Input

Input Number	Description	Value	Units	Reference
2.40	MPB Concrete structure thickness, typical Lower level foundation Walls	 >3 3	 ft ft	Ref. 473 -4.84
2.41	Glass Tubing Dimensions	Inner diameter, wall thickness, and tolerances as specified in Table 2.6-3	mm	Ref. 4.47,
2.42	BoroBond4	As specified in Table 2.3-5	at /b-cm	Ref. 4.48, App. A
2.43	SALI	As specified in Table 2.3-7	at/molecule	Ref. 4.51
2.44	Bubble Alumina	As specified in Table 2.3-7	wt %	Ref. 4.52
2.45	Flooding level above concrete floor in room	As specified in Tables 7 & 8 of Ref. 4.56	in. gU/l	Ref. 4.56, Table 7 & Table 8
2.46	#3 Inner Container	As specified in Table 2.8-1	in.	Ref. 4.59
2.47	#4 Inner Container	As specified in Table 2.8-1	in.	Ref. 4.60
2.48	#5 Inner Container	As specified in Table 2.8-1	in.	Ref. 4.61
2.49	Tube Vault Can	As specified in Table 2.8-1	in.	Ref. 4.62
2.50	#3 Outer Container	As specified in Table 2.8-2	in.	Ref. 4.63, 4.64, 4.65
2.51	#4 Outer Container	As specified in Table 2.8-2	in.	Ref. 4.66, 4.67, 4.68
2.52	#5 Outer Container	As specified in Table 2.8-2	in.	Ref. 4.69, 4.70, 4.71, 4.72

2.2 ELEMENT AND NUCLIDE DATA

2.2.1 Natural Element Data

Table 2.2-1 contains a list of elements with their atomic masses and maximum theoretical densities from the Chart of Nuclides [Ref. 4.15], with the exception of the uranium density. Natural enrichment uranium density values cited from various references vary from 18.95 g/cm^3 [Ref. 4.15] to 19.1 g/cm^3 [Ref. 4.2]. A value of 19.05 was chosen from The Chemistry of Uranium [Ref. 4.23] for consistency with conservative past NCS practices. This table contains data for the naturally occurring elements. The elemental data is color coded so that its natural state at standard temperature and pressure [STP, defined as 0°C (273.15 K) at 1 atmosphere (101.325 kPa)] [Ref. 4.15, p. 13, Fig. 6, and note 136] is easily identified. The following is the color code: black is solid, green is gas, blue is liquid and red is for elements with element numbers lower than Thorium (90) that do not occur in nature. All data are listed to the number of known significant figures.

Table 2.2-1. Natural Element Data [Chart of Nuclides, 17th edition, Design Input 2.1]

Element Number	Element	Symbol	Atomic Mass	Specific [1] Gravity or g/L	Element Number	Element	Symbol	Atomic Mass	Specific [1] Gravity or g/L
1	Hydrogen *	H	1.00794	0.08988	50	Tin	Sn	118.710	5.7 – 7.3
2	Helium *	He	4.002602	0.1785	51	Antimony	Sb	121.760	6.691
3	Lithium	Li	6.941	0.534	52	Tellurium	Te	127.60	6.24
4	Beryllium	Be	9.012182	1.848	53	Iodine	I	126.90447	4.93
5	Boron	B	10.811	2.35	54	Xenon *	Xe	131.293	5.887
6	Carbon	C	12.0107	1.8 - 3.5	55	Cesium	Cs	132.9054519	1.873
7	Nitrogen *	N	14.0067	1.2506	56	Barium	Ba	137.327	3.5
8	Oxygen *	O	15.9994	1.429	57	Lanthanum [2]	La	138.90547	6.145
9	Fluorine *	F	18.9984032	1.696	58	Cerium	Ce	140.116	6.770
10	Neon *	Ne	20.1797	0.89990	59	Praseodymium	Pr	140.90765	6.773
11	Sodium	Na	22.98976928	0.971	60	Neodymium	Nd	144.242	7.008
12	Magnesium	Mg	24.3050	1.738	61	Promethium	Pm	……..	7.264
13	Aluminum	Al	26.9815386	2.6989	62	Samarium	Sm	150.36	7.520
14	Silicon	Si	28.0855	2.33	63	Europium	Eu	151.964	5.244
15	Phosphorus	P	30.973762	1.82	64	Gadolinium	Gd	157.25	7.901
16	Sulfur	S	32.065	2.07	65	Terbium	Tb	158.92535	8.230
17	Chlorine *	Cl	35.453	3.214	66	Dysprosium	Dy	162.500	8.551
18	Argon *	Ar	39.948	1.784	67	Holmium	Ho	164.93032	8.795
19	Potassium	K	39.0983	0.862	68	Erbium	Er	167.259	9.066
20	Calcium	Ca	40.078	1.55	69	Thulium	Tm	168.93421	9.321
21	Scandium	Sc	44.955912	2.989	70	Ytterbium	Yb	173.04	6.039-
22	Titanium	Ti	47.867	4.54	71	Lutetium	Lu	174.967	9.841
23	Vanadium	V	50.9415	6.11	72	Hafnium	Hf	178.49	13.31
24	Chromium	Cr	51.9961	7.19	73	Tantalum	Ta	180.94788	16.654
25	Manganese	Mn	54.938045	7.3	74	Tungsten	W	183.84	19.3
26	Iron	Fe	55.845	7.874	75	Rhenium	Re	186.207	21.02
27	Cobalt	Co	58.933195	8.9	76	Osmium	Os	190.23	22.57
28	Nickel	Ni	58.6934	8.902	77	Iridium	Ir	192.217	22.42
29	Copper	Cu	63.546	8.96	78	Platinum	Pt	195.084	21.45
30	Zinc	Zn	65.409	7.133	79	Gold	Au	196.966569	~19.3
31	Gallium	Ga	69.723	5.904	80	Mercury	Hg	200.59	13.546
32	Germanium	Ge	72.64	5.323	81	Thallium	Tl	204.3833	11.85
33	Arsenic	As	74.92160	5.7	82	Lead	Pb	207.2	11.35
34	Selenium	Se	78.96	4.7	83	Bismuth	Bi	208.98040	9.747
35	Bromine	Br	79.904	3.12	84	Polonium	Po	……..	9.32
36	Krypton *	Kr	83.798	3.733	85	Astatine	At	……..	……..
37	Rubidium	Rb	85.4678	1.532	86	Radon *	Rn	……..	9.73
38	Strontium	Sr	87.62	2.54	87	Francium	Fr	……..	……..

Table 2.2-1. Natural Element Data [Chart of Nuclides, 17th edition, Design Input 2.1]

Element Number	Element	Symbol	Atomic Mass	Specific [1] Gravity or g/L	Element Number	Element	Symbol	Atomic Mass	Specific [1] Gravity or g/L
39	Yttrium	Y	88.90585	4.469	88	Radium	Ra	……..	5
40	Zirconium	Zr	91.224	6.506	89	Actinium	Ac [3]	……..	10.07
41	Niobium	Nb	92.90638	8.57	90	Thorium	Th	232.03806	11.72
42	Molybdenum	Mo	95.94	10.22	91	Protactinium	Pa	231.03588	15.37
43	Technetium	Tc	……..	11.50	92	Uranium	U	238.02891	19.05 [4]
44	Ruthenium	Ru	101.07	12.41	93	Neptunium	Np	……..	20.25
45	Rhodium	Rh	102.90550	12.41	94	Plutonium	Pu	……..	19.84
46	Palladium	Pd	106.42	12.02	95	Americium	Am	……..	13.67
47	Silver	Ag	107.8682	10.50	96	Curium	Cm	……..	13.5
48	Cadmium	Cd	112.411	8.65	97	Berkelium	Bk	……..	~14
49	Indium	In	114.818	7.31	98	Californium	Cf	……..	……..

[1] Specific Gravity measured at 20°C for solids and liquids, Density measured at 0°C in g/L for gases

[2] Beginning of Lanthanide Series

[3] Beginning of Actinide Series

[4] Natural Uranium Density values cited from various references vary from 18.916 g/cm^3 [Ref. 4.15] to 19.1 g/cm^3 [Ref. 4.2]. A value of 19.05 was chosen from The Chemistry of Uranium [Ref. 4.23] for consistency with conservative past NCS practices.

Gas, Liquid, Solid at 20°C or artificially prepared, does not exist naturally for elements with nuclide number < 90

* Indicates a gas at STP

2.2.2 Isotopic Data

Table 2.2-2 contains a list of isotopes with their atomic weight and atom percent in the naturally occurring element from the Chart of Nuclides [Ref. 4.15]. For some isotopes, designated by "*", significant differences in atom percent values have been observed in some samples. In all cases, the atom percentages of all isotopes in the element sum to 100%. All data are listed to the number of known significant figures.

Table 2.2-2. Isotopic Distributions, Atomic Weights, and Atom Percent [Design Input 2.2]

Isotope	Z	A	Atomic Weight	Atom Percent**	Isotope	Z	A	Atomic Weight	Atom Percent**
H-1	1	1	1.00782503207	99.9885	Sn-112	50	112	111.904818207	0.97
H-2*	1	2	2.01410177785	0.0115	Sn-114	50	114	113.902778869	0.66
He-3*	2	3	3.01602931914	0.000134	Sn-115	50	115	114.903342397	0.34
He-4	2	4	4.00260325415	99.999866	Sn-116	50	116	115.901740530	14.54
Li-6*	3	6	6.015122794	7.59	Sn-117	50	117	116.902951656	7.68
Li-7*	3	7	7.016004548	92.41	Sn-118	50	118	117.901603167	24.22
Be-9	4	9	9.012182201	100.	Sn-119	50	119	118.903307630	8.59
B-10*	5	10	10.012936992	19.9	Sn-120	50	120	119.902194676	32.58
B-11*	5	11	11.009305406	80.1	Sn-122	50	122	121.903439046	4.63
C-12	6	12	12.0000000	98.93	Sn-124	50	124	123.905273946	5.79
C-13	6	13	13.00335483778	1.07	Sb-121	51	121	120.903815686	57.21
N-14	7	14	14.00307400478	99.636	Sb-123	51	123	122.904213970	42.79
N-15	7	15	15.00010889823	0.364	Te-120	52	120	119.904020222	0.09
O-16	8	16	15.99491461956	99.757	Te-122	52	122	121.903043898	2.55

Table 2.2-2. Isotopic Distributions, Atomic Weights, and Atom Percent [Design Input 2.2]

Isotope	Z	A	Atomic Weight	Atom Percent**	Isotope	Z	A	Atomic Weight	Atom Percent**
O-17	8	17	16.999131703	0.038	Te-123	52	123	122.904270029	0.89
O-18	8	18	17.999161001	0.205	Te-124	52	124	123.902817896	4.74
F-19	9	19	18.998403224	100.	Te-125	52	125	124.904430731	7.07
Ne-20	10	20	19.99244017542	90.48	Te-126	52	126	125.903311696	18.84
Ne-21	10	21	20.993846684	0.27	Te-128	52	128	127.904463056	31.74
Ne-22	10	22	21.991385113	9.25	Te-130	52	130	129.906224399	34.08
Na-23	11	23	22.98976928087	100.	I-127	53	127	126.904472681	100.
Mg-24	12	24	23.985041699	78.99	Xe-124	54	124	123.905893003	0.0952
Mg-25	12	25	24.985836917	10.00	Xe-126	54	126	125.904273634	0.0890
Mg-26	12	26	25.982592929	11.01	Xe-128	54	128	127.903531275	1.9102
Al-27	13	27	26.981538627	100.	Xe-129	54	129	128.904779435	26.4006
Si-28	14	28	27.97692653246	92.223	Xe-130	54	130	129.903508007	4.0710
Si-29	14	29	28.976494700	4.685	Xe-131	54	131	130.905082362	21.2324
Si-30	14	30	29.973770171	3.092	Xe-132	54	132	131.904153457	26.9086
P-31	15	31	30.973761629	100.	Xe-134	54	134	133.905394464	10.4357
S-32	16	32	31.972070999	94.99	Xe-136	54	136	135.907218794	8.8573
S-33	16	33	32.971458759	0.75	Cs-133	55	133	132.905451932	100.
S-34	16	34	33.967866902	4.25	Ba-130	56	130	129.906320811	0.106
S-36	16	36	35.967080760	0.01	Ba-132	56	132	131.905061288	0.101
Cl-35	17	35	34.968852682	75.76	Ba-134	56	134	133.904508383	2.417
Cl-37	17	37	36.965902591	24.24	Ba-135	56	135	134.905688591	6.592
Ar-36	18	36	35.967545105	0.3365	Ba-136	56	136	135.904575945	7.854
Ar-38	18	38	37.962732394	0.0632	Ba-137	56	137	136.905827384	11.232
Ar-40	18	40	39.96238312251	99.6003	Ba-138	56	138	137.905247237	71.698
K-39	19	39	38.963706679	93.2581	La-138	57	138	137.907111930	0.090
K-40	19	40	39.963998475	0.0117	La-139	57	139	138.906353267	99.910
K-41	19	41	40.961825762	6.7302	Ce-136	58	136	135.907172422	0.185
Ca-40	20	40	39.962590983	96.941	Ce-138	58	138	137.905991321	0.251
Ca-42	20	42	41.958618014	0.647	Ce-140	58	140	139.905438706	88.450
Ca-43	20	43	42.958766628	0.135	Ce-142	58	142	141.909244205	11.114
Ca-44	20	44	43.955481754	2.086	Pr-141	59	141	140.907652769	100.
Ca-46	20	46	45.953692587	0.004	Nd-142	60	142	141.907723297	27.2
Ca-48	20	48	47.952534177	0.187	Nd-143	60	143	142.909814290	12.2
Sc-45	21	45	44.955911909	100.	Nd-144	60	144	143.910087274	23.8
Ti-46	22	46	45.952631555	8.25	Nd-145	60	145	144.912573636	8.3
Ti-47	22	47	46.951763088	7.44	Nd-146	60	146	145.913116939	17.2
Ti-48	22	48	47.947946281	73.72	Nd-148	60	148	147.916893288	5.7
Ti-49	22	49	48.947869982	5.41	Nd-150	60	150	149.920890888	5.6
Ti-50	22	50	49.944791194	5.18	Sm-144	62	144	143.911999478	3.07
V-50	23	50	49.947158485	0.250	Sm-147	62	147	146.914897923	14.99
V-51	23	51	50.943959507	99.750	Sm-148	62	148	147.914822674	11.24
Cr-50	24	50	49.946044205	4.345	Sm-149	62	149	148.917184735	13.82
Cr-52	24	52	51.940507472	83.789	Sm-150	62	150	149.917275539	7.38
Cr-53	24	53	52.940649386	9.501	Sm-152	62	152	151.919732425	26.75
Cr-54	24	54	53.938880395	2.365	Sm-154	62	154	153.922209273	22.75
Mn-55	25	55	54.938045141	100.	Eu-151	63	151	150.919850161	47.81

Table 2.2-2. Isotopic Distributions, Atomic Weights, and Atom Percent [Design Input 2.2]

Isotope	Z	A	Atomic Weight	Atom Percent**	Isotope	Z	A	Atomic Weight	Atom Percent**
Fe-54	26	54	53.939610501	5.845	Eu-153	63	153	152.921230339	52.19
Fe-56	26	56	55.934937475	91.754	Gd-152	64	152	151.919790996	0.20
Fe-57	26	57	56.935393969	2.119	Gd-154	64	154	153.920865598	2.18
Fe-58	26	58	57.933275558	0.282	Gd-155	64	155	154.922622022	14.80
Co-59	27	59	58.933195048	100.	Gd-156	64	156	155.922122743	20.47
Ni-58	28	58	57.935342907	68.0769	Gd-157	64	157	156.923960135	15.65
Ni-60	28	60	59.930786372	26.2231	Gd-158	64	158	157.924103912	24.84
Ni-61	28	61	60.931056033	1.1399	Gd-160	64	160	159.927054146	21.86
Ni-62	28	62	61.928345115	3.6345	Tb-159	65	159	158.925346757	100.
Ni-64	28	64	63.927965959	0.9256	Dy-156	66	156	155.924283110	0.056
Cu-63	29	63	62.929597474	69.15	Dy-158	66	158	157.924409487	0.095
Cu-65	29	65	64.927789485	30.85	Dy-160	66	160	159.925197517	2.329
Zn-64	30	64	63.929142222	48.268	Dy-161	66	161	160.926933364	18.889
Zn-66	30	66	65.926033419	27.975	Dy-162	66	162	161.926798447	25.475
Zn-67	30	67	66.927127345	4.102	Dy-163	66	163	162.928731159	24.896
Zn-68	30	68	67.924844154	19.024	Dy-164	66	164	163.929174751	28.260
Zn-70	30	70	69.925319274	0.631	Ho-165	67	165	164.930322070	100.
Ga-69	31	69	68.925573587	60.108	Er-162	68	162	161.928778264	0.139
Ga-71	31	71	70.924701349	39.892	Er-164	68	164	163.929200229	1.601
Ge-70	32	70	69.924247381	20.38	Er-166	68	166	165.930293061	33.503
Ge-72	32	72	71.922075815	27.31	Er-167	68	167	166.932048159	22.869
Ge-73	32	73	72.923458945	7.76	Er-168	68	168	167.932370224	26.978
Ge-74	32	74	73.921177767	36.72	Er-170	68	170	169.935464312	14.910
Ge-76	32	76	75.921402557	7.83	Tm-169	69	169	168.934213250	100.
As-75	33	75	74.921596478	100.	Yb-168	70	168	167.933896895	0.13
Se-74	34	74	73.922476436	0.89	Yb-170	70	170	169.934761837	3.04
Se-76	34	76	75.919213597	9.37	Yb-171	70	171	170.936325799	14.28
Se-77	34	77	76.919914038	7.63	Yb-172	70	172	171.936381469	21.83
Se-78	34	78	77.917309090	23.77	Yb-173	70	173	172.938210787	16.13
Se-80	34	80	79.916521271	49.61	Yb-174	70	174	173.938862089	31.83
Se-82	34	82	81.916699401	8.73	Yb-176	70	176	175.942571683	12.76
Br-79	35	79	78.918337087	50.69	Lu-175	71	175	174.940771819	97.41
Br-81	35	81	80.916290563	49.31	Lu-176	71	176	175.942686310	2.59
Kr-78	36	78	77.920364783	0.355	Hf-174	72	174	173.940046178	0.16
Kr-80	36	80	79.916378965	2.286	Hf-176	72	176	175.941408631	5.26
Kr-82	36	82	81.913483600	11.593	Hf-177	72	177	176.943220651	18.60
Kr-83	36	83	82.914136099	11.500	Hf-178	72	178	177.943698766	27.28
Kr-84	36	84	83.911506687	56.987	Hf-179	72	179	178.945816145	13.62
Kr-86	36	86	85.910610729	17.279	Hf-180	72	180	179.946549953	35.08
Rb-85	37	85	84.911789737	72.17	Ta-180	73	180	179.947464831	0.012
Rb-87	37	87	86.909180526	27.83	Ta-181	73	181	180.947995763	99.988
Sr-84	38	84	83.913425275	0.56	W-180	74	180	179.946704459	0.12
Sr-86	38	86	85.909260204	9.86	W-182	74	182	181.948204156	26.50
Sr-87	38	87	86.908877124	7.00	W-183	74	183	182.950222951	14.31
Sr-88	38	88	87.905612124	82.58	W-184	74	184	183.950931118	30.64
Y-89	39	89	88.905848295	100.	W-186	74	186	185.954364127	28.43

Table 2.2-2. Isotopic Distributions, Atomic Weights, and Atom Percent [Design Input 2.2]

Isotope	Z	A	Atomic Weight	Atom Percent**	Isotope	Z	A	Atomic Weight	Atom Percent**
Zr-90	40	90	89.904704416	51.45	Re-185	75	185	184.952954982	37.40
Zr-91	40	91	90.905645767	11.22	Re-187	75	187	186.955753109	62.60
Zr-92	40	92	91.905040847	17.15	Os-184	76	184	183.952489071	0.02
Zr-94	40	94	93.906315192	17.38	Os-186	76	186	185.953838158	1.59
Zr-96	40	96	95.908273386	2.80	Os-187	76	187	186.955750458	1.96
Nb-93	41	93	92.906378058	100.	Os-188	76	188	187.955838228	13.24
Mo-92	42	92	91.906810991	14.77	Os-189	76	189	188.958147470	16.15
Mo-94	42	94	93.905088269	9.23	Os-190	76	190	189.958447048	26.26
Mo-95	42	95	94.905842129	15.90	Os-192	76	192	191.961480690	40.78
Mo-96	42	96	95.904679477	16.68	Ir-191	77	191	190.960594046	37.3
Mo-97	42	97	96.906021465	9.56	Ir-193	77	193	192.962926430	62.7
Mo-98	42	98	97.905408169	24.19	Pt-190	78	190	189.959931655	0.014
Mo-100	42	100	99.907477336	9.67	Pt-192	78	192	191.961038005	0.782
Ru-96	44	96	95.907597835	5.54	Pt-194	78	194	193.962680253	32.967
Ru-98	44	98	97.905287132	1.87	Pt-195	78	195	194.964791134	33.832
Ru-99	44	99	98.905939302	12.76	Pt-196	78	196	195.964951521	25.242
Ru-100	44	100	99.904219476	12.60	Pt-198	78	198	197.967892790	7.163
Ru-101	44	101	100.905582087	17.06	Au-197	79	197	196.966568662	100.
Ru-102	44	102	101.904349312	31.55	Hg-196	80	196	195.965832649	0.15
Ru-104	44	104	103.905432701	18.62	Hg-198	80	198	197.966769032	9.97
Rh-103	45	103	102.905504292	100.	Hg-199	80	199	198.968279932	16.87
Pd-102	46	102	101.905608544	1.02	Hg-200	80	200	199.968326004	23.10
Pd-104	46	104	103.904035834	11.14	Hg-201	80	201	200.970302268	13.18
Pd-105	46	105	104.905084920	22.33	Hg-202	80	202	201.970643011	29.86
Pd-106	46	106	105.903485715	27.33	Hg-204	80	204	203.973493933	6.87
Pd-108	46	108	107.903891701	26.46	Tl-203	81	203	202.972344220	29.52
Pd-110	46	110	109.905153254	11.72	Tl-205	81	205	204.974427541	70.48
Ag-107	47	107	106.905096820	51.839	Pb-204	82	204	203.973043589	1.4
Ag-109	47	109	108.904752292	48.161	Pb-206	82	206	205.974465278	24.1
Cd-106	48	106	105.906459410	1.25	Pb-207	82	207	206.975896887	22.1
Cd-108	48	108	107.904183683	0.89	Pb-208	82	208	207.976652071	52.4
Cd-110	48	110	109.903002070	12.49	Bi-209	83	209	208.980398734	100.
Cd-111	48	111	110.904178107	12.80	Th-232	90	232	232.038055325	100.
Cd-112	48	112	111.902757809	24.13	Pa-231	91	231	231.035883990	100.
Cd-113	48	113	112.904401662	12.22	U-234**	92	234	234.040952088	0.0054
Cd-114	48	114	113.903358540	28.73	U-235**	92	235	235.043929918	0.7204
Cd-116	48	116	115.904755809	7.49	U-238**	92	238	238.050788247	99.2742
In-113	49	113	112.904057761	4.29					
In-115	49	115	114.903878484	95.71					

*Significant differences in the atom percent values have been observed in some samples.

**Atom percentages are for naturally occurring materials, including those for uranium.

2.2.3 Uranium Enrichment

The isotopic distribution for uranium in Table 2.2-2 is for natural (non-enriched) uranium. UPF processes highly enriched uranium. Y70-150 [Ref. 4.31] contains direction in Appendix B, "Nuclear Criticality Safety Program Fundamental Criteria," item 5, which states "Processes in which unintended commingling of materials of different enrichments is possible shall be evaluated at the maximum credible enrichment available." [Design Input 2.3] This means that NCS analysis must be based on the most conservative possible enrichment. Although there are no bulk quantities of uranium at 100% enrichment, a specific isotopic distribution for the highest enrichment handled is difficult to define. Therefore, for consistency and simplicity, all fissile materials are considered to have a ^{235}U enrichment of 100 wt %, unless a controlled specification imposes an enrichment criterion. In cases where enrichment is specified and controlled, the fissile material is considered to have the maximum ^{235}U enrichment in the specification.

2.3 URANIUM METAL, COMPOUND, AND MIXTURE DATA

2.3.1 Uranium Metal and Compounds—Density and Hydration Data

For uranium compounds, various densities and H/U values were researched to find appropriate models for handling and storage of dry compounds in containers at UPF. This may be applied to all processes for handling dry compounds.

2.3.1.1 Theoretical Data for Uranium Metal and Uranium Compounds

The natural uranium metal density of 19.05 g/cm^3 [Design Input 2.4] was taken from Katz & Rabinowitch [Ref. 4.23]. Natural uranium compound density data were taken from the CRC Handbook of Chemistry and Physics, 94th edition, page 4-97 [Design Input 2.5, Ref. 4.2]. Natural uranium has an atomic weight of 238.02891 (see Table 2.2-1).

2.3.1.2 Hydration of "Dry" Uranium Compounds in Air

"Hydration" can be used to refer to water absorbed into the compound, forming a molecular bonded "hydrate," which makes a different crystalline structure. In addition, hydration can be used to refer to hygroscopic adsorption, in which water molecules attach to the surface of a crystal structure (particle of the compound) and take up some of the space that would otherwise be "void" or air. In older technical references especially, it is difficult to discern any difference between uses of the two terms. In either case, water vapor from humid air can be absorbed into compounds, especially when material is stored in containers or collects as holdup in equipment. Even compounds that are produced at Y-12 as completely anhydrous have been observed to gain weight over time when in storage. For these reasons, common uranium compounds handled at Y-12 were researched, to determine appropriate maximum hydrogen to uranium atom ratio (H/U) values for NCS analyses of "dry" uranium compounds in air at Y-12.

UO_2 and U_3O_8

Y/DD-1246 [Ref. 4.4] has a small section on "Hygroscopic Properties," in which data from experiments in ORNL-TM-2001/59 [Ref. 4.22] are cited. TANSAO, 99, 361-362 [Ref. 4.17] summarizes and discusses several of the values from Ref. 4.4. These consisted of small samples exposed to 70% and 97.5% humidity air for various times up to several months and were used to assign H/U values for UO_2 and U_3O_8 [Design Input 2.9]. For UO_2, bulk quantities are not typically stable in air unless processed to "passivate" the material, which essentially converts the outside layer of each particle into UO_3 or U_3O_8. The passivation material would be a very small percentage but could have some associated hydration, so bulk quantities of UO_2 could be measured to contain some water due to a mixture of compounds. It would be acceptable to evaluate each compound separately, with the applicable hydration, and use the one that is most limiting for nuclear safety as the bounding compound. Alternatively, it is acceptable to model the material as a theoretical mixture of the higher density UO_2 and enough water to attain the H/U of the other compound. This would be conservative since the material is less than optimum moderation level. Note that the experimental data from those sources for UO_3 was not used in this DAC since it was not representative of Y-12-produced material (it was pot-produced, very small particle size, very small batch sizes) and the production method has been shown to be very important to the hygroscopic qualities, as discussed under "UO_3" below.

<u>UF_4</u>

Although the planned operations at UPF will not utilize large quantities of this compound, legacy material from Building 9212 may need to be handled. *The Chemistry of Uranium* (Katz & Rabinowitch) [Ref. 4.23] states UF_4 is not appreciably hygroscopic, for material from high temperature hydro-fluorination, which is the Y-12 method of UF_4 production. That reference cites an experiment where a sample of UF_4 only increased 0.05% in weight from air exposure for 564 hours [Design Input 2.10]. This weight increase is equivalent to 0.05-g water in 100-g compound, which is an H/U value of essentially 0. No further information was found, so a bounding H/U value of 1 is chosen for UF_4.

<u>UO_3</u>

The following general understanding of UO_3 is mainly from three sources: Katz & Rabinowitch [Ref. 4.23], DP-749 [Ref. 4.24], and CCG-339 [Ref. 4.25] [Design Input 2.11]. UO_3 has many crystalline phases and an amorphous phase, variously referred to as polymorphs α, β, γ, δ, and sometimes others and are cited before the compound (e.g., α -UO_3) or with parenthetical roman numeral-type designations following the compound [e.g., UO_3 (I)]. The phase mainly depends on the method and temperature of formation, although transfers between phases can be accomplished with various temperature and water treatments. The typical hydrates are UO_3•0.5 H_2O (hemihydrate), UO_3•H_2O (monohydrate), or UO_3•2H_2O (dihydrate), with H/U values of 1, 2, and 4, respectively. The phase formed at Y-12 is typically the third one, γ-UO_3 or UO_3(III), since it forms by large-volume or continuous denitration of uranyl nitrate hexahydrate (UNH) at temperatures from 250°C to 400°C [Ref. 4.24, Table 1, and Ref. 4.25, Fig. 3]. This phase is typically formed as anhydrous (no water content), but the product may contain a small fraction of hydrates due to the exposure to the waters formed in the reaction. Each phase of UO_3 tends toward certain hydrate formations. DP-749 [Ref. 4.24, p. 8] describes an experiment where γ -UO_3 was exposed to water at 70°C and formed α -UO_3 •H_2O (H/U=2). This matches results found in shallow bed Y-12 experiments cited in CCG-339 [Ref. 4.25, p. 14] that predicted that the maximum amount of moisture adsorbed at room temperature results in H/U atom ratio of 2, based on weight gain. It is not known whether this was complete conversion to a monohydrate or a partial conversion with a mixture of hydrates. Although it has been established that a di-hydrate exists, the Y-12 production material experiments are taken to be bounding of a maximum H/U value for typical handling and storage conditions at Y-12, including UPF. A contributing factor for the experiment may be the large particle size, which could limit hydration towards the center of the particle. A conservatism in using this data is that the experiment used an extremely shallow bed (described as essentially a single layer of microspheres), and UO_3 storage at Y-12 is in bulkier quantities within tanks and cans, with only a small amount of the material exposed to the humidity from air. In CCG-339 [Ref. 4.25], the experiment with Y-12 production UO_3 in a crucible with a material depth of about 1.8 cm showed much slower H_2O adsorption with possible equilibrium content less than that in a thin layer. Therefore, a bounding H/U value for UO_3 handling and storage in cans is set at H/U=2. Table 2.3-1 summarizes the values developed for each compound.

Table 2.3-1. Hydration Summary for "Dry" Uranium Compounds

Description	H/U Atom Ratio	Discussion	Reference
UO_2	0	No hydrates, From ORNL experiment	4.4
UO_3	2	Based on Y-12 production form and experiments	4.23, 4.24, 4.25
U_3O_8	0.94	From ORNL experiment	4.4, 4.22
UF_4	1	Bounding value – no hydration expected based on production method	4.23

For mixtures of compounds or for a single model to represent several compounds, a bounding model can be created with the highest uranium density of all available materials and the highest H/U ratio of all materials, which is conservative for under moderated materials.

2.3.1.3 Uranium Compound Bulk Densities—Dry and Wet

Uranium compounds can have a range of average bulk densities, that is, the mass of compound in a measured volume, with interstices between material particles. The bulk density of material depends on the method of production and types of other processing, such as grinding and sieving. The highest typical bulk density should be used for normal dry conditions since it has the least neutron leakage. Average bulk density ranges for the uranium compounds historically handled at the Y-12 complex are from 2.4 to 6.6 g/cm^3 [Design Input 2.6, Ref. 4.4]. Most values from Table 1 in Y/DD-1246 [Ref. 4.4] were taken directly from NCS-RTI-035-08 [Ref. 4.20], which was authored by Roger Spence, an experienced denitrator process engineer. The high-end value for UO_3 is bounding of the 4.2 g/cc value determined in CSE-DNT-079, Rev. 6 [Ref. 4.21], which cited a variety of sources and data. Note that use of this bulk density information requires justification related to the expected method of production and sources of the bulk density values. If possible, it is best to use measured data from the actual process being analyzed.

Under normal process conditions, uranium compounds are typically powder with various consistencies such as granular or flour-like. These compounds exhibit a bulk density representing a weighted average of the denser compound particles and the air filled voids between them. For a given mass at the bulk densities typically encountered for most compounds, water flooding increases k_{eff} more than it would were the compound at a higher density because the system is less than optimally moderated at typical bulk densities; i.e., the system is on the under-moderated side of the critical mass as a function of density curve. Experimental results in Y/DD-1246 [Ref. 4.4] indicate that water added slowly to a container of oxide will not decrease the bulk density in the absence of agitation. This result indicates that just the existing void space is filled with water and the compound does not expand or puff up. Therefore, the lowest bulk densities should be used for flooded conditions in the absence of process-specific data. This resulted in the reference-recommended maximum H/U values [Design Input 2.7].

For flooding of most uranium compounds, this is more reactive than higher densities for the same given mass because the system is less than optimally moderated at typical bulk densities. Experimental results in Y/DD-1246 [Ref. 4.4] indicate that water added slowly to a container of oxide will not decrease the overall bulk oxide density in the absence of agitation. This means that just the existing void space is filled with water and the compound does not "puff" up. Therefore, the lowest bulk densities should be used for flooded conditions in the absence of process-specific data. This resulted in the reference-recommended maximum H/U values [Design Input 2.7].

An exception is recognized in Ref. 4.4 for UO_2, which behaves more like metal in that the optimum concentration for minimum volume occurs at the highest density. In the reference, this resulted in recommendation to use highest density for flooded conditions for UO_2 [Design Input 2.8]. This may not be the optimum for all masses and equipment configurations.

2.3.1.4 Insoluble Uranium-Water Mixture Data

Material models generally use additive volumes to determine maximum average homogeneous densities, volume fractions, and H/U ratios for wet/flooded uranium metal and oxides. Inputs for calculation of these values are based on inputs described in other subsections of Sect. 2.3.1.

2.3.2 Uranium Solution Guidelines

The SCALE computer code [Ref. 4.16] is used to determine uranyl nitrate ($UO_2(NO_3)_2$) and uranyl fluoride (UO_2F_2) solution properties. Input to the code included uranium concentration; excess acid molarity (typically 0.0, no excess acid); and solution temperature. Number densities and solution density are calculated as discussed in Sect. 6.3.2.

2.3.3 Chemicals in Liquid Form

Many chemicals in liquid form are used in the processes at UPF. Some are used as pure chemicals and others as solutions of the chemical with water. Table 2.3-2 contains a list of the more common liquid chemicals used at UPF and their densities [Design Input 2.15]. Table entries showing 100 mass % for concentration indicate pure chemicals. Other table entries are for solutions of the chemical in water. Some chemicals are listed more than once, showing a density at more than one solution concentration. Some chemicals have values reported as specific gravity (e.g., $d^{15}{}_4$, which is the specific gravity at 15°C relative to water at 4°C). The density of water at 4°C is 0.9999749 g/cm^3 [Design Input 2.14].

Table 2.3-2. Density of Chemicals in Liquid Form [Design Input 2.15]

Chemical	Concentration of Chemical in Solution [mass %]	Formula	Reported Value	Units	Temp [°C]	Reference
Acetic acid	100	CH_3COOH	1.0498	g/cm^3	20	4.30, p. 2-115
Acetone	100	$(CH_3)_2CO$	0.7845	g/cm^3	25	4.2, p. 3-4
Acetonitrile	100	CH_3CN	0.7857	g/cm^3	20	4.2, p. 3-6
Aluminum nitrate	32	$Al(NO_3)_3$	1.3036	$d^{15}{}_4$	15	4.29, p. 70
Ammonia	30	NH_3	0.8920	g/cm^3	20	4.30, p. 2-104
Chromic acid	50	H_2CrO_4	1.505	$d^{15}{}_4$	15	4.30, p. 2-105
Dibutyl carbitol (diethylene glycol dibutyl ether)	100	$C_{12}H_{26}O_3$	0.885	g/cm^3	25	4.2, p. 3-176
Dodecane	100	$CH_3(CH_2)_{10}CH_3$	0.7495	g/cm^3	20	4.2, p. 3-236
Hydrochloric acid	40	HCl	1.1980	g/cm^3	20	4.30, p. 2-106
Hydrochloric acid	38	HCl	1.1885	g/cm^3	20	4.30, p. 2-106
Hydrochloric acid	30	HCl	1.1493	g/cm^3	20	4.30, p. 2-106
Hydrofluoric acid	50	HF	1.155	$d^{20}{}_4$	20	4.30, p. 2-106
Hydrogen peroxide	55	H_2O_2	1.2188	$d^{18}{}_4$	18	4.30, p. 2-106
Hydrogen peroxide	35	H_2O_2	1.1327	$d^{18}{}_4$	18	4.30, p. 2-106
Nitric acid	70	HNO_3	1.4134	g/cm^3	20	4.30, p. 2-108

Table 2.3-2. Density of Chemicals in Liquid Form [Design Input 2.15]

Chemical	Concentration of Chemical in Solution [mass %]	Formula	Reported Value	Units	Temp [°C]	Reference
Nitric acid	50	HNO_3	1.3100	g/cm^3	20	4.30, p. 2-107
Nitric acid	30	HNO_3	1.1800	g/cm^3	20	4.30, p. 2-107
Phosphoric acid	100	H_3PO_4	1.870	g/cm^3	20	4.30, p. 2-108
Sodium hydroxide	50	NaOH	1.5253	g/cm^3	20	4.30, p. 2-110
Sodium nitrate	45	$NaNO_3$	1.3683	g/cm^3	20	4.30, p. 2-110
Sulfuric acid	50	H_2SO_4	1.3951	g/cm^3	20	4.30, p. 2-112
Sulfuric acid	98	H_2SO_4	1.8361	g/cm^3	20	4.30, p. 2-113
Tributyl phosphate	100	$(C_4H_9O)_3PO$	0.9727	g/cm^3	25	4.2, p. 3-518

2.3.4 Chemicals in Solid Form

Several compounds, mixtures, and alloys have been predefined in the SCALE computer code. These predefined materials include many used in criticality safety analyses. Most of the data in this section are from the standard composition library in SCALE 6.1 [Ref. 4.18].

2.3.4.1 Molecular Data for Pure Compounds

Data for non-uranium-bearing molecules and compounds, including graphite, in this section represent many of the materials that may be used at UPF. Table 2.3-3 contain the name, molecular formula, and theoretical density for standard elements and compounds used in the SCALE code system. The first 10 materials (Al_2O_3 through H_2O) can be used directly in SCALE by entering either the molecular formula or the name in the standard composition section of the SCALE input file. For benzene, graphite, plexiglass, and polyethylene, the name is entered; the other four materials are specified using the molecular formula. For consistency, the same densities should also be used in MCNP calculations.

Bubble-alumina and SALI are commercially available insulating materials. The data for them are from Material Cut Sheets provided by the vendor.

Table 2.3-3. Pure Non-Fissile Material Data [Design Input 2.16]

Name	Molecule	Theoretical Density (g/cm^3)	Reference
Aluminum oxide	Al_2O_3	3.97	Ref. 4.18, Table M8.2.4
Boron carbide	B_4C	2.52	Ref. 4.18, Table M8.2.4
Benzene	C_6H_6	0.8765	Ref. 4.18, Table M8.2.4
Beryllium oxide	BeO	3.0	Ref. 4.18, Table M8.2.4
Gadolinium oxide	Gd_2O_3	7.07	Ref. 4.18, Table M8.2.4
Graphite	C	2.3	Ref. 4.18, Table M8.2.4
Plexiglass	$C_5H_8O_2$	1.18	Ref. 4.18, Table M8.2.4
Polyethylene	CH_2	0.92	Ref. 4.18, Table M8.2.4
Polyvinyl chloride	C_2H_3Cl	1.6	Ref. 4.18, Table M8.2.4
Water	H_2O	0.9982*	Ref. 4.18, Table M8.2.4
Bubble-alumina	>99% Al_2O_3	0.96	Ref. 4.52
SALI low-density alumina)	80 wt% Al_2O_3 20 wt% SiO_2	0.48	Ref. 4.51

Table 2.3-3. Pure Non-Fissile Material Data [Design Input 2.16]

Name	Molecule	Theoretical Density (g/cm^3)	Reference
Silicon Carbide	SiC	3.16	Ref. 4.2, Sect. 4, p. 4-88
Silicon Dioxide	SiO_2 (α-quartz) (β-quartz) (tridymite) (cristobalite) (vitreous)	 2.648 2.533 2.265 2.334 2.196	Ref. 4.2, Sect. 4, p. 4-88

*This water density corresponds to four decimal places to the density reported in Ref. 4.2, p.6-7, for water at 20°C [Design Input 2.14]

2.3.4.2 Molecular Data for Mixtures and Alloys

The following material data contain many of the materials used in criticality safety analyses. The information in Table 2.3-4 contains weight percent of each element or nuclide in the mixture and its theoretical density. All these materials can be used directly in SCALE by entering its name in the standard composition section of the SCALE input file.

Table 2.3-4. Alloy and Mixture Data (Ref. 4.18, Table M8.2.5) [Design Input 2.17]

Name	Element: Wt %	Density (g/cm^3)	Name	Element: Wt %	Density (g/cm^3)
CarbonSteel	Fe: 99.0 C: 1.0	7.8212	u(.27)metal [1]	^{235}U: 0.27 ^{238}U: 99.73	19.05
Dry-Air	C: 0.0126 N: 76.5081 O: 23.4793	0.0012	Kerosene	C: 84.0 H: 16.0	0.82
Granite	H: 0.0336 O: 47.8286 F: 0.0901 Na: 2.2501 Mg: 0.1449 Al: 7.4752 Si: 32.8046 P: 0.0393 K: 5.0108 Ca: 1.1876 Ti: 0.2520 Mn: 0.0465 Fe: 2.8367	2.66	mgconcrete [2]	Fe: 0.5595 H: 0.3319 C: 10.5321 O: 49.9430 Na: 0.1411 Mg: 9.4200 Al: 0.7859 Si: 4.2101 S: 0.2483 Cl: 0.0523 K: 0.9445 Ca: 22.6318 Ti: 0.1488 Mn: 0.0512	2.147
Inconel	Si: 2.5 Ti: 2.5 Cr: 15.0 Fe: 7.0 Ni: 73.0	8.3	SS304	C: 0.08 Si: 1.0 P: 0.045 Cr: 19.0 Mn: 2.0 Fe: 68.375 Ni: 9.5	7.94

Table 2.3-4. Alloy and Mixture Data (Ref. 4.18, Table M8.2.5) [Design Input 2.17]

Name	Element: Wt %	Density (g/cm^3)	Name	Element: Wt %	Density (g/cm^3)
Limestone	H: 0.0863 C: 11.3548 O: 49.6925 Na: 0.0371 Mg: 4.7656 Al: 0.4294 Si: 2.4299 P: 0.0175 S: 0.0251 K: 0.2744 Ca: 30.4731 Ti: 0.0360 Fe: 0.3783	2.15	SS316	C: 0.08 Si: 1.0 P: 0.045 Cr: 17.0 Mn: 2.0 Fe: 65.375 Ni: 12.0 Mo: 2.5	8.03
Pyrex	B: 3.7 Al: 1.0 O: 53.5 Si: 37.7 Na: 4.1	2.23	Zirc4	Zr: 98.23 Sn: 1.45 Fe: 0.21 Cr:: 0.10 Hf: 0.01	6.56

[1] Depleted Uranium
[2] Magnuson's Concrete

2.3.5 BoroBond4

The BoroBond4™ neutron absorbing material is required to meet specifications on minimum boron and hydrogen content, as specified in JS-YMN1-801649-A002 [Ref. 4.49]. BoroBond4™ consists of a mixture of ordinary Class F fly ash and natural B_4C powders that are uniformly distributed and encapsulated throughout the solid $MgKPO_4 \cdot 6H_2O$ material system, a chemically bonded phosphate-based ceramic. The hydrogen content is specified since the hydrogen is necessary to thermalize the neutrons so that they can be absorbed by the boron. More information on the development of BoroBond4™ minimum boron and hydrogen contents may be found in Y/DD-965 [Ref. 4.50]. Each Rackable Can Storage Box (RCSB) has an associated data package that lists the weight percents of the materials used in the batch to fill that particular RCSB. The fly ash constituents are simplified for the calculation model to a nominal 10 wt % FeO_2, 40 wt % Al_2O_3, and 50% SiO_2. Y/DD-965 analyzed varying the weight percents of FeO_2, Al_2O_3, and SiO_2 and determined that the exact composition was irrelevant for criticality safety purposes. The same can be said for the MgO andKH_2PO_4 weight percents as far as criticality safety calculations are concerned. Table 2.3-5 contains the atom densities of BoroBond4from Y/DD-1215 for cases where 0, 5, 40, 50, and 60 lbs of water were eliminated from the BoroBond4 in a standard RCSB [Ref. 4.48].[Design Input 2.42] Only the Hydrogen and Oxygen atom densities change due to the change in water content in the RCSB. All other atom densities remained constant.

Table 2.3-5 BoroBond4 Data (Ref. 4.48, App. A)

Element	Base H_2O content Atom density (at/b-cm)	5 lb decrease in H_2O content Atom density (at/b-cm)	40 lb decrease in H_2O content Atom density (at/b-cm)	50 lb decrease in H_2O content Atom density (at/b-cm)	60 lb decrease in H_2O content Atom density (at/b-cm)
Mg	0.003247	0.003247	0.003247	0.003247	0.003247
O	0.039400	0.039340	0.038915	0.038794	0.038672
K	0.002971	0.002971	0.002971	0.002971	0.002971
H	0.030314	0.030193	0.029344	0.029101	0.028858
P	0.002971	0.002971	0.002971	0.002971	0.002971
Fe	0.000500	0.000500	0.000500	0.000500	0.000500
Al	0.003130	0.003130	0.003130	0.003130	0.003130
Si	0.003320	0.003320	0.003320	0.003320	0.003320
B-10	0.000616	0.000616	0.000616	0.000616	0.000616
B-11	0.002478	0.002478	0.002478	0.002478	0.002478
C	0.000773	0.000773	0.000773	0.000773	0.000773

2.3.6 Machine Coolant

The coolant used for all machine operations except the Electric Discharge Machine (EDM) is a mixture of 10% TRIM C350 and water [Design Input 2.18]. According to the data and information sheet [Ref. 4.28] TRIM C350 is a colorless to pale yellow liquid having a recommended mixture for moderate to heavy-duty machining of 8 vol% to 10 vol% C350 and water. The Material Safety Data Sheet for TRIM C350 [Ref. 4.27] lists it as a Premium Synthetic Metalworking Fluid manufactured by Master Chemical Corporation. Concentrated C350 has a specific gravity (H_2O = 1) of 0.999 to 1.105. C350 has no immediate hazards, is nontoxic, and not carcinogenic.

The Y-12 Analytical Chemistry laboratory (ACL) analyzed C350 to determine its elemental composition [Ref. 4.26]. Table 2.3-6 contains the Y-12 ACL results [Design Input 2.18, Assumption 3.5].

Table 2.3-6. C350 Results from Y-12 Analytical Chemistry Laboratory Report

Element	Result (wt %)	Confidence (%)
Carbon	32.60	0.23
Hydrogen	10.49	0.17
Nitrogen	N/A	---
Oxygen	65	---

Density of 100% C350: 1.0542 g/cm^3

Measured Density of 10 vol% C350 – 90% water: 1.0007 g/cm^3

2.3.7 Concrete Composition

Concrete is an engineering material that is often encountered. Its composition is variable and can change its effectiveness as both a reflector and moderator depending upon its thickness and composition as described in TANSAO, 61, 182-184 [Ref. 4.5]. The effects of concrete as a reflector and as an interstitial material between fissile units are highly dependent on its density, constituents, and water content, which vary with age, exposure to the elements, temperature, and humidity. It must be demonstrated that the concrete used in computational models is realistic and appropriately conservative for the particular placement of concrete in the computational model.

Reference 4.5 contains an analysis comparing the effect on overall system k_{eff} for eight different types of concrete. Both dry and wet fissile systems were analyzed in SCALE models. The dry system consisted of a 1.49-cm thick, 100% ^{235}U metal slab. For the wet system, the metal slab was replaced with a 4.9-cm thick UO_2F_2 solution slab having an H/U ratio of 50. The fissile slab was placed between tight-fitting concrete slabs having thicknesses varying from 0 cm to 60 cm. The analysis shows that, in all cases for concrete reflector thickness greater than 30 cm, standard SCALE composition "Magnuson's Concrete" produced the highest overall system k_{eff} [Design Input 2.20]. The analysis also shows that concrete thicknesses greater than 45 cm are effectively infinite [Design Input 2.21].

2.3.8 Isotopic Composition of Selected Compounds/Alloys

MCNP requires material data to be entered by isotope with either the associated atom fraction or weight fraction. Table 2.3-7 and Table 2.3-8 contain a list of compounds/alloys that are commonly used in MCNP inputs and therefore require isotopic data. The compounds and alloys taken from tables 2.3-3 through 2.3-5 and listed in Table 2.3-7 are those compounds/alloys containing elements that have more than one primary isotope. The elements need to be broken down into isotopes assuming the natural isotopic abundance from the 17th edition of the Nuclides and Isotopes Chart of the Nuclides, Ref. 4.15. The Elemental breakdown in Table 2.3-7 is either a molecule specifying the relative number of each element (i.e. B_4C) or weight fraction of each element or molecule in the alloy (i.e. SS304).

Table 2.3-7 Compounds/Alloys requiring Isotopic Data

Compound/ Alloy	Elemental Breakdown	Density (g/cm^3)	Compound/ Alloy	Elemental Breakdown	Density (g/cm^3)
Boron carbide	B_4C	2.52	Polyvinyl chloride	C_2H_3Cl	1.6
Gadolinium oxide	Gd_2O_3	7.07	CarbonSteel	Fe: 99.0 C: 1.0	7.8212
Silicon Dioxide (α-quartz) (β-quartz) (tridymite) (cristobalite) (vitreous)	SiO_2	2.196 2.533 2.265 2.334 2.648	Inconel (wt%)	Si: 2.5 Ti: 2.5 Cr: 15.0 Fe: 7.0 Ni: 73.0	8.3

Table 2.3-7 Compounds/Alloys requiring Isotopic Data

Compound/ Alloy	Elemental Breakdown	Density (g/cm^3)	Compound/ Alloy	Elemental Breakdown	Density (g/cm^3)
Limestone (wt%)	H: 0.0863 C: 11.3548 O: 49.6925 Na: 0.0371 Mg: 4.7656 Al: 0.4294 Si: 2.4299 P: 0.0175 S: 0.0251 K: 0.2744 Ca: 30.4731 Ti: 0.0360 Fe: 0.3783	2.15	mgconcrete (wt%)	Fe: 0.5595 H: 0.3319 C: 10.5321 O: 49.9430 Na: 0.1411 Mg: 9.4200 Al: 0.7859 Si: 4.2101 S: 0.2483 Cl: 0.0523 K: 0.9445 Ca: 22.6318 Ti: 0.1488 Mn: 0.0512	2.147
Pyrex (wt%)	B: 3.7 Al: 1.0 O: 53.5 Si: 37.7 Na: 4.1	2.23	Zirc4 (wt%)	Zr: 98.23 Sn: 1.45 Fe: 0.21 Cr:: 0.10 Hf: 0.01	6.56
			Silicon Carbide	SiC	3.16
SS304 (wt%)	C: 0.08 Si: 1.0 P: 0.045 Cr: 19.0 Mn: 2.0 Fe: 68.375 Ni: 9.5	7.94	SS316 (wt%)	C: 0.08 Si: 1.0 P: 0.045 Cr: 17.0 Mn: 2.0 Fe: 65.375 Ni: 12.0 Mo: 2.5	8.03
Granite (wt%)	H: 0.0336 O: 47.8286 F: 0.0901 Na: 2.2501 Mg: 0.1449 Al: 7.4752 Si: 32.8046 P: 0.0393 K: 5.0108 Ca: 1.1876 Ti: 0.2520 Mn: 0.0465 Fe: 2.8367	2.66			
Bubble-alumina	>99% Al_2O_3	0.96	SALI (low-density alumina)	80 wt% Al_2O_3 20 wt% SiO_2	0.48

2.4 STANDARD DIMENSIONAL DATA

2.4.1 Reflection Guidelines

The following standardized reflection conditions should be used to the extent practical, in the absence of specific NCS requirements and/or specific design information. These specified reflection conditions represent conservative conditions that are expected to be bounding of most anticipated reflection conditions in the facility. Judgment must be exercised to determine if any specific materials or conditions could create more effective reflection than that specified below.

2.4.1.1 Full Reflection

Y70-150 [Ref. 4.31] requires in Appendix B on "*Nuclear Criticality Safety Program Fundamental Criteria*" item 9 that "Any single fissile unit shall be shown to be subcritical under full (12 inch thick) tight fitting water reflection" [Design Input 2.22]. Appendix A of that procedure gives a definition for *fissile unit*, which includes single parts, single process containers, and most groups of portable items that are controlled as a single item under container handling requirements [Design Input 2.23].

The required 12-in.-thick water reflection is considered effectively infinite water reflection, as discussed in Ref. 4.14, which lists 300 mm (11.8 in.) thickness of water reflection as effectively infinite [Design Input 2.24]. That reference lists Ref. 4.19 as a source for stating that "the effectiveness of hydrocarbons as reflectors saturates at thicknesses of about 100 mm." (4 in.) [Design Input 2.25]. Although water is not a hydrocarbon, that statement is based on calculated data contained in Table XX on page 42 of Ref. 4.19 for various thicknesses of various reflectors around three different cores of 93.5 wt% ^{235}U: a solid metal core, a metal/water core at H/U=30, and a well-moderated metal/water core at H/U=300. The water data from the table is graphed in Fig. 21 of Ref. 4.19 [reproduced as an excerpt in Fig. 2.4-1] and shows that the reflection effect behaves in a similar manner for all three cores, with small changes in reflection thickness having relatively large effects for thinner reflectors and gradually becoming less with thicker reflectors. However, the graph shows points at a thickness of 20 cm, but the source data is for 25.0 and 25.4 cm thicknesses. This makes it appear that the slope in the higher thickness values is greater than the data shows.

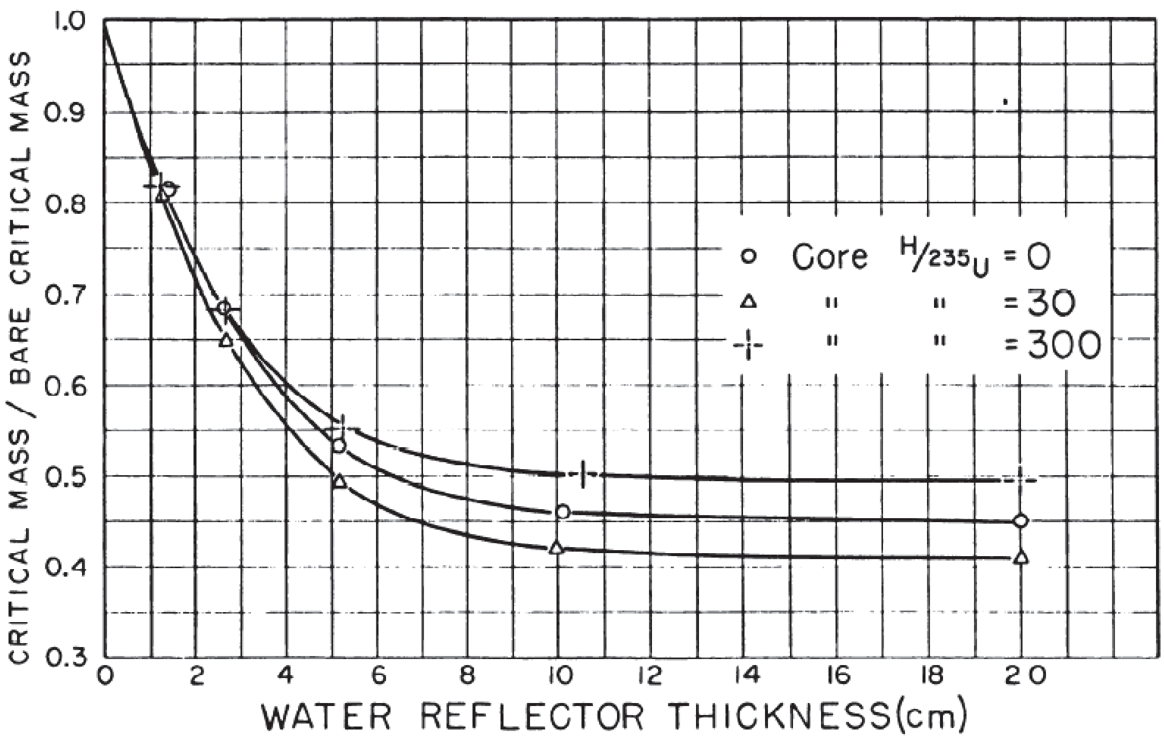


Fig. 2.4-1. Critical mass vs. water reflector thickness [Design Input 2.25].

The effectiveness in the graph is measured as the ratio of the reflected critical mass to the bare critical mass.

2.4.1.2 Reflection From Hands on Small Items

Human hands around a small item, such as a fissile container, are considered bounded by 0.5-in.-thick tight-fitting contiguous water. Although parts of the hands may be thicker than this, hands cannot completely surround a can with no leakage paths. This is illustrated by Fig. 2.4-2 , which is excerpted from the 2011 International Conference on Nuclear Criticality Safety (ICNC) paper, "An Experimental Study of the Effect of Operator Hands on the Reactivity of a Fast Metal System," Percher and Heinrichs [Design Input 2.26, Ref. 4.11]. This shows results of experimental data collected for various combinations of operator hands on spherical systems of uranium metal and Lucite. The spherical system contained 23 kg U (93% enriched) with an outer diameter (OD) of 6.24 in. The data shows that 0.9-cm (0.354-in.)-thick water reflection bounds any pair of operator hands and most sets of three or four hands in the experiment. This indicates that ½-in.-thick water reflection is a conservative reflection condition for a hand-held item [Design Input 2.27]. The water reflection discussion in Sect. 2.4.1.1 shows that water reflection effectiveness behaves about the same for moderated and non-moderated systems.

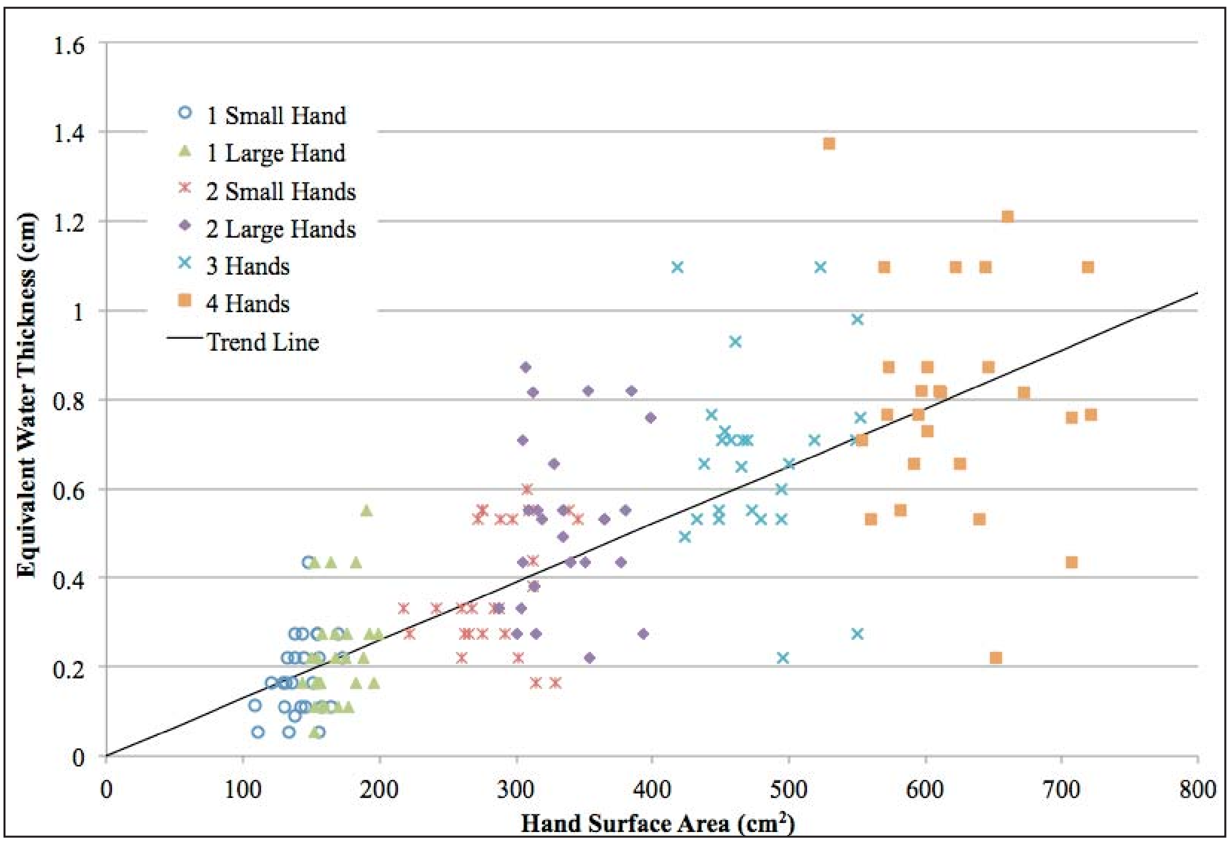


Fig. 2.4-2. Reflector value of operator hands [Design Input 2.26].

2.4.1.3 Standard Glovebox, Airlock, and Hood (Enclosures)

Floors

Glovebox construction is defined by several design criteria contained in Ref. 4.45, Sect. 3-1106, "Gloveboxes, Hoods, and Process Enclosures," and Subsect. 3-1106.1, "General Including Gloveboxes."

DC-3-1106.1.10 "Operations enclosed within the gloveboxes shall not require routine manual lifting of objects over 15 lb." [Design input 2.38]

DC-3-1106.1.22 "Floor thickness [of gloveboxes] shall be designed to support design loads and operating conditions and activities but shall be a minimum of 7 gauge." [Design Input 2.33]

DC-3-1106.1.61 "Glovebox windows shall be constructed of Lexan MR-10 with a nominal thickness of 3/8 in. NOTE: Additional thicknesses, wire glass, fire-rated glass, or laminated safety glass may be used in some special situations with approval by the Company." [Design Input 2.35]

The thickness of 7 gauge steel is 3/16=0.1875 in. [Design Input 2.34]. That thickness and comparisons of various reflectors [Design Input 2.36] are used in Sect. 2.4.1.

Walls and Roof

The standard for windows is 3/8 in. Lexan, which is a polycarbonate [Design Input 2.35]. The remaining parts of the glovebox walls and roof are relatively thinner sheet metal, compared to the floor, since they do not withstand the same load distributions [Assumption 3.9]. The exact configuration of window versus metal for the walls and roofs may not be known.

2.4.1.4 Reflection around Enclosures and Other Equipment

Spacing from Reflecting Surfaces

Spacing of components reflectors is defined by NCS design criteria in DE-PE-801768-A004, [Ref. 4.35]. These are listed in full here.

DC-2-302.7.2 "Gloveboxes, airlocks, and hoods shall have a minimum of 35 inches between the enclosure floor and the building floor." [Design Input 2.37]

DC-2-302.7.3 "Gloveboxes, airlocks, and hoods shall have a minimum of 35 inches between the enclosure and the nearest wall."

DC-2-302.10.4.1 "Tanks shall have a minimum of 35 inches edge-to-edge between the bottom of the tank and concrete building floor, and a minimum of 24 inches edge-to-edge between the outer wall of the tank and the nearest wall."

DC-2-302.10.4.2 "Pumps shall have a minimum of 8 inches edge-to-edge between the pump and concrete building floors."

DC-2-302.10.4.3 "Coolers and condensers shall have a minimum of 24 inches edge-to-edge between the cooler/condenser and concrete building floors."

DC-2-302.10.4.4 "Items on tank, process, and support skids shall have:

- A minimum of 8 inches edge-to edge between the item and the building floors
- A minimum of 24 inches edge-to-edge between the item and the nearest wall
- A minimum of 10 feet edge-to-edge between the item and the nearest concrete wall."

Room and Building Structure

There are two main buildings in UPF that contain fissile material: the Main Process Building (MPB) and the Salvage and Accountability Building (SAB). Typical concrete rooms for the MPB (a.k.a. "bays") are shown on Rev. A architectural drawing [Ref. 4.73 – 4.84]. These include the following drawings:

- A2E922600A220, *Main Process Building Section A*, Rev. A,
- A2E922600A221, *Main Process Building Section B,* Rev. A
- A2E922600A222, *Main Process Building Section C*, Rev. A
- A2E922600A223, *Main Process Building Section D*, Rev. A
- A2E922600A224, *Main Process Building Section E*, Rev. A
- A2E922600A225, *Main Process Building Section F*, Rev. A
- A2E922600A226, *Main Process Building Section G*, Rev. A
- A2E922600A227, *Main Process Building Section H*, Rev. A
- A2E922600A228, *Main Process Building Section J*, Rev. A
- A2E922600A229, *Main Process Building East Section K*, Rev. A
- A2E922600A230, *Main Process Building East Section L*, Rev. A
- A2E922600A231, *Main Process Building East Section M*, Rev. A

The outer concrete walls of the MPB appear to be about 3 ft thick along with the walls of the corridor separating MPB-East and MPB-West. From the references, the concrete floor slabs between floors are thinner than the walls (about 15 in. based on measuring using the drawing scale). [Design Input 2.39]

Typical rooms for the SAB are shown on Rev. B architectural drawing [Ref. 4.85 – 4.87]. These include the following drawings:

- A2E922601A101, *Salvage and Accountability Building First Level Plan*, Rev. B
- A2E922601A102, *Salvage and Accountability Building Second Level Plan*, Rev. B
- A2E922601A103, *Salvage and Accountability Building Third Level Plan*, Rev. B

The material and dimensional characteristics of the SAB outer walls have yet to be defined. Interior walls are metal stud construction and much thinner.

The MPB-West is about 234.5 ft. long (east/west) by 162 ft. wide (north/south) containing seven sets of columns running east/west with typically 30 ft. spacing between columns. The MPB-East is about 243 ft. long (east/west) by 162 ft. wide (north/south) containing seven sets of columns running east/west with typically 30 ft. spacing between columns. Both MPBs contain 3 columns running north/south in each set with typically 56 ft. between columns. There are several rooms of various size, vestibules and corridors in the MPBs. The distance between the first floor and the second floor, including the thickness of the second floor, is 28 ft. The distance between the second floor and the third floor, including the thickness of the third floor, is 26 ft. The distance between the third floor and roof, including the thickness of the roof, is 33 ft. 4 in.

The SAB is about 270 ft. long (east/west) by 157.5 ft. wide (north/south) containing 8 sets of columns running east/west with typical 30 ft. spacing between columns. Each set of columns contain 4 columns, running north/south, with typically 30 ft. spacing between columns. There are several rooms of various size, vestibules and corridors in the SAB. Like the MPB, the floors between levels appear to be ~15 in. thick concrete. The composition and thickness of the outer and inner walls is unknown. The distance between the first floor and the second floor, including the thickness of the second floor, is 28 ft. The distance between the second floor and the third floor, including the thickness of the third floor, is 26 ft. The distance between the third floor and roof, including the thickness of the roof, is 32 ft. 7 in.

Operators

Operators are good reflectors for fissile materials, since humans are composed largely of water. A standard water cuboid model for an operator reflector is developed in Sect. 6.4.1.6. An assumption [Assumption 3.7] is made for the numbers of operator reflectors that are considered bounding of typical UPF operations in section 6.4.1.4.

Standard Atmosphere

Standard air is approximately 76.51% Nitrogen, 23.48% Oxygen, and 0.01% Carbon, by weight, with other trace elements and compounds including water. Standard air density is approximately 0.0012 g/cm^3 at sea level (15ºC, 101325 Pa) Design Input 2.17].

2.4.1.5 Standard Concrete Room Wall Thickness

The standard UPF room has structural walls, a ceiling, and floor of varying concrete thicknesses. As discussed in Sect. 2.4.1.4, the walls appear to be about 3 ft thick between rooms/bays. The lower floor slab is shown to be much thicker (>3 ft) and is commonly discussed as being about 9 ft thick [Design Input 2.40].

2.4.1.6 Standard Person

A standard water model to represent the reflection effect of operating personnel on fissile equipment is developed in CCG-342 [Ref. 4.1]. The cuboid dimensions [Design Input 2.32] were determined on the basis of data from ICRP Publication 23 (Ref. 4.44) conversion of partial density water and other hydrogen contents to a full-density water model with the same total hydrogen content, adjustment to the height, and appropriate assumptions on relative width and depth.

2.5 SPRINKLER EFFECTS

When performing computer calculations that address the effects from sprinkler activation, water density in air and water film thickness on items must be considered.

2.5.1 Evaluating Atmospheric Water from Sprinklers

Estimates of the maximum amount of interspersed moderation that can be expected from various sources, including fire sprinklers, are published in Ref. 4.13 & 4.54. The reported values seek to find the maximum k_{eff} resulting from water spray density from fire sprinklers and estimate the water density at several heights above a floor. The maximum density achieved was less than 0.0005 g/cm^3 [Design Input 2.28].

An effect from the discharge of fire sprinklers is the presence of low-density water between interacting units of enriched uranium (i.e., interspersed or interstitial water). The typical relationship of array k_{eff} with increasing water density is an initial rise to a peak representing optimum moderation between interacting units followed by a decrease to a low point where the density of water is sufficient to reduce or eliminate interaction between units. Beyond this low point, the array k_{eff} typically increases again to a peak at full-density water that corresponds to the fully reflected single unit k_{eff}. In addition to the response described for interspersed water, similar effects are observed when water is present as a film of full-density water on the exterior surface of interacting units.

The water density from fire sprinklers will vary throughout UPF since it depends on sprinkler head spacing, height from sprinkler head to equipment, system supply pressure, layering of sprinkler heads, deflection from structures and equipment, amount of water discharged from a sprinkler head at a given water pressure, and other factors and assumptions. Because the design of the sprinkler system for UPF has not been finalized, the actual expected water density from sprinklers is not yet known. However, an upper bound of possible water densities from sprinkler activation can be determined.

2.5.2 Water Film Thickness from Fire Sprinklers

Fire sprinkler activation results in interspersed water moderation but also forms a film or coating of water on items. Y/DD-762 [Ref. 4.12] concludes that a film thickness of 3.5 mm (0.35 cm) is the maximum expected for non-horizontal surfaces [Design Input 2.29]. A water film thickness of 7 mm (0.7 cm) should be used on horizontal surfaces [Design Input 2.29]. For vertical arrays of horizontal cylinders, lower cylinders may have twice the film thickness of the top-most cylinder.

These conclusions are based on results of experiments done for NCS on arrays of cylinders at the Savannah River Plant [Ref. 4.46]. The full scale test involved Plexiglas cylinders at various axial angles. At some spray conditions, there was droplet formation and at others a continuous film formed on the surface. Ultrasonic measurements determined water thickness and average film thickness was determined for droplets by visual observation of pictures showing the percentage of the surface that was covered with droplets. Some experiments were also performed on cast and machined aluminum metal surfaces, and the recommended results were deemed applicable to metal.

2.5.3 Liquid Level on Room Floor due to spill and Water from Sprinklers

Liquid containing fissile material may accumulate on process area floors due to spills from tanks, components, and liquid transfer carts. The spills can then be diluted and the liquid level increased due to the addition of fire sprinkler water. The overall change in neutron multiplication over the affected process area and its components is a function of the spill concentration and level. DAC-EN-801768-A119 [Ref. 4.56] contains an analysis of the initial spill level if all fissile liquid in each process area is released to the floor. The uranium concentration at various liquid levels, based on adding water to the initial fissile liquid, is also shown.

In only two cases was the initial spill of fissile material greater than 0.5 in. deep and in both cases the uranium concentration was approximately 20 gU/l. In another 2 cases with water dilution the spill at 1-in. deep is at 44 gU/l and 43 gU/l. Both these cases occur in vestibules, which is subcritical with no other fissile material. Additional calculations of the uranium concentration were done for specific liquid depths ranging from 0.75-in. to 5-inches. CSPS-EN-801768-ARAY-B001, Rev. A, control 6.3.2 [Ref. 4.58] limits the liquid fissile contents of a vestibule to a maximum of 2 LTCs. Since vestibules contain no fissile material storage, no other fissile material is present in the vestibule with the 2 LTC.

CSPS-EN-801768-FLM-B001, Rev. A, control 6.1.1.5 [Ref. 4.57] limits the accumulation of solution in any room to a maximum of 3-in. deep. Spill analyses therefore need to examine uranium concentrations and spill depths over a range of values. It must be demonstrated that the spill volumes and room areas used in the calculations are realistic and appropriately conservative for spill scenarios used in the computational models.

2.6 STRUCTURAL MATERIAL INCLUDING PIPING AND TUBING

UPF Design Code of Record (COR), PL-RM-801768-A001 [Ref. 4.6] contains a list of all applicable specifications for the UPF project. Although none of the following specifications are explicitly listed in the Code of Record many are cited as requirements in specified documents. For example ASME B31.3—2012, which is listed in the Code of Record, lists requirements from ASTM A312/A312M is the specification for *Seamless, Welded Austenitic Stainless Steel Pipe* [Ref. 4.7] which refers to ASTM A999 [Ref. 4.9] for OD tolerances.

Other specifications such as ASTM A554 which is the specification for *Welded Stainless Steel Mechanical Tubing* [Ref. 4.8] can be inferred from the following statement at the beginning of the Code of Record:

The specific references to Federal Laws, Statutes and Regulations in this COR have been identified as they relate to UPF design. This does not constitute an all-inclusive list. The UPF project will adhere to all Federal Laws, Statutes and Regulations in the design of the facility. The State and Local Laws identified in this COR constitute the complete list that the design of UPF will adhere to. This official COR documents only the main basis record and does not elaborate to a specific part or section as may be referenced in the requirements of the UPF Systems Requirements Document or UPF Design Criteria.

2.6.1 Pipe and Tube Dimensions

When modeling tanks, pipes, trays, containers, and other fissile-bearing items, the displacement of uranium material and the neutron absorption of structural material is ignored in computer calculations. Fissile material is modeled to the maximum outer dimension of the item plus tolerance. This will ensure that the fissile geometry will be adequately conservative with allowance for corrosion and erosion.

Pipes are specified by the Nominal Pipe Size (NPS) Designator. Table 2.6-1 contains pipe specifications for stainless steel pipe sizes from 1/8 in. to 12 in. from ASTM A312, Table X1.1 [Ref. 4.7]. ASTM A312 Sect. 5.1 states material furnished under this specification shall conform to the applicable requirements of the current edition of ASTM A999.The OD tolerances are from ASTM A999 Table 1. The pipe wall thickness changes with pipe schedule. The pipe outer diameter, nominal wall thickness for schedule 40 pipe, and outer diameter tolerance are contained in Table 2.6-1.

Table 2.6-1. Pipe Dimensions per ASTM A312 [Ref. 4.7, Design Input 2.30]

NPS Designator	ASTM A312 Outside Diameter (in.)	ASTM A999 Nominal Wall Thickness Sch 40 (in.)	Outer Diameter Tolerance (in.)
1⁄8	0.405	0.068	1/64
1⁄4	0.540	0.088	1/64
3⁄8	0.675	0.091	1/64
1⁄2	0.840	0.109	1/64
3⁄4	1.050	0.113	1/64
1	1.315	0.133	1/64
1 1⁄4	1.660	0.140	1/64
1 1⁄2	1.900	0.145	1/64
2	2.375	0.154	1/32
2 1⁄2	2.875	0.203	1/32
3	3.500	0.216	1/32
3 1⁄2	4.000	0.226	1/32
4	4.500	0.237	1/32
5	5.563	0.258	1/16
6	6.625	0.280	1/16
8	8.625	0.322	1/16
10	10.750	0.365	3/32
12	12.750	0.375	3/32

Tube size is specified by its outer diameter. Table 2.6-2 contains the outer diameter tolerance specifications for stainless steel tubes from 0.5 in to 10.0 in. from ASTM A554 [Ref. 4.8].The "outer diameter tolerance" is the maximum allowed ovality tolerance for a given outer diameter and wall thickness. Section 9 of this standard contains the permissible variations in dimensions – Round Tubing. ASTM 554, section 9.1 specifies the use of Table 2 for all conditions except tubing with bead removed. ASTM 554, section 9.2 specifies Table 3 for tubing with bead removed.

For all tubing diameters ≤ 7.5 in., the tolerances in Table 2 are larger than the tolerances in Table 3. For tubing diameters > 7.5 in., the difference between the now larger Table 3 tolerances and the Table 2 tolerances are less than 0.002 in. Therefore, Table 2 tolerances were used to calculate maximum outer diameters. For tubing outer diameter ≤ 7.5 in., Table 2 contains several tolerances for a given pipe outer diameter, based on wall thickness. In all cases, the highest tolerance value was chosen, which corresponds to the largest wall thickness. For tubing outer diameters > 7.5 in., the tolerance is calculated using 0.00125 in./in. of circumference. The tube outer diameter and outer diameter tolerance are contained in Table 2.6-2 to three significant figures.

Table 2.6-2. Tube Outer Diameter and Tolerance per ASTM A554 [Ref. 4.8, Design Input 2.31]

Outer Diameter (in.)	Outer Diameter Tolerance (in.)	Outer Diameter + Tolerance (in.)
0.25	0.004	0.254
0.375	0.004	0.379
0.5	0.010	0.510
1.0	0.010	1.010
1.5	0.010	1.510
2.0	0.012	2.012
2.5	0.014	2.514
3.0	0.020	3.020
3.5	0.020	3.520
4.0	0.025	4.025
4.5	0.025	4.525
5.0	0.025	5.025
5.5	0.030	5.530
6.0	0.030	6.030
6.5	0.030	6.530
7.0	0.030	7.030
7.5	0.030	7.530
8.0	0.031	8.031
8.5	0.033	8.533
9.0	0.035	9.035
9.5	0.037	9.537
10.0	0.039	10.039

Glass pipe/tube available today is not formally standardized across manufacturers like stainless steel pipe and tube. It is available in a wide range of regular and specialty sizes. The standard cut sheet from design is for a "Duran Group" glass that is 120.00 ± 0.04 mm ID with a thickness of 9.80 ± 1.10 mm, adding 2 maximum thicknesses to the ID plus its tolerance, gives 141.84 mm max OD = 5.5843-inch OD maximum. This cut sheet was taken from Ref. 4.47. [Note: In the operating plant, most of the glass tanks and equipment are made of 6-inch or 4-inch "conical glass", which was American-made and based on English units, but that product is not available today.]. Therefore, glass tanks should be modeled and controlled with an OD of at least 5.5843 inches. That is bounded by the stainless steel pipe maximum of 5.626 inches, so either number can be used. Table 2.6-3 dimensions for several glass tube sizes from the Duran Group.

Table 2.6-3 Glass Tank Diameter and Tolerances from Duran Group [Ref. 4.47, Design Input 2.41]

Inside Diameter (mm)	Max. Wall Thickness (mm)	Max. Outer Diameter (cm)	Max. Outer Radius (cm)	Max. Outer Diameter (in.)
70 ± 0.03	9.20 ± 0.90	9.0230	4.5115	3.5524
75 ± 0.03	9.70 ± 0.90	9.6230	4.8115	3.7886
80 ± 0.03	9.20 ± 1.00	10.0430	5.0215	3.9539
85 ± 0.03	9.60 ± 1.00	10.6230	5.3115	4.1823
90 ± 0.03	10.00 ± 1.00	11.2030	5.6015	4.4106
95 ± 0.03	9.60 ± 1.00	11.6230	5.8115	4.5760
100 ± 0.04	9.50 ± 1.00	12.1040	6.0520	4.7654
110 ± 0.04	7.30 ± 1.00	12.6640	6.3320	4.9858
120 ± 0.04	9.80 ± 1.10	14.1840	7.0920	5.5843
140 ± 0.04	9.70 ± 1.20	16.1840	8.0920	6.3717
150 ± 0.05	9.60 ± 1.30	17.1850	8.5925	6.7657
160 ± 0.05	7.20 ± 1.10	17.6650	8.8325	6.9547
200 ± 0.07	9.30 ± 1.40	22.1470	11.0735	8.7193
210 ± 0.07	9.50 ± 1.40	23.1870	11.5935	9.1287
225 ± 0.08	9.30 ± 2.00	24.7680	12.3840	9.7512

2.6.2 Piping System Specifications

Pipe used within UPF is classified based on the type of service it will encounter. The different classifications of pipe are described in UPF construction specification documents [Ref. 4.36 through 4.43] and are depicted on drawings as a number associated with the section of pipe (the line specification). Some of the more common UPF pipe specifications, along with the service requirements from Sect. 1.01A of each reference, are given in Table 2.6-3. The service requirements column for each specification cites ASME B31.3 [Ref. 4.10].

Table 2.6-4. Pipe Systems Material, Service, and Scope [Design Input 2.13]

Line Specification	Systems	Service Requirements	Reference
400513.19	STAINLESS STEEL SYSTEMS (UTILITY SERVICE)	Scope of this construction specification includes stainless steel (schedule 40S) Normal Fluid Service Piping (as defined by ASME B31.3) for UPF. This piping does not contain uranium or nitric acid solutions during normal operations. The maximum temperature and pressure for this specification is 375°F (190.6°C) and 165 psig. Products used in this specification will be rated for the maximum temperature and pressure listed above.	Ref. 4.36
400513.20	STAINLESS STEEL SYSTEMS (SCHEDULE 10S)	Scope of this construction specification includes stainless steel (schedule 10S) Normal Fluid Service Piping (as defined by ASME B31.3) for the process exhaust and process off-gas systems in UPF. In vacuum service for gases, the maximum temperature and vacuum pressure for this specification is 300°F (148.9°C) and 28-in. Hg (vacuum). Products used in this specification will be rated for the maximum temperature and pressure listed above.	Ref. 4.37
400513.21	STAINLESS STEEL SYSTEMS (CATEGORY D SERVICE)	Scope of this construction specification includes stainless steel (schedule 40S) Category D Service Piping (as defined by ASME B31.3) for UPF. The maximum temperature and pressure for this specification is 300°F (148.9°C) and 150 psig. Products used in this specification will be rated for the maximum temperature and pressure listed above.	Ref. 4.38
402513.30	STAINLESS STEEL SYSTEMS (NITRIC ACID, SEVERE SERVICE SYSTEMS)	Scope of this construction specification includes single wall stainless steel (schedule 40S) Normal Fluid Service Piping (as defined by ASME B31.3) for severe service nitric acid and/or uranium-bearing solutions greater than 40% nitric acid concentration by weight or less than 40% nitric acid but with elevated temperatures greater than 120°F (48.9°C) associated with UPF. The maximum temperature and pressure for this specification is 375°F (190.6°C) and 165 psig. Products used in this specification will be rated for the maximum temperature and pressure listed above.	Ref. 4.39

Table 2.6-4. Pipe Systems Material, Service, and Scope [Design Input 2.13]

Line Specification	Systems	Service Requirements	Reference
402513.31	STAINLESS STEEL SYSTEMS (MODERATE SERVICE NITRIC ACID & URANIUM PROCESS SYSTEMS)	The scope of this construction specification includes single wall stainless steel (schedule 40S) Normal Fluid Service Piping (as defined by ASME B31.3) for nitric acid and/or uranium-bearing solutions with up to 40% nitric acid concentration by weight associated with UPF. The maximum temperature and pressure for this specification is 120°F (48.9°C) and 200 psig for process solutions above 10% HNO_3 and sodium hydroxide; while a solution having a HNO_3 concentration at or below 10% may have a maximum temperature and pressure of 220°F (104.4°C) and 200 psig. In vacuum service for gases, the maximum temperature and vacuum pressure for this specification is 220°F (104.4°C) and 1×10^{-8} torr (vacuum). Products used in this specification will be rated for the maximum temperature and pressure listed above.	Ref. 4.40
402513.32	STAINLESS STEEL SYSTEMS (MODERATE SERVICE NITRIC ACID AND URANIUM PROCESS SYSTEMS LOCATED IN NON-LARGE GEOMENTRY EXCLUSION AREAS)	The scope of this construction specification includes single-wall stainless steel (schedule 40S) Normal Fluid Service Piping (as defined by ASME B31.3) for nitric acid and/or uranium-bearing solutions with up to 40% nitric acid concentration by weight associated with UPF. The maximum temperature and pressure for this specification is 120°F (48.9°C) and 200 psig for process solutions above 10% HNO_3; while a solution having a HNO_3 concentration at or below 10% may have a maximum temperature and pressure of 220°F (104.4°C) and 200 psig. This specification includes the piping that runs between maintenance access enclosures (MAEs) and/or Large Geometry Exclusion Areas (LGEAs) through Non-LGEAs. Products used in this specification will be rated for the maximum temperature and pressure listed above.	Ref. 4.41
400513.43	HASTELLOY C-276 SYSTEMS	Scope of this construction specification includes single-wall Hastelloy (schedule 40) Category M Fluid Service Piping (as defined by ASME B31.3) for highly corrosive process solutions in UPF. Low carbon nickel-molybdenum-chromium alloy UNS N10276 Hastelloy (a registered trademark of Cabot Corporation) C-276 piping systems is the material utilized for this service. The maximum temperature and pressure for this specification is 400°F (204.4°C) and 150 psig. Products used in this specification will be rated for the maximum temperature and pressure listed above.	Ref. 4.42

Table 2.6-4. Pipe Systems Material, Service, and Scope [Design Input 2.13]

Line Specification	Systems	Service Requirements	Reference
402513.60	STAINLESS STEEL SYSTEMS (HIGH TEMPERATURE SERVICE)	The scope of this construction specification includes single-wall stainless steel (schedule 40S) Normal Fluid Service (severe cyclic conditions) (as defined by ASME B31.3) for nitric acid and/or uranium-bearing process exhaust gases associated with the UPF Facility. The maximum temperature and pressure for this specification is to 1200°F (648.9°C) and up to 150 psig. The specification is rated for Process Vacuum (VPR) levels of 10^{-8} torr. Products used in this specification will be rated for the maximum temperature and pressure listed above (except CF/NW flanges - vacuum only service).	Ref. 4.43

2.7 AVOGADRO'S CONSTANT

One extra constant was taken from Chart of Nuclides [Ref. 4.15]. Avogadro's Constant is from the "Fundamental General Physics Constants" table in the inside back cover of Ref. 4.15. This value is listed in Table 2.7-1.

Table 2.7-1. Avogadro's Constant [Design Input 2.12]

Description	Symbol	Value	Units
Avogadro's Constant	N_A	6.02214179E+23	Entities/Mole

2.8 CONTAINERS

The #3 can, #4 can, #5 can, and tube vault can will be used to move and hold processed uranium at UPF. It is common NCS practice to model containers to their outside dimensions including tolerances. In keeping with that practice each container is modeled using its Outer Diameter (OD) plus tolerance and the height is modeled from the outside bottom to the top of the container with the lid. The applicable drawings and dimension are described below for each inner container.

2.8.1 Inner Can

The following standardized dimensions should be used to the extent practical, in the absence of specific NCS requirements and/or specific design information. The specified dimensions represent conservative conditions that are expected to be bounding. The derivation of the conservative dimensions of all inner cans is discussed below.

2.8.1.1 #3 Inner Can

Drawing M802228-0031, Rev. A [Ref. 4.59] describes the #3 inner can assembly. This drawing shows the can height without lid to be 4.40 in., the overall maximum height to be 4.95 in., and the outer diameter to be 5.94 inches. The can height and outer diameter have a tolerance of 0.06 for a maximum outer diameter of 6.0 inches. These values are listed in Table 2.8-1.

2.8.1.2 #4 Inner Can

Drawing M802228-0036, Rev. A [Ref. 4.60] describes the #4 inner can assembly. This drawing shows the can height without lid to be 10.00 in., the overall maximum height to be 10.59 in., and the outer diameter to be 4.84 inches. The can height and outer diameter have a tolerance of 0.06 for a maximum outer diameter of 4.90 inches. These values are listed in Table 2.8-1.

2.8.1.3 #5 Inner Can

Drawing M802228-0041, Rev. A [Ref. 4.61] describes the #5 inner can assembly. This drawing shows the can height without lid to be 8.25 in., the overall maximum height to be 8.78 in., and the outer diameter to be 5.94 inches. The can height and outer diameter has a tolerance of 0.06 for a maximum outer diameter of 6.0 inches. These values are listed in Table 2.8-1.

2.8.1.4 Tube Vault Can

Drawing M2B900000A117, Rev. C [Ref. 4.62] describes the tube vault can. This drawing shows the overall nominal height to be 8.750 in. with a tolerance of ±0.031 inch for an overall maximum height of 8.781 inches. The outer diameter is 6.059 in. inches with a tolerance of ±0.031 inches for a maximum outer dimension of 6.090 inches. These values are listed in Table 2.8-1.

Table 2.8-1 Fissile Material Inner Container Details

	#3 Inner Can (Ref. 4.59)	#4 Inner Can (Ref. 4.60)	#5 Inner Can (Ref. 4.61)	Tube Vault Can (Ref. 4.62)
Nom. OD (in.)	5.94	4.84	5.94	6.059
Tolerance (in.)	0.06	0.06	0.06	0.031
Nom. OH w/o lid (in.)	4.40	10.00	8.25	---
Tolerance (in.)	0.06	0.06	0.06	---
Nom. OH (in.)	---	---	---	8.750
Tolerance (in.)	---	---	---	0.031
Max. OH (in.)	4.95	10.59	8.78	

2.8.2 Outer Containers

The #3, #4, and #5 containers are used to move and hold processed uranium at UPF. These are robust containers intended to hold their corresponding inner cans rather than hold material placed directly inside. Each outer container weldment is comprised of a cylindrical can base and threaded neck with a separate multi-component threaded lid. Both the inner and outer dimensions of the can are provided. The outer diameter is from the main body of the can, excluding flange, upper section, and lid. The outer height is from the outside bottom of the container to the outside top of the lid. The applicable drawings and dimensions are described below for each outer container.

2.8.2.1 #3 Outer Container

Drawings M802228-0001, Rev. A; M802228-0002, Rev. 0; and M802228-0003, Rev. 0, [Ref. 4.63, 4.64 and 4.65] describe the #3 outer container. Ref. 4.63 drawing shows the inner diameter to be 6.440 in., with Ref. 4.65 listing a tolerance of 0.06 inch. This is a geometric feature control frame which refers to the tolerance on the surface. Ref. 4.64 shows the container height without lid to be 5.25 inches with a tolerance of 0.02 inch and the outer body diameter to be 6.536 inches. The same 0.06 in. tolerance used for the inner diameter is used for the tolerance of the outer diameter. Per Ref. 4.63 the overall height is 5.96, with a tolerance of 0.01. These values are listed in Table 2.8-2.

2.8.2.2 #4 Outer Container

Drawings M802228-0011, Rev. A; M802228-0012, Rev. A; and M802228-0013, Rev. A, [Ref. 4.66, 4.67 and 4.68] describe the #4 outer container. Ref. 4.66 drawing shows the inner diameter to be 5.280 in., with Ref. 4.68 listing a tolerance of 0.06 inch. This is a geometric feature control frame which refers to the tolerance on the surface. Ref. 4.67 shows the container height without lid to be 11.0 inches with a tolerance of 0.02 inches and the outer body diameter to be 5.376 inches. The same 0.06 in. tolerance used for the inner diameter is used for the tolerance of the outer diameter. Per Ref. 4.66 the overall height is 11.60, with a tolerance of 0.01. These values are listed in Table 2.8-2.

2.8.2.3 #5 Outer Container

Drawings M802228-0021, Rev. A; M802228-0022, Rev. A; M802228-0023, Rev. A and M802228- 0026, Rev. 0 [Ref. 4.69, Ref. 4.70, Ref. 4.71 and Ref. 4.72] describe the #5 outer container. Ref. 4.69 shows the inner diameter to be 6.440 in., with Ref. 4.71 listing a tolerance of 0.06 inch. This is a geometric feature control frame which refers to the tolerance on the surface. Ref. 4.70 shows the container height without lid to be 9.35 in. with a tolerance of 0.02 inches. Ref. 4.70 and Ref. 4.71 shows the outer body diameter to be 6.536 inches. The same 0.06 in. tolerance is used for the tolerance of the outer diameter. However, there is no overall height listed on any of the referenced drawings so it needs to be derived from other dimensions.

A maximum inside height of 9.72 in. is listed in Ref. 4.69. This is the distance from the top of the curve at the container bottom to the bottom of the can lid at its highest point. To find the outer container height this distance needs to be added to the distance from the outside bottom of the container to the top of the curve at the container bottom plus tolerances and the thickness of the lid plus tolerances. The values for the distance from the outside bottom of the can to the lower surface of the curved section, the thickness of the can bottom material and their tolerances are listed in Ref. 4.71. The values for the lid thickness and its tolerance are listed in Ref. 4.72. These values are listed in Table 2.8-2.

Table 2.8-2 Fissile Material Outer Container Details

	#3 Outer Can		#4 Outer Can		#5 Outer Can	
	Dimension	**Reference Drawing**	**Dimension**	**Reference Drawing**	**Dimension**	**Reference Drawing**
Inner Diameter (in.)	6.440	Ref. 4.63	5.280	Ref. 4.66	6.440	Ref. 4.69
ID Tolerance (in.)	0.06	Ref. 4.65	0.06	Ref. 4.68	0.06	Ref. 4.71
Outer Diameter (in.)	6.536	Ref. 4.64 & 4.65	5.376	Ref. 4.67 & Ref. 4.68	6.536	Ref. 4.70 & Ref. 4.71
OD Tolerance	0.06	Ref. 4.65	0.06	Ref. 4.68	0.06	Ref. 4.71
Nom. OH w/o lid (in.)	5.25	Ref. 4.64	11.00	Ref. 4.67	9.35	Ref. 4.70
Tolerance (in.)	0.02	Ref. 4.64	0.02	Ref. 4.67	0.02	Ref. 4.70
Outer Height (in.)	5.96	Ref. 4.63	11.60	Ref. 4.66	---	---
Height Tolerance (in.)	0.01	Ref. 4.63	0.01	Ref. 4.66	---	---
Inside Height IH (Max.) with lid **w/o bottom curved section** **w/o top lid thickness**	---	---	---	---	9.72	Ref. 4.69
Bottom Curve Height (in.)	---	---	---	---	0.25	Ref. 4.71
Bottom Curve Height Tolerance (in.)	---	---	---	---	0.06	Ref. 4.71
Curve Thickness (in.)	---	---	---	---	0.048	Ref. 4.71
Curve Thickness Tolerance (in.)	---	---	---	---	0.005	Ref. 4.71
Top Lid Thickness (in.)	---	---	---	---	0.06	Ref. 4.72
Lid Thickness Tolerance (in.)	---	---	---	---	0.01	Ref. 4.72

3. ASSUMPTIONS

3.1 ASSUMPTION SUMMARY

Table 3.1-1. Assumptions

Assumption No.	Assumption	Justification	Conf. Req'd? Y/N	Recommended Confirmation Method
3.1	Interstitial moderation from fire sprinkler activation cannot credibly exceed water at a density of 0.1 g/cm^3. Sprinkler water densities will be much less than this in UPF.	Ref. 4.13 provides estimates of the maximum water density expected from fire sprinkler activation. The maximum fire sprinkler water density achieved was 0.0005 g/cm^3 [Design Input 2.28]. The value of 0.1 g/cm^3 is more than two orders of magnitude larger than this value.	No	N/A
3.2	Magnuson's concrete is appropriate for use as a reflector.	Ref. 4.5 contains an analysis of eight different types of concrete reflectors onto slabs of both metal and solution systems. Magnuson's concrete produced the highest system k_{eff} compared to the other eight concretes for concrete reflectors greater than 30 cm thick.	No	N/A
3.3	The reflection from non-structural walls is assumed to be bounded by 2-in.-thick water.	The 2-in. thickness is chosen, because it is bounding of the thickness of two glovebox walls and is also half of the thickness of water that is essentially saturated [Design Input 2.25].	No	N/A
3.4	Combining uranium compounds (U-metal, UO_2, UO_3, U_3O_8) with water using the volume additive method with full-density materials is conservative.	These materials are not readily absorbed in water so the water at most fills the voids in the materials. The upper limit of the volume fraction of water that can mix with the compound is thus 1 minus the density of the material divided by its maximum density.	No	N/A
3.5	Coolant composed of 10% C350 and 90% water by volume mixed using the volume additive method is an acceptable mixture for analyzing machining operations.	For medium to heavy machining, the recommendation is to use 8% to 10% C350 with water [Refs. 4.26, 4.27, and 4.28]. C350 has almost as much hydrogen as water and ~1/3 more carbon and oxygen.	No	N/A

Table 3.1-1. Assumptions

Assumption No.	Assumption	Justification	Conf. Req'd? Y/N	Recommended Confirmation Method
3.6	The reflection effects to fissile items from glovebox windows and walls are assumed to be bounded by 1-in.-thick water slabs.	The typical walls are sheet metal, and the windows are typically 3/8-in.-thick Lexan. Steel reflection is comparable to the same thickness of water reflection at less than 2 in. thicknesses per Refs. 4.19 and 4.32. The average reflection from the windows and steel are judged to be bounded by 1-in.-thick water for neutron reflection to items within the gloveboxes.	No	N/A
3.7	The following numbers of operator reflectors are assumed to be bounding of typical UPF operations: • Number per Workstation: 2 • Number by Storage Rack: 2 • Number per 10 Tanks: 1	Workstations and Racks: Fissile material items typically only need one operator at a time. Operations should not require help in manual lifting at glovebox workstations due to hoists being available for items more than 15 lb. Tanks will be contained within gloveboxes or HLPRs, so operators will not have routine access to stand close to them.	No	N/A
3.8	The reflection from glovebox floors for light-use gloveboxes is assumed to be bounded by 0.25-in.-thick SS304L.	Design criteria only require 0.1875 in. thickness as a minimum. The assumption is not being applied to gloveboxes that have heavy equipment or Magna-motion carts.	No	N/A
3.9	The walls and roofs of gloveboxes and enclosures are assumed to be thinner-sheet steel than the glovebox floors.	The floors are required to support equipment and operations within the glovebox and spread the weight out to the glovebox legs. This amount of integrity is not required for the walls and ceilings.	No	N/A
3.10	The effectively infinite thickness conclusion from Ref. 4.5 for concrete applies to the concrete in UPF floors, walls, and ceilings.	Ref. 4.5 contains an analysis of eight different types of concretes for both metal and solution systems. The effect of additional reflector thickness past 45 cm was not significant.	No	N/A

Table 3.1-1. Assumptions

Assumption No.	Assumption	Justification	Conf. Req'd? Y/N	Recommended Confirmation Method
3.11	Bubble Alumina, which is used as an insulation material and is a neutron reflector, is 100% Al_2O_3 with a density of 1.0 g/cm^3	The Data sheet in RP-EN-801768-A031 (Ref. 4.52) describes Bubble Alumina as a high strength, low thermal conductivity fibrous ceramic composed of 99 wt% Aluminum Oxide with on organics and a density of 0.96 g/cm^3. Since this material is used as a reflector increasing the density to 1.0 g/cm^3 adds conservatism.	No	N/A
3.12	SALI, which is used as an insulation material and is a neutron reflector, is composed of 45 wt% SiO_2 and 55 wt% Al_2O_3 with a density of 0.6 g/cm^2.	The Data Sheet in RP-EN-801768-A030 (Ref. 4.51) describes SALI as 80% Al_20_3 and 20% SiO_2 at a density of 0.48 g/cm^3. The Equipment Data Sheet in DS-801932-0003, Rev. page 1 of 3, Inspection/Acceptance Requirement 3 2 located in DAC-EN-801768-A116, Rev. 0, Appendix F (Ref. 4.53), states "Density analysis shall be a 0.6 g/cc or less." The density of the material is thus set at 0.6 g/cm^3, which is greater than the density in the Data Sheet and is thus conservative. Because SiO_2 is a better reflector than Al_2O_3, in general k_{eff} increases with increasing SiO_2 content. The SiO_2 content is thus increased in 45 wt% which is conservative.	No	N/A
3.13	The following spill levels and concentrations are appropriate for use on room floors due to fissile material spills and fire sprinkler water: • 0.5 –in. 200 gU/l or max. concentration in process • 1.0 in. - 40 gU/l • 2.0 in. – 20 gU/l • 3.0 in. – 15 gU/l.	DAC-EN-801768-A119, Rev. A (Ref. 4.56) contains an analysis of the liquid contents of all tanks and components in the MPB, SAB, PSB and HEUMF Corridor based on room size from current drawings and current Material Energy Balances. In only 2 cases are the spill heights over 0.5 in. and in these cases the uranium concentration is ~20 gU/l.	No	N/A

4. REFERENCES

4.1 CCG-342, Rev. 1, C. J. Shields, *Evaluation of Equivalent and Bounding Reflection Conditions for Fissile Material Cylinders*, BWXT Y-12, L.L.C., Y-12 National Security Complex, September 2005. [SAP DMS]

4.2 *CRC Handbook of Chemistry and Physics*, 95th edition, W. M. Haynes editor, CRC Press, Boca Raton, FL, 2013 [ORNL Library].

4.3 CCG-425, Rev. 3, J. J. Lichtenwalter, *The Criticality Safety of Water-Moderated, Water-Reflected Uranium Metal of Various Shapes and Sizes*, BWXT Y-12, L.L.C., Y-12 National Security Complex, January 2006. [SAP DMS]

4.4 Y/DD-1246, Rev. 0, J. J. Lichtenwalter, *Absorptions of Water into Uranium Powder and Implications to Nuclear Criticality Safety*, B&W Technical Services Y-12, Y-12 National Security Complex, May 2008. [SAP DMS]

4.5 TANSAO,61,182-184, G. R. Handley, et al., “Effects of Concrete Composition in Nuclear Criticality Safety Calculations,” Trans. Am. Nucl. Soc., 61, 182–184, June 1990. [InfoWorks]

4.6 PL-RM-801768-A001, Rev. 4, *UPF Code of Record*, Consolidated Nuclear Security, LLC, Y-12 National Security Complex, 9/18/15. [InfoWorks]

4.7 ASTM A312/A312M-07, *Standard Specification for Seamless, Welded, and Heavily Cold Worked Austenitic Stainless Steel Pipes*, ASTM International, West Conshohocken, PA, Approved: 9/1/2007. [ORNL Library].

4.8 ASTM A554-03, *Standard Specification for Welded, Stainless Steel Mechanical Tubing*, ASTM International, West Conshohocken, PA, Approved: 9/10/2003 [ORNL Library].

4.9 ASTM A999/A999M-01, *Standard Specification for General Requirements for Alloy and Stainless Steel Pipe*, ASTM International, West Conshohocken, PA, Approved: 3/10/2001 [ORNL Library].

4.10 ASME B31.3-2006, *Process Piping ASME Code for Pressure Piping, B31*, American Society of Mechanical Engineers, New York, NY, Date of Issuance: 5/31/2007. [ORNL Library]

4.11 Percher ICNC 2011, C. Percher and D. Heinrichs, *An Experimental Study of the Effect of Operator Hands on the Reactivity of a Fast Metal System*, International Conference on Nuclear Criticality Safety, Lawrence Livermore National Laboratory, 2011. [InfoWorks]

4.12 Y/DD-762 (PECD-Y12-970001), R. L. Frost, *Demonstration of Double Contingency During Fire Suppression System (Sprinkler) Activation*, Lockheed Martin Energy Systems, Oak Ridge Y-12 Plant, 6/3/1997. [SAP DMS]

4.13 Wetzel NCSD 2013, Larry L. Wetzel, Crandon M. O’Donnell, Daniel L. Ashworth, “Interspersed Moderation, What is Credible?” paper 31.3 in ANS NCSD 2013 – Criticality Safety in the Modern Era: Raising the Bar, Wilmington NC, Sept. 29 – Oct. 3, 2013. [InfoWorks]

4.14 TID-7016, Rev. 2, J. T. Thomas, editor, *Nuclear Safety Guide*, US Nuclear Regulatory Commission report NUREG/CR-00951 ORNL/NUREG/CSD-6, June 1978. [InfoWorks]

4.15 *NUCLIDES*, *Nuclides and Isotopes Chart of the Nuclides,* 17th Edition, Knolls Atomic Power Laboratory for Bechtel Marine Propulsion Co., Schenectady, NY, 2010. [InfoWorks]

4.16 ORNL/TM-2005/39, *SCALE: A Comprehensive Modeling and Simulation Suite for Nuclear Safety Analysis and Design*, Ver. 6.1, CCC-785, Oak Ridge National Laboratory for the U.S. Department of Energy, Oak Ridge, TN, 6/9/2011. [InfoWorks]

4.17 TANSAO, 99, 361-362, J. J. Lichtenwalter, "Absorption of Water into Uranium Powder and Implications to Nuclear Criticality Safety," Trans. Am. Nucl. Soc., 99, 361-362, November 2008. [InfoWorks]

4.18 ORNL/TM-2005/39, Ver. 6.1, Vol. III, Sect. M8, L. M. Petrie, et al., *Standard Composition Library*, UT-Battelle, LLC, Oak Ridge National Laboratory, 6/9/2001. [InfoWorks]

4.19 LA-3612, Rev. 0, W. R. Stratton, *Criticality Data and Factors Affecting Criticality of Single Homogeneous Units*, Los Alamos Scientific Laboratory of the University of California, Los Alamos, NM, September 22, 1967. [InfoWorks]

4.20 NCS-RTI-035-08, R. D. Spence, Request for Technical Information from Jerry Lichtenwalter, "Bulk Densities of Nearly Pure Uranium Compounds," 3/25/2008. [InfoWorks]

4.21 CSE-DNT-079, Rev. 6, S. L. Larson, *Criticality Safety Evaluation for Denitrator*, BWXT Y-12 L.L.C., Y-12 National Security Complex, 5/10/2012. [SAP DMS]

4.22 ORNL/TM-2001/59, A. S. Icenhour, L. M. Toth, and H. Luo, *Water Sorption and Gamma Radiolysis Studies for Uranium Oxides*, UT-Battelle, Oak Ridge National Laboratory, February 2002. [ORNL Library]

4.23 W580837-TheChemistryofUranium, J. J. Katz and E. Rabinowitch, *The Chemistry of Uranium Part I: The Element, Its Binary and Related Compounds*, McGraw-Hill Book Company, Inc., 1st Edition, 1951. [InfoWorks]

4.24 DP-749 UO3 Hydration, W. R. Cornman, Jr., *Preparation and Characterizations of the Polymorphs of UO_3*, Savannah River Laboratory, E. I. du Pont Nemours & Co., August 1962. [InfoWorks]

4.25 CCG-339, D. A. Reed and D. D. Butcher, *Miscellaneous Notes on Hydration of Uranium Trioxide*, Lockheed Martin Energy Systems, Oak Ridge Y-12 Plant, August 1999. [InfoWorks]

4.26 ACL Report for Sample A123200177, *Report for Sample A123200177 (U)*, Analytical Chemistry Organization (Quality Services), B&W Technical Services Y-12, Y-12 National Security Complex, 1/24/2013. [InfoWorks]

4.27 C350 MSDS, *Material Safety Data Sheet for TRIM C350*, Master Chemical Corporation, Perrysburg, OH, February 11, 2013. [InfoWorks]

4.28 C350 Data and Information, *TRIM C350 Premium Synthetic Metalworking Fluid*, Master Chemical Corporation, Perrysburg, OH, April 9, 2013. [InfoWorks]

4.29 *International Critical Tables of Numerical Data, Physics, Chemistry and Technology*, Vol. 3, E. W. Washburn, editor, published for the National Research Council by McGraw-Hill Book Company, Inc., NY, 1928 [ORNL Library].

4.30 *Perry's Chemical Engineers' Handbook*, 8th Edition, D. W. Green, editor, Section 2, Physical and Chemical Data, McGraw-Hill, NY, 2008 [ORNL Library].

4.31 Y70-150, *Nuclear Criticality Safety Program*, Consolidated Nuclear Security, LLC, Y-12 National Security Complex, Revision: 10/28/2015. [SAP DMS]

4.32 TID-7028, *Critical Dimensions of Systems Containing U^{235}, Pu^{239}, and U^{233}*, Atomic Energy Commission, Washing, D.C., June 1964. [InfoWorks]

4.33 COI-OP-801768-A008, Preliminary UPF Estimate of Solutions Containing Uranium, Consolidated Nuclear Security, LLC, Y-12 National Security Complex,2/01/2016. [InfoWorks]

4.34 15 CFR 206, *Standard Gauge for Sheet and Plate Iron and Steel*, U.S. Govt. Printing Office, Washington, D.C., 1/16/2014.

4.35 DE-PE-801768-A004, Rev. 10, *UPF Criticality Safety Design Criteria, Chapter2, Section 300, of the UPF Design Criteria*, Consolidated Nuclear Security, LLC, Y-12 National Security Complex, 1/07/2016.

4.36 CS-EP-801768-400513.19-A001, Rev. 1, *Construction Specification Section 400513.19 Stainless Steel Systems (Utility Service)*, B&W Technical Services Y 12, Y-12 National Security Complex, 6/17/2013. [InfoWorks]

4.37 CS-EP-801768-400513.20-A001, Rev. 1, *Construction Specification Section 400513.20 Stainless Steel Systems (Schedule 10S)*, B&W Technical Services Y 12, Y-12 National Security Complex, 6/17/2013. [InfoWorks]

4.38 CS-EP-801768-400513.21-A001, Rev. 1, *Construction Specification Section 400513.21 Stainless Steel Systems (Category D Service)*, B&W Technical Services Y 12, Y-12 National Security Complex, 6/17/2013. [InfoWorks]

4.39 CS-EP-801768-402513.30-A001, Rev. 1, *Construction Specification Section 402513.30 Stainless Steel Systems (Nitric Acid, Severe Service Systems)*, B&W Technical Services Y 12, Y-12 National Security Complex, 6/17/2013. [InfoWorks]

4.40 CS-EP-801768-402513.31-A001, Rev. 1, *Construction Specification Section 402513.31 Stainless Steel Systems (Moderate Service Nitric Acid & Uranium Process Systems)*, B&W Technical Services Y 12, Y-12 National Security Complex, 6/17/2013. [InfoWorks]

4.41 CS-EP-801768-402513.32-A001, Rev. 1, *Construction Specification Section 402513.32 Stainless Steel Systems (Moderate Service Nitric Acid & Uranium Process Systems Located in Non-LGEAs)*, B&W Technical Services Y 12, Y-12 National Security Complex, 6/17/2013. [InfoWorks]

4.42 CS-EP-801768-400513.43-A001, Rev. 1, *Construction Specification Section 400513.43 Hastelloy C276 Systems*, B&W Technical Services Y 12, Y-12 National Security Complex, 6/17/2013. [InfoWorks]

4.43 CS-EP-801768-402513.60-A001, Rev. 1, *Construction Specification Section 402513.60 Stainless Steel Systems (High Temperature Service)*, B&W Technical Services Y 12, Y-12 National Security Complex, 6/17/2013. [InfoWorks]

4.44 ICRP Publication 23, *Report of the Task Group on Reference Man*, International Commission on Radiological Protection, Pergamon Press, NY, 1975. [ORNL Library]

4.45 DE-PE-801768-A032, Rev. 11, *UPF Process Design Criteria, Chapter 3, Section 1100, of the UPF Design Criteria*, Consolidated Nuclear Security, LLC, Y-12 National Security Complex, 2/18/2016. [InfoWorks]

4.46 NMP-NCS-930043, *Water Film Thickness Study (U)*, R.H. Ross, Westinghouse Savannah River Company, 10/29/1993. [InfoWorks]

4.47 RP-EN-801768-A029, Duran Precision Bore Tubing, http://www.duran-group.com/uploads/tx_fedownloads/DURAN_Precision_bore_tubing_E.pdf, 04/08/2015,. [InfoWorks]

4.48 Y/DD-1215 000 05, L. C. Masters, *Calculations for Various 20 kg Fissile Material Loadings in Rackable Can Storage Boxes (RCSBs)*, B&W Technical Services Y-12, Y-12 National Security Complex, 5/2/2014. [SAP DMS]

4.49 JS-YMN1-801649-A002, Rev. 3, R. D. Aigner, *Specification Requirements for Castable Neutron Absorption System*, B&W Technical Services Y-12, Y-12 National Security Complex, 7/15/2013. [SAP DMS]

4.50 Y/DD-965, J. J. Lichtenwalter & L. E. Johnsen, *BoroBond4TM,* B&W Technical Services Y-12, Y-12 National Security Complex, 1/30/2001. [SAP DMS]

4.51 RP-EN-801768-A030, Alumina - SALI, Material Cut Sheets, ZIRCAR alumina Insulation Type SALI, http://www.zircarceramics.com/pages/rigidmaterials/specs/sali.htm, 10/1/2014. [InfoWorks]

4.52 RP-EN-801768-A031, Alumina - Bubble, Material Cut Sheets, ZIRCAR Bubble Alumina, Bulletin No. ZPI-805, ZIRCAR Products, INC. 110 North Main St., P.O. Box 458, Florida, New York, 10921-0458, August, 1994. [InfoWorks]

4.53 DAC-EN-801768-A116, Rev. 0, Nuclear Criticality Safety Calculations for Normal Casting, Appendix F (DS-801932-0003, Rev. 2, *Insulation*, Mold Stack Assembly – Ceramic Parts, March 6, 2013), 10/09/2015. [InfoWorks] (Committed)

4.54 Wetzel ICNC-2015, Larry L. Wetzel & Brandon O'Donnell, "*Further Work on Credible Levels of Water Moderation*", ICNC 2015, pp. 123 – 133, Charlotte, NC, September 13-17, 2015 [InfoWorks]

4.55 RP- YAREA-F-0455 000 00, D.F. Hollenbach and R.G. Taylor, Validation of SCALE6.1.1 for Criticality Safety Analyses on the REDHAT LINUX Workstations (COMD3 & ENGHPC01 Cluster), Consolidated Nuclear Security, LLC, Y 12 National Security Complex, 3/18/2015. [SAP DMS]

4.56 DAC-EN-801768-A119, Rev. A, Room Concentration Calculations for Facility Liquid Management, Consolidated Nuclear Security, LLC, Y-12 National Security Complex, 02/15/2016. [InfoWorks] (Preliminary)

4.57 CSPS-EN-801768-FLM-B001, Rev. A, Nuclear Criticality Safety Process Study of the Facility Liquid Management, Consolidated Nuclear Security, LLC, Y-12 National Security Complex, 03/11/2016. [InfoWorks]

4.58 CSPS-EN-801768-ARAY-B001, Rev. A, Nuclear Criticality Safety Process Study of Floor Storage, Consolidated Nuclear Security, LLC, Y-12 National Security Complex, 11/05/2015. [InfoWorks]

4.59 M802228-0031, *#3 Inner Can Assembly*, Rev. A, B & W Technical Services Y-12, LLC, Y-12 National Security Complex, 8/14/2014. [SAP DMS]

4.60 M802228-0036, *#4 Inner Can Assembly*, Rev. A, B & W Technical Services Y-12, LLC, Y-12 National Security Complex, 8/14/2014. [SAP DMS]

4.61 M802228-0041, *#5 Inner Can Assembly*, Rev. A, B & W Technical Services Y-12, LLC, Y-12 National Security Complex, 8/14/2014. [SAP DMS]

4.62 M2B900000A117, *Tube Vault Can (Generic Metal Can)*, Rev. C, Consolidated Nuclear Security, LLC, Y-12 National Security Complex, 5/20/2015. [SAP DMS]

4.63 M802228-0001, *#3 Outer Container*, Rev. A, B & W Technical Services Y-12, LLC, Y-12 National Security Complex, 11/26/2013. [SAP DMS]

4.64 M802228-0002, *#3 Outer Container Body Weldment*, Rev. 0, B & W Technical Services Y-12, LLC, Y-12 National Security Complex, 3/26/2013. [SAP DMS]

4.65 M802228-0003, *#3 Can Base*, Rev. 0, B & W Technical Services Y-12, LLC, Y-12 National Security Complex, 3/26/2013. [SAP DMS]

4.66 M802228-0011, *#4 Outer Container*, Rev. A, B & W Technical Services Y-12, LLC, Y-12 National Security Complex, 11/26/2013. [SAP DMS]

4.67 M802228-0012, *#4 Outer Container Body Weldment*, Rev. A, B & W Technical Services Y-12, LLC, Y-12 National Security Complex, 11/26/2013. [SAP DMS]

4.68 M802228-0013, *#4 Can Base*, Rev. A, B & W Technical Services Y-12, LLC, Y-12 National Security Complex, 11/26/2013. [SAP DMS]

4.69 M802228-0021, *#5 Outer Container*, Rev. A, B & W Technical Services Y-12, LLC, Y-12 National Security Complex, 11/26/2013. [SAP DMS]

4.70 M802228-0022, *#5 Outer Container Body Weldment*, Rev. A, B & W Technical Services Y-12, LLC, Y-12 National Security Complex, 11/26/2013. [SAP DMS]

4.71 M802228-0023, *#5 Can Base*, Rev. A, B & W Technical Services Y-12, LLC, Y-12 National Security Complex, 11/26/2013. [SAP DMS]

4.72 M802228-0026, *#5 Outer Lid Seal Plug*, Rev. A, B & W Technical Services Y-12, LLC, Y-12 National Security Complex, 11/26/2013. [SAP DMS]

4.73 A2E922600A220, *Main Process Building Section A*, Rev. A, Consolidated Nuclear Security, LLC, Y-12 National Security Complex, 03/10/2016. [InfoWorks]

4.74 A2E922600A221, *Main Process Building Section B,* Rev. A, Consolidated Nuclear Security, LLC, Y-12 National Security Complex, 03/10/2016. [InfoWorks]

4.75 A2E922600A222, *Main Process Building Section C*, Rev. A, Consolidated Nuclear Security, LLC, Y-12 National Security Complex, 03/10/2016. [InfoWorks]

4.76 A2E922600A223, *Main Process Building Section D*, Rev. A, Consolidated Nuclear Security, LLC, Y-12 National Security Complex, 03/10/2016. [InfoWorks]

4.77 A2E922600A224, *Main Process Building Section E*, Rev. A, Consolidated Nuclear Security, LLC, Y-12 National Security Complex, 03/10/2016. [InfoWorks]

4.78 A2E922600A225, *Main Process Building Section F*, Rev. A, Consolidated Nuclear Security, LLC, Y-12 National Security Complex, 03/10/2016. [InfoWorks]

4.79 A2E922600A226, *Main Process Building Section G*, Rev. A, Consolidated Nuclear Security, LLC, Y-12 National Security Complex, 03/10/2016. [InfoWorks]

4.80 A2E922600A227, *Main Process Building Section H*, Rev. A, Consolidated Nuclear Security, LLC, Y-12 National Security Complex, 03/10/2016. [InfoWorks]

4.81 A2E922600A228, *Main Process Building Section J*, Rev. A, Consolidated Nuclear Security, LLC, Y-12 National Security Complex, 03/10/2016. [InfoWorks]

4.82 A2E922600A229, *Main Process Building East Section K*, Rev. A, Consolidated Nuclear Security, LLC, Y-12 National Security Complex, 03/10/2016. [InfoWorks]

4.83 A2E922600A230, *Main Process Building East Section L*, Rev. A, Consolidated Nuclear Security, LLC, Y-12 National Security Complex, 03/10/2016. [InfoWorks]

4.84 A2E922600A231, *Main Process Building East Section M*, Rev. A, Consolidated Nuclear Security, LLC, Y-12 National Security Complex, 03/10/2016. [InfoWorks]

4.85 A2E922601A101, *Salvage and Accountability Building First Level Plan*, Rev. B, Consolidated Nuclear Security, LLC, Y-12 National Security Complex, 11/17/2015. [InfoWorks]

4.86 A2E922601A102, *Salvage and Accountability Building Second Level Plan*, Rev. B, Consolidated Nuclear Security, LLC, Y-12 National Security Complex, 11/17/2015. [InfoWorks]

4.87 A2E922601A103, *Salvage and Accountability Building Third Level Plan*, Rev. B, Consolidated Nuclear Security, LLC, Y-12 National Security Complex, 11/17/2015. [InfoWorks]

4.88 COI-ED-801768-A008, R0, *White Space Count for Criticality Safety in support of Liquid Management*, Consolidated Nuclear Security, LLC, Y-12 National Security Complex, 11/24/2016. [InfoWorks]

5. MARGIN

Data provided in Sect. 3 are used to produce the information contained in Sect. 6, which will be used as input and reference for future NCS DACs. In many cases, the data are not changed or are, at most, rounded to fewer significant figures, such as elemental and isotopic data from the Chart of Nuclides [Ref. 4.15]. In other cases, equations were developed that calculate atom densities, material densities, H/U ratios, or other material data. In all cases, the final results for the operations are contained in Sect. 6.

6. ANALYTICAL METHODS AND COMPUTATIONS

This section contains physical constants such as atomic weights, material densities, and other properties of materials.

This section also contains modeling guidelines for NCS DACs that are considered reasonable engineering approximations of conservative assumptions. In many cases the engineering judgment used to support these values is discussed.

6.1 DESIGN INPUT SUMMARY

Table 2.1-1 summarizes the design inputs used in this DAC. The applicable value or its location and its reference are listed for each input. If not specifically in Table 2.1-1, the input values are listed in the subsections following the table. The inputs are either used as is or modified, as described in section 6. The final results are listed in summary Table 7.1-1, along with the section 6 subsection where the initial design inputs are modified.

6.2 ELEMENT AND NUCLIDE DATA

6.2.1 Natural Element Data

The atomic mass and specific gravity or density of the elements in Sect. 2.2.1 may contain as many as 10 significant figures. For calculational purposes, the atomic mass values have been rounded to no more than four significant figures past the decimal place.

For solids and liquids, the elemental specific gravity—a dimensionless value—is listed for each natural element at 20ºC. With the exception of uranium, the elemental specific gravity is converted to density by multiplying its value by the density of water at 20ºC (0.9982067 g/cm^3) [Design Input 2.14] and rounding to three significant figures to the right of the decimal. The calculated densities are listed in Table 6.2-1.

For gases, the elemental density, in g/L, is listed for each natural element at STP. With the exception of hydrogen, which is listed with a 10^{-4} exponent, all values for gases have been rounded to at least three significant figures to the right of the decimal with a 10^{-3} exponent.

Table 6.2-1 contains the list of elements, having naturally occurring isotopic distributions, with the atomic number, chemical symbol, atomic mass, and density at STP.

Table 6.2-1 Natural Element Data

Nuclide Number	Element	Symbol	Atomic Mass	Density (g/cm^3)	Nuclide Number	Element	Symbol	Atomic Mass	Density (g/cm^3)
1	Hydrogen*	H	1.0079	0.8988E-4	50	Tin	Sn	118.710	5.7 – 7.3
2	Helium*	He	4.0026	0.1785E-3	51	Antimony	Sb	121.760	6.679
3	Lithium	Li	6.941	0.533	52	Tellurium	Te	127.60	6.229
4	Beryllium	Be	9.0122	1.845	53	Iodine	I	126.9045	4.921
5	Boron	B	10.811	2.346	54	Xenon*	Xe	131.293	5.887E-3
6	Carbon	C	12.0107	1.8 - 3.5	55	Cesium	Cs	132.9055	1.870
7	Nitrogen*	N	14.0067	1.2506E-3	56	Barium	Ba	137.327	3.494
8	Oxygen*	O	15.9994	1.429E-3	57	lanthanum	La*	138.9055	6.134
9	Fluorine*	F	18.9984	1.696E-3	58	Cerium	Ce	140.116	6.758
10	Neon*	Ne	20.1797	0.8999E-3	59	Praseodymium	Pr	140.9077	6.761

Table 6.2-1 Natural Element Data

Nuclide Number	Element	Symbol	Atomic Mass	Density (g/cm^3)	Nuclide Number	Element	Symbol	Atomic Mass	Density (g/cm^3)
11	Sodium	Na	22.9898	0.969	60	Neodymium	Nd	144.242	6.995
12	Magnesium	Mg	24.3050	1.735	61	Promethium	Pm	……..	7.251
13	Aluminum	Al	26.9815	2.694	62	Samarium	Sm	150.36	7.507
14	Silicon	Si	28.0855	2.326	63	Europium	Eu	151.964	5.235
15	Phosphorus	P	30.9738	1.817	64	Gadolinium	Gd	157.25	7.887
16	Sulfur	S	32.065	2.066	65	Terbium	Tb	158.9254	8.215
17	Chlorine*	Cl	35.453	3.214E-3	66	Dysprosium	Dy	162.500	8.536
18	Argon*	Ar	39.948	1.784E-3	67	Holmium	Ho	164.9303	8.779
19	Potassium	K	39.0983	0.860	68	Erbium	Er	167.259	9.050
20	Calcium	Ca	40.078	1.547	69	Thulium	Tm	168.9342	9.304
21	Scandium	Sc	44.9559	2.984	70	Ytterbium	Yb	173.04	6.891
22	Titanium	Ti	47.867	4.532	71	Lutetium	Lu	174.967	9.823
23	Vanadium	V	50.9415	6.099	72	Hafnium	Hf	178.49	13.286
24	Chromium	Cr	51.9961	7.177	73	Tantalum	Ta	180.9479	16.624
25	Manganese	Mn	54.9380	7.287	74	Tungsten	W	183.84	19.265
26	Iron	Fe	55.845	7.860	75	Rhenium	Re	186.207	20.982
27	Cobalt	Co	58.9332	8.884	76	Osmium	Os	190.23	22.530
28	Nickel	Ni	58.6934	8.886	77	Iridium	Ir	192.217	22.380
29	Copper	Cu	63.546	8.944	78	Platinum	Pt	195.084	21.412
30	Zinc	Zn	65.409	7.120	79	Gold	Au	196.9666	~19.265
31	Gallium	Ga	69.723	5.893	80	Mercury	Hg	200.59	13.522
32	Germanium	Ge	72.64	5.313	81	Thallium	Tl	204.3833	11.829
33	Arsenic	As	74.9216	5.690	82	Lead	Pb	207.2	11.330
34	Selenium	Se	78.96	4.692	83	Bismuth	Bi	208.9804	9.730
35	Bromine	Br	79.904	3.114	84	Polonium	Po	……..	9.303
36	Krypton*	Kr	83.798	3.733E-3	85	Astatine	At	……..	……..
37	Rubidium	Rb	85.4678	1.529	86	Radon*	Rn	……..	9.73E-3
38	Strontium	Sr	87.62	2.535	87	Francium	Fr	……..	……..
39	Yttrium	Y	88.9059	4.461	88	Radium	Ra	……..	4.991
40	Zirconium	Zr	91.224	6.494	89	Actinium	Ac**	……..	10.052
41	Niobium	Nb	92.9064	8.555	90	Thorium	Th	232.0381	11.699
42	Molybdenum	Mo	95.94	10.202	91	Protactinium	Pa	231.0359	15.342
43	Technetium	Tc	……..	11.479	92	Uranium	U	238.0289	19.05
44	Ruthenium	Ru	101.07	12.388	93	Neptunium	Np	……..	20.214
45	Rhodium	Rh	102.9055	12.388	94	Plutonium	Pu	……..	19.804
46	Palladium	Pd	106.42	11.998	95	Americium	Am	……..	13.645
47	Silver	Ag	107.8682	10.481	96	Curium	Cm	……..	13.476
48	Cadmium	Cd	112.411	8.634	97	Berkelium	Bk	……..	~13.975
49	Indium	In	114.818	7.297	98	Californium	Cf	……..	……..

Table 6.2-1 Natural Element Data

Nuclide Number	Element	Symbol	Atomic Mass	Density (g/cm^3)	Nuclide Number	Element	Symbol	Atomic Mass	Density (g/cm^3)

*Beginning of Lanthanide Series

**Beginning of Actinide Series

Gas, Liquid, Solid at 20°C or artificially prepared for Nuclide Numbers < 90, does not exist naturally

* Indicates a gas at STP

6.2.2 Isotopic Data

The isotopic atomic mass values listed in Table 3.2-2 have up to 13 significant figures. For calculational purposes, the atomic mass values have been rounded to no more than four significant figures past the decimal place. The sum of the atom percentages of all isotopes in an element is 100%. For all isotopes in Table 3.2-2 except ^{3}He and ^{4}He, the Atom Percent contains no more than four significant figures past the decimal place and are therefore not rounded. For ^{3}He and ^{4}He, since the ^{3}He lists only three significant figures and its value is less than10^{-3}%, the actual values for ^{4}He are maintained. Table 6.2-2 contains the list of all isotopes, their atomic number and Z number, their rounded atomic mass, and their abundance in the naturally occurring element. The weight percentages were calculated using the raw data from Table 2.2-2. The partial atomic mass for each isotope was computed as a product of its atomic weight and atom fraction divided by the total element atomic weight multiplied by 100 and rounded to no more than 4 significant figures past the decimal point.

Table 6.2-2 Isotopic Data

Isotope	Z	A	Atomic Mass	Atom Percent**	Weight Percent***
H-1	1	1	1.0078	99.9885	99.9770
H-2*	1	2	2.0141	0.0115	0.0230
He-3*	2	3	3.0160	0.000134	0.0001
He-4	2	4	4.0026	99.999866	99.9999
Li-6*	3	6	6.0151	7.59	6.5785
Li-7*	3	7	7.0160	92.41	93.4215
Be-9	4	9	9.0122	100.	100
B-10*	5	10	10.0129	19.9	18.4309
B-11*	5	11	11.0093	80.1	81.5691
C-12	6	12	12.0000	98.93	98.8416
C-13	6	13	13.0034	1.07	1.1584
N-14	7	14	14.0031	99.636	99.6102
N-15	7	15	15.0001	0.364	0.3898
O-16	8	16	15.9949	99.757	99.7290
O-17	8	17	16.9991	0.038	0.0404
O-18	8	18	17.9992	0.205	0.2306
F-19	9	19	18.9984	100.	100
Ne-20	10	20	19.9924	90.48	89.6388
Ne-21	10	21	20.9938	0.27	0.2809
Ne-22	10	22	21.9914	9.25	10.0803

Table 6.2-2 Isotopic Data

Isotope	Z	A	Atomic Mass	Atom Percent**	Weight Percent***
Na-23	11	23	22.9898	100.	100
Mg-24	12	24	23.9850	78.99	77.9500
Mg-25	12	25	24.9858	10.00	10.2801
Mg-26	12	26	25.9826	11.01	11.7699
Al-27	13	27	26.9815	100.	100
Si-28	14	28	27.9769	92.223	91.8665
Si-29	14	29	28.9765	4.685	4.8336
Si-30	14	30	29.9738	3.092	3.2999
P-31	15	31	30.9738	100.	100
S-32	16	32	31.9721	94.99	94.7153
S-33	16	33	32.9715	0.75	0.7712
S-34	16	34	33.9679	4.25	4.5022
S-36	16	36	35.9671	0.01	0.0112
Cl-35	17	35	34.9689	75.76	74.7256
Cl-37	17	37	36.9659	24.24	25.2744
Ar-36	18	36	35.9675	0.3365	0.3030
Ar-38	18	38	37.9627	0.0632	0.0601
Ar-40	18	40	39.9624	99.6003	99.6370
K-39	19	39	38.9637	93.2581	92.9371
K-40	19	40	39.9640	0.0117	0.0120
K-41	19	41	40.9618	6.7302	7.0510
Ca-40	20	40	39.9626	96.941	96.6618
Ca-42	20	42	41.9586	0.647	0.6774
Ca-43	20	43	42.9588	0.135	0.1447
Ca-44	20	44	43.9555	2.086	2.2878
Ca-46	20	46	45.9537	0.004	0.0046
Ca-48	20	48	47.9525	0.187	0.2237
Sc-45	21	45	44.9559	100.	100
Ti-46	22	46	45.9526	8.25	7.9201
Ti-47	22	47	46.9518	7.44	7.2978
Ti-48	22	48	47.9479	73.72	73.8451
Ti-49	22	49	48.9479	5.41	5.5322
Ti-50	22	50	49.9448	5.18	5.4049
V-50	23	50	49.9472	0.250	0.2451
V-51	23	51	50.9440	99.750	99.7549
Cr-50	24	50	49.9460	4.345	4.1737
Cr-52	24	52	51.9405	83.789	83.6994
Cr-53	24	53	52.9406	9.501	9.6736
Cr-54	24	54	53.9389	2.365	2.4534
Mn-55	25	55	54.9380	100.	100

Table 6.2-2 Isotopic Data

Isotope	Z	A	Atomic Mass	Atom Percent**	Weight Percent***
Fe-54	26	54	53.9396	5.845	5.6456
Fe-56	26	56	55.9349	91.754	91.9015
Fe-57	26	57	56.9354	2.119	2.1604
Fe-58	26	58	57.9333	0.282	0.2925
Co-59	27	59	58.9332	100.	100
Ni-58	28	58	57.9353	68.0769	67.1977
Ni-60	28	60	59.9308	26.2231	26.7760
Ni-61	28	61	60.9311	1.1399	1.1834
Ni-62	28	62	61.9283	3.6345	3.8348
Ni-64	28	64	63.9280	0.9256	1.0082
Cu-63	29	63	62.9296	69.15	68.4792
Cu-65	29	65	64.9278	30.85	31.5208
Zn-64	30	64	63.9291	48.268	47.1761
Zn-66	30	66	65.9260	27.975	28.1962
Zn-67	30	67	66.9271	4.102	4.1972
Zn-68	30	68	67.9248	19.024	19.7558
Zn-70	30	70	69.9253	0.631	0.6746
Ga-69	31	69	68.9256	60.108	59.4205
Ga-71	31	71	70.9247	39.892	40.5795
Ge-70	32	70	69.9242	20.38	19.6181
Ge-72	32	72	71.9221	27.31	27.0401
Ge-73	32	73	72.9235	7.76	7.7903
Ge-74	32	74	73.9212	36.72	37.3677
Ge-76	32	76	75.9214	7.83	8.1837
As-75	33	75	74.9216	100.	100
Se-74	34	74	73.9225	0.89	0.8332
Se-76	34	76	75.9192	9.37	9.0092
Se-77	34	77	76.9199	7.63	7.4329
Se-78	34	78	77.9173	23.77	23.4563
Se-80	34	80	79.9165	49.61	50.2114
Se-82	34	82	81.9167	8.73	9.0570
Br-79	35	79	78.9183	50.69	50.0650
Br-81	35	81	80.9163	49.31	49.9350
Kr-78	36	78	77.9204	0.355	0.3301
Kr-80	36	80	79.9164	2.286	2.1801
Kr-82	36	82	81.9135	11.593	11.3323
Kr-83	36	83	82.9141	11.500	11.3787
Kr-84	36	84	83.9115	56.987	57.0642
Kr-86	36	86	85.9106	17.279	17.7146
Rb-85	37	85	84.9118	72.17	71.7006

Table 6.2-2 Isotopic Data

Isotope	Z	A	Atomic Mass	Atom Percent**	Weight Percent***
Rb-87	37	87	86.9092	27.83	28.2994
Sr-84	38	84	83.9134	0.56	0.5363
Sr-86	38	86	85.9093	9.86	9.6679
Sr-87	38	87	86.9089	7.00	6.9435
Sr-88	38	88	87.9056	82.58	82.8524
Y-89	39	89	88.9058	100	100
Zr-90	40	90	89.9047	51.45	50.7061
Zr-91	40	91	90.9056	11.22	11.1809
Zr-92	40	92	91.9050	17.15	17.2781
Zr-94	40	94	93.9063	17.38	17.8911
Zr-96	40	96	95.9083	2.80	2.9438
Nb-93	41	93	92.9064	100.	100
Mo-92	42	92	91.9068	14.77	14.1494
Mo-94	42	94	93.9051	9.23	9.0345
Mo-95	42	95	94.9058	15.90	15.7290
Mo-96	42	96	95.9047	16.68	16.6743
Mo-97	42	97	96.9060	9.56	9.6565
Mo-98	42	98	97.9054	24.19	24.6862
Mo-100	42	100	99.9075	9.67	10.0701
Ru-96	44	96	95.9076	5.54	5.2573
Ru-98	44	98	97.9053	1.87	1.8115
Ru-99	44	99	98.9059	12.76	12.4874
Ru-100	44	100	99.9042	12.60	12.4553
Ru-101	44	101	100.9056	17.06	17.0331
Ru-102	44	102	101.9043	31.55	31.8120
Ru-104	44	104	103.9054	18.62	19.1433
Rh-103	45	103	102.9055	100.	100
Pd-102	46	102	101.9056	1.02	0.9768
Pd-104	46	104	103.9040	11.14	10.8771
Pd-105	46	105	104.9051	22.33	22.0131
Pd-106	46	106	105.9035	27.33	27.1985
Pd-108	46	108	107.9039	26.46	26.8301
Pd-110	46	110	109.9052	11.72	12.1044
Ag-107	47	107	106.9051	51.839	51.3762
Ag-109	47	109	108.9048	48.161	48.6238
Cd-106	48	106	105.9065	1.25	1.1777
Cd-108	48	108	107.9042	0.89	0.8543
Cd-110	48	110	109.9030	12.49	12.2113
Cd-111	48	111	110.9042	12.80	12.6284
Cd-112	48	112	111.9028	24.13	24.0208

Table 6.2-2 Isotopic Data

Isotope	Z	A	Atomic Mass	Atom Percent**	Weight Percent***
Cd-113	48	113	112.9044	12.22	12.2736
Cd-114	48	114	113.9034	28.73	29.1113
Cd-116	48	116	115.9048	7.49	7.7228
In-113	49	113	112.9041	4.29	4.2185
In-115	49	115	114.9039	95.71	95.7815
Sn-112	50	112	111.9048	0.97	0.9144
Sn-114	50	114	113.9028	0.66	0.6333
Sn-115	50	115	114.9033	0.34	0.3291
Sn-116	50	116	115.9017	14.54	14.1960
Sn-117	50	117	116.9030	7.68	7.5631
Sn-118	50	118	117.9016	24.22	24.0550
Sn-119	50	119	118.9033	8.59	8.6040
Sn-120	50	120	119.9022	32.58	32.9072
Sn-122	50	122	121.9034	4.63	4.7545
Sn-124	50	124	123.9053	5.79	6.0434
Sb-121	51	121	120.9038	57.21	56.8078
Sb-123	51	123	122.9042	42.79	43.1922
Te-120	52	120	119.9040	0.09	0.0846
Te-122	52	122	121.9030	2.55	2.4361
Te-123	52	123	122.9043	0.89	0.8572
Te-124	52	124	123.9028	4.74	4.6025
Te-125	52	125	124.9044	7.07	6.9205
Te-126	52	126	125.9033	18.84	18.5890
Te-128	52	128	127.9045	31.74	31.8150
Te-130	52	130	129.9062	34.08	34.6951
I-127	53	127	126.9045	100.	100
Xe-124	54	124	123.9059	0.0952	0.0898
Xe-126	54	126	125.9043	0.0890	0.0853
Xe-128	54	128	127.9035	1.9102	1.8609
Xe-129	54	129	128.9048	26.4006	25.9204
Xe-130	54	130	129.9035	4.0710	4.0279
Xe-131	54	131	130.9051	21.2324	21.1697
Xe-132	54	132	131.9042	26.9086	27.0339
Xe-134	54	134	133.9054	10.4357	10.6434
Xe-136	54	136	135.9072	8.8573	9.1686
Cs-133	55	133	132.9055	100.	100
Ba-130	56	130	129.9063	0.106	0.1003
Ba-132	56	132	131.9051	0.101	0.0970
Ba-134	56	134	133.9045	2.417	2.3568
Ba-135	56	135	134.9057	6.592	6.4758

Table 6.2-2 Isotopic Data

Isotope	Z	A	Atomic Mass	Atom Percent**	Weight Percent***
Ba-136	56	136	135.9046	7.854	7.7727
Ba-137	56	137	136.9058	11.232	11.1976
Ba-138	56	138	137.9052	71.698	72.0000
La-138	57	138	137.9071	0.090	0.0894
La-139	57	139	138.9064	99.910	99.9106
Ce-136	58	136	135.9072	0.185	0.1794
Ce-138	58	138	137.9060	0.251	0.2470
Ce-140	58	140	139.9054	88.450	88.3173
Ce-142	58	142	141.9092	11.114	11.2563
Pr-141	59	141	140.9077	100.	100
Nd-142	60	142	141.9077	27.2	26.7609
Nd-143	60	143	142.9098	12.2	12.0878
Nd-144	60	144	143.9101	23.8	23.7462
Nd-145	60	145	144.9126	8.3	8.3389
Nd-146	60	146	145.9131	17.2	17.4000
Nd-148	60	148	147.9169	5.7	5.8455
Nd-150	60	150	149.9209	5.6	5.8207
Sm-144	62	144	143.9120	3.07	2.9382
Sm-147	62	147	146.9149	14.99	14.6459
Sm-148	62	148	147.9148	11.24	11.0567
Sm-149	62	149	148.9172	13.82	13.6868
Sm-150	62	150	149.9173	7.38	7.3580
Sm-152	62	152	151.9197	26.75	27.0263
Sm-154	62	154	153.9222	22.75	23.2880
Eu-151	63	151	150.9199	47.81	47.4814
Eu-153	63	153	152.9212	52.19	52.5186
Gd-152	64	152	151.9198	0.20	0.1932
Gd-154	64	154	153.9209	2.18	2.1338
Gd-155	64	155	154.9226	14.80	14.5808
Gd-156	64	156	155.9221	20.47	20.2969
Gd-157	64	157	156.9240	15.65	15.6173
Gd-158	64	158	157.9241	24.84	24.9461
Gd-160	64	160	159.9271	21.86	22.2318
Tb-159	65	159	158.9253	100.	100
Dy-156	66	156	155.9243	0.056	0.0537
Dy-158	66	158	157.9244	0.095	0.0923
Dy-160	66	160	159.9252	2.329	2.2921
Dy-161	66	161	160.9269	18.889	18.7062
Dy-162	66	162	161.9268	25.475	25.3852
Dy-163	66	163	162.9287	24.896	24.9618

Table 6.2-2 Isotopic Data

Isotope	Z	A	Atomic Mass	Atom Percent**	Weight Percent***
Dy-164	66	164	163.9292	28.260	28.5086
Ho-165	67	165	164.9303	100.	100
Er-162	68	162	161.9288	0.139	0.1346
Er-164	68	164	163.9292	1.601	1.5691
Er-166	68	166	165.9303	33.503	33.2368
Er-167	68	167	166.9320	22.869	22.8243
Er-168	68	168	167.9324	26.978	27.0866
Er-170	68	170	169.9355	14.910	15.1486
Tm-169	69	169	168.9342	100.	100
Yb-168	70	168	167.9339	0.13	0.1262
Yb-170	70	170	169.9348	3.04	2.9855
Yb-171	70	171	170.9363	14.28	14.1066
Yb-172	70	172	171.9364	21.83	21.6911
Yb-173	70	173	172.9382	16.13	16.1207
Yb-174	70	174	173.9389	31.83	31.9958
Yb-176	70	176	175.9426	12.76	12.9742
Lu-175	71	175	174.9408	97.41	97.3956
Lu-176	71	176	175.9427	2.59	2.6044
Hf-174	72	174	173.9400	0.16	0.1559
Hf-176	72	176	175.9414	5.26	5.1850
Hf-177	72	177	176.9432	18.60	18.4393
Hf-178	72	178	177.9437	27.28	27.1973
Hf-179	72	179	178.9458	13.62	13.6552
Hf-180	72	180	179.9465	35.08	35.3673
Ta-180	73	180	179.9475	0.012	0.0119
Ta-181	73	181	180.9480	99.988	99.9881
W-180	74	180	179.9467	0.12	0.1175
W-182	74	182	181.9482	26.50	26.2270
W-183	74	183	182.9502	14.31	14.2406
W-184	74	184	183.9509	30.64	30.6582
W-186	74	186	185.9544	28.43	28.7567
Re-185	75	185	184.9530	37.40	37.1482
Re-187	75	187	186.9558	62.60	62.8518
Os-184	76	184	183.9525	0.02	0.0193
Os-186	76	186	185.9538	1.59	1.5543
Os-187	76	187	186.9558	1.96	1.9263
Os-188	76	188	187.9558	13.24	13.0821
Os-189	76	189	188.9581	16.15	16.0425
Os-190	76	190	189.9584	26.26	26.2232
Os-192	76	192	191.9615	40.78	41.1523

Table 6.2-2 Isotopic Data

Isotope	Z	A	Atomic Mass	Atom Percent**	Weight Percent***
Ir-191	77	191	190.9606	37.3	37.0564
Ir-193	77	193	192.9629	62.7	62.9436
Pt-190	78	190	189.9599	0.014	0.0136
Pt-192	78	192	191.9610	0.782	0.7695
Pt-194	78	194	193.9627	32.967	32.7786
Pt-195	78	195	194.9648	33.832	33.8124
Pt-196	78	196	195.9650	25.242	25.3568
Pt-198	78	198	197.9679	7.163	7.2691
Au-197	79	197	196.9666	100.	100
Hg-196	80	196	195.9658	0.15	0.1465
Hg-198	80	198	197.9668	9.97	9.8392
Hg-199	80	199	198.9683	16.87	16.7328
Hg-200	80	200	199.9683	23.10	23.0274
Hg-201	80	201	200.9703	13.18	13.2044
Hg-202	80	202	201.9706	29.86	30.0641
Hg-204	80	204	203.9735	6.87	6.9856
Tl-203	81	203	202.9723	29.52	29.3162
Tl-205	81	205	204.9744	70.48	70.6838
Pb-204	82	204	203.9730	1.4	1.3781
Pb-206	82	206	205.9745	24.1	23.9555
Pb-207	82	207	206.9759	22.1	22.0743
Pb-208	82	208	207.9767	52.4	52.5921
Bi-209	83	209	208.9804	100.	100
Th-232	90	232	232.0381	100.	100
Pa-231	91	231	231.0359	100.	100
U-234**	92	234	234.0410	0.0054	0.0053
U-235**	92	235	235.0439	0.7204	0.7114
U-238**	92	238	238.0508	99.2742	99.2833

*Significant differences in the atom percent values have been observed in some samples.

**Atom Percentages are for naturally occurring materials, including those for uranium.

***Calculated using Equation 5.3.11.

6.2.3 Uranium Enrichment

Use of the highest credible enrichment, unless specified for a particular process where commingling is not possible, is bounded by 100% ^{235}U in all data for this DAC. Note that some comparisons are made using data for 93.5% enriched uranium, but since the compared results all use the same enrichment and it is a high enrichment, they are considered valid for 100% enrichment also.

For consistency and simplicity, all fissile materials are considered to have a ^{235}U enrichment of 100 wt %, unless a controlled specification imposes the enrichment. In cases where enrichment is specified and controlled, the fissile material is considered to have the maximum ^{235}U enrichment in the specification. In these cases, such as weapons specifications, consideration must be given to the possibility of introducing other streams of uranium with higher enrichments.

6.3 URANIUM METAL, COMPOUND, AND MIXTURE DATA

6.3.1 Uranium Metal and Compounds—Density and Hydration Data

Equations used to calculate various component properties; such as densities, atom fractions, volume fractions, H/U ratios, etc.; of uranium compounds are presented. Although in most cases uranium components are used in the examples, the equations can be used for any compound.

For uranium compounds, various densities and H/U values were researched to find appropriate models for handling and storage of wet and dry compounds in containers at UPF. This may be applied to all processes for handling dry compounds.

6.3.1.1 Theoretical Data for Uranium Metal and Uranium Compounds

The equation used to the convert from natural uranium to 100% ^{235}U:

$$\rho_{C100} = \rho_C \times \left(\frac{n_U \times AW_{235} + \sum_{i=1}^{m} n_i \times AW_i}{n_U \times AW_{Unat} + \sum_{i=1}^{m} n_i \times AW_i}\right) \qquad \text{Eq. 6.3.1}$$

where:
- ρ_{C100} = Density of compound for 100% enriched U to be calculated (g/cm^3)
- ρ_C = Compound density for natural U (g/cm^3)
- n_i = Number of atoms of element "i" in compound (atoms/molecule)
- n_U = Number of atoms of U in compound (atoms)
- AW_i = Atomic weight of element "i" (g/mole)
- AW_{Unat} = Atomic weight of natural uranium (g/mole)
- AW_{235} = Atomic weight of ^{235}U (g/mole)
- m = Number of non-uranium isotopes/element types in compound/molecule

For this conversion, ρ_C comes from Design Input 2.5 [referenced in Sect. 2.3.1.1], the n values come from the compound formulae, and AW values come from Sect. 2.2.1, Table 2.2-1, and Sect. 2.2.2, Table 2.2-2, rounded to four digits after the decimal.

Example: Convert the density of U_3O_8 for 100% ^{235}U from that in natural U_3O_8 (8.38 g/cm^3).

$$\rho_{100} = 8.38 \times \left(\frac{3 \times 235.0439 + 8 \times 15.9994}{3 \times 238.02891 + 8 \times 15.9994}\right) = 8.29\ {}^{g}/_{cm^3}$$

For the uranium density in the 100% enriched compound, the formula is:

$$\rho_{U100} = \rho_{C100} \times \left(\frac{n_{235} \times AW_{235}}{n_{235} \times AW_{235} + \sum_{i=1}^{m} n_i \times AW_i}\right) \qquad \text{Eq. 6.3.2}$$

where the terms are the same as above and $n_{235} = n_U$.

Example: Determine the uranium density in the converted U_3O_8 for 100% ^{235}U (8.29 g/cm^3).

$$\rho_{U100} = 8.29 \times \left(\frac{3 \times 235.0439}{3 \times 235.0439 + 8 \times 15.9994}\right) = 7.02\ {}^{g}/_{cm^3}$$

Equations 6.3.1 and 6.3.2 were used to convert the data from Tables 2.1-1, 2.2-1, and 2.2-2 from natural enrichment to 100 wt % ^{235}U enrichment. Results are shown in Table 6.3-1. The relationships shown are used for all evaluation activities involving these materials, unless enrichment is specified as discussed in Section 6.2.3.

Table 6.3-1. Uranium Metal and Compound Theoretical Densities Enriched to 100% ^{235}U

Material	Material Density (g/cm^3)	Uranium Density (g/cm^3)
U	18.81	18.81
UO_2	10.85	9.55
UO_3	7.22	6.00
U_3O_8	8.29	7.02
UF_4	6.64	5.02

6.3.1.2 Hydration of "Dry" Uranium Compounds in Air

Table 6.3-2 summarizes the values determined from reference research in Sect. 2.3.1.2 for each compound.

Table 6.3-2. Hydration for "Dry" Uranium Compounds

Compound	H/U atom ratio
UO_2	0
UO_3	2
U_3O_8	0.94
UF_4	1

For mixtures of compounds or for a single model to represent several compounds, a bounding model can be created with the highest uranium density of all available materials and the highest H/U ratio of all materials.

6.3.1.3 Uranium Compound Bulk Densities—Dry and Wet

The range of typical loose powder bulk densities for the most common uranium compounds currently handled in Building 9212 is shown in Table 6.3-3. Note that use of this bulk density information requires justification related to the expected method of production and sources of the bulk density values. If possible, it is best to use measured data from the actual process being analyzed.

As discussed in Sect. 2.3.1.2, recommendations for densities to be used for flooded conditions were based on a set of experiments with oxides in beakers performed at Y-12 and reported in 2008. For most compounds in Table 6.2-3, the optimal moderation condition results from using the minimum bulk density and flooding the interstitial space with water. For UO_2, the optimum is to use the highest density. This may not be the optimum for all masses and equipment configurations.

These rules should be followed, using the minimum or maximum bulk densities for the process being evaluated. Values for the typical range were given for UO_3 and U_3O_8. Values for UO_2 and UF_4 were calculated using the equations in Sect. 6.3.1.4. Table 6.3-3 gives the results of following those recommendations.

Table 6.3-3. Uranium Compound Typical Bulk Powder Densities and Corresponding Optimum H/U Values for Flooded Conditions

Description	Typical Y-12 Density Range (g compound/cm^3)	Optimum Density for Wet Powder (g/cm^3)*	Optimum H/U for Wet Powder*
UO_2	4.0 - 6.63	6.63	1.74
UO_3	3.44 - 4.3	3.44	10.4
U_3O_8	2.4 - 4.3	2.4	7.1
UF_4	3.0 - 3.5	3.0	6.3

*These are optimum based on the minimum or maximum typical value from column 2. Process-specific data must be used if outside this range.

6.3.1.4 Insoluble Uranium-Water Mixture Data

This section contains equations, formulas, and examples for calculating input values for selected uranium compounds. The materials of interest (U-metal, UO_2, UO_3, and U_3O_8) are insoluble in water and can therefore be combined using the volume additive method [Assumption 3.4]. All mixtures are composed of water at 20°C with a maximum density of 0.9982 g/cm^3 as shown in Sect. 2.1 [Design Input 2.14 rounded to four significant figures] and one of the following uranium materials: U-metal, UO_2, UO_3, or U_3O_8,. The uranium in all of the mixtures is 100% ^{235}U at the values shown in Table 6.3-1. (The Table 6.3-1 values were derived from maximum theoretical densities of natural enrichment uranium metal and compounds [Design Inputs 2.4 and 2.5] corrected to account for 100% ^{235}U enrichment per Sect. 6.3.1.1).

For each uranium compound, the uranium compound density corrected for 100% ^{235}U enrichment Uranium-metal/water systems are calculated at intervals of 0.005 gU/cm^3 from 0.00 to 0.10 gU/cm^3, intervals of 0.010 gU/cm^3 from 0.10 to 0.20 gU/cm^3, intervals of 0.050 from 0.20 to 1.0 gU/cm^3, intervals of 0.10 from 1.0 to 2.0 gU/cm^3, and intervals of 0.2 g/cm^3 from 1.0 gU/cm^3 to full theoretical density. Uranium-oxide/water systems are calculated at intervals of 0.010 g/cm^3 from 0.0 to 0.01 gU/cm^3, intervals of 0.10 from 0.10 to 1.0 gU/cm^3, and intervals of 0.2 gU/cm3 from 1.0 gU/cm^3 to full density. Additional mixture densities were calculated at water volume fraction intervals of 0.05 or where felt appropriate. The following values are calculated for each compound listed in Table 6.3-1: uranium density, water density, uranium compound volume fraction, water volume fraction, mixture density, hydrogen, oxygen, uranium and total atom densities, and hydrogen to uranium atom ratios (H/U). The equations used to calculate these values are Eqs. 6.3.3 through 6.3.11 below. The results are shown in Tables 6.3-4, 6.3-5, 6.3-6, and 6.3-7 for U-metal, UO_2, UO_3, and U_3O_8 respectively

Uranium Density Calculations in a Compound

The standard equation used to calculate the density of one isotope or element in a compound is:

$$\rho_I = \rho_C \times \left(\frac{n_I \times AW_I}{\sum_{i=1}^{m} n_i \times AW_i}\right) \qquad \text{Eq. 6.3.3}$$

where:
ρ_I = Density of isotope/element "I" to be calculated (g/cm^3)
ρ_C = Compound density (g/cm^3)
n_I = Number of atoms of isotope/element "*I*" in compound (Atoms)
AW_I = Atomic weight of isotope/element "I" in compound (g/mole)
n_i = Number of atoms of isotope/element "*i*" in compound (Atoms)

AW_i = Atomic weight of isotope/element "i" in compound (g/mole)
m = Number of isotopes/element types in compound/molecule

Example: Calculate the density of ^{235}U in full-density U_3O_8 (8.29 g/cm^3).

$$\rho_{235} = 8.29 \times \left(\frac{3 \times 235.0439}{3 \times 235.0439 + 8 \times 15.9994}\right) = 7.02 \ {}^{g}/_{cm^3}$$

Volume Fraction Calculations

The standard equation used to calculate the volume fraction of a material for a volume additive calculation is:

$$VF_I = \frac{\rho_I}{\rho_T} \qquad \text{Eq. 6.3.4}$$

where: VF_I = Volume fraction of material "I" (dimensionless)
ρ_I = Average density of material "I" (g/cm^3)
ρ_T = Theoretical maximum density (g/cm^3)

Example: Calculate the volume fraction ^{235}U relative to full-density U-metal (18.81 g/cm^3) given a density of 1.0 g/cm^3.

$$VF_{235} = {}^{1.0}/_{18.81} = 0.05316$$

When all other volume fractions are known, the remaining volume fraction can be calculated by subtracting them from 1.0 as follows:

$$VF_I = 1.0 - \sum_{i=1}^{m} VF_i \qquad \text{Eq. 6.3.5}$$

where: VF_I = Volume fraction of unknown isotope/element "I" (dimensionless)
VF_i = Known volume fraction "i" (dimensionless)
m = Total number of isotopes/nuclides in compound

Example: Calculate the volume fraction water in a uranium-water mixture given the uranium volume fraction is 0.05316.

$$VF_{water} = 1.0 - 0.05316 = 0.94684$$

Density Calculations using Volume Fractions

The standard equation to calculate a material density from its theoretical density and volume fraction is:

$$\rho_I = VF_I \times \rho_T \qquad \text{Eq. 6.3.6}$$

where: ρ_I = Density of material "I" (g/cm^3)
VF_I = Volume fraction of material "I" (dimensionless)
ρ_T = Theoretical maximum density of material "I" (g/cm^3)

Example: Calculate the water density given a full density of 0.9982 and a volume fraction of 0.9019.

$$\rho_{water} = 0.9019 \times 0.9982 = 0.9003 \ {}^{g}/_{cm^3}$$

Total Mass Density Calculations using Partial Mass Densities

The standard equation to calculate a total material density from several partial densities is:

$$\rho_{Tot} = \sum_{i=1}^{m} \rho_i \qquad \text{Eq. 6.3.7}$$

where:
- ρ_{Tot} = Total density of material (g/cm^3)
- ρ_i = Partial density of element "i" in material (g/cm^3)
- m = Number of isotopes/element types in compound/molecule

Example: Calculate the total density of the mixture containing a U_3O_8 partial density of 0.9 g/cm^3 and a water partial density of 0.8898 g/cm^3.

$$\rho_{Tot} = 0.9000 + 0.8898 = 1.7898 \ {}^{g}/_{cm^3}$$

Isotopic Atom Density Calculations in Material with multiple Elements

The standard equation used to calculate the density of one isotope or element in a compound is:

$$N_I = \rho_I \times \left(\frac{N_A \times b}{AW_I}\right) \times \left(\frac{n_I \times AW_I}{\sum_{i=1}^{m}(n_i \times AW_i)}\right) \qquad \text{Eq. 6.3.8}$$

where:
- N_I = Atom density of isotope/element "*I*" in compound/molecule (atom/b-cm)
- ρ_I = Density of isotope/element "*I*" to be calculated (g/cm^3)
- N_A = Avogadro's Constant (Entities/Mole)
- b = 10^{-24} (cm^2)
- AW_I = Atomic mass of isotope/element "I" (g/mole)
- AW_i = Atomic mass of isotope/element "i" (g/mole)
- n_i = Number of atoms "i" in compound/molecule
- m = Number of isotopes/element types in compound/molecule

Example: Calculate the atom density of ^{235}U in U_3O_8 at a density of 5.0 g/cm^3.

$$\rho_{235} = 5.0 \times \left(\frac{6.0221 \times 10^{23} \times 10^{-24}}{235.0439}\right) \times \left(\frac{3 \times 235.0439}{3 \times 235.0439 + 8 \times 15.9994}\right) = 1.0842 \times 10^{-02} \ {}^{Atom}/_{b-cm}$$

Total Atom Density Calculation using Partial Atom Densities

The standard equation to calculate the total atom density from several constituent atom densities is:

$$N_{Tot} = \sum_{i=1}^{m} N_i \qquad \text{Eq. 6.3.9}$$

where:
- N_{Tot} = Total atom density of material (atoms/b-cm)
- N_i = Partial atom density of element/isotope "i" in material (atoms/b-cm)
- m = Number of isotopes/element types in compound/molecule

Example: Calculate the total density of the mixture containing U_3O_8 and water where the atom density of hydrogen is 6.6413×10^{-2}, oxygen is 3.3438×10^{-2} and ^{235}U is 8.6740×10^{-5}.

$$N_{Tot} = 6.6413 \times 10^{-2} + 3.3438 \times 10^{-2} + 8.6740 \times 10^{-5} = 9.9938 \times 10^{-2}\ {}^{atoms}/_{b-cm}$$

H/U Ratio Calculations

The standard equation used to calculate the hydrogen to uranium ratio (H/U) is:

$$H/U = \frac{N_H}{N_U} \qquad \text{Eq. 6.3.10}$$

Where:
H/U = Hydrogen to uranium atom ratio (dimensionless)
N_H = Atom density of hydrogen in material (atom/b-cm)
N_U = Atom density of uranium in material (atom/b-cm)

Example: Calculate the H/U ratio of a material that has atom densities of 6.6413E-02 atoms/b-cm for hydrogen and 8.6740E-05 atoms/b-cm for ^{235}U.

$$H/U = \frac{6.6413 \times 10^{-2}}{8.6740 \times 10^{-5}} = 765.66$$

Weight Fraction of Isotope in Elements having multiple Isotopes

The standard equation used to calculate the density of one isotope or element in a compound is:

$$WF_I = \left(\frac{AF_I \times AW_I}{\sum_{i=1}^{m}(AF_i \times AW_i)}\right) \qquad \text{Eq. 6.3.11}$$

where:
WF_I = Weight Fraction of isotope "*I*" in Element (Dimensionless Ratio)
AW_I = Atomic mass of isotope "I" in Element (g/mole)
AW_i = Atomic mass of isotope "i" in Element (g/mole)
AF_I = Atom Fraction of isotope "I" in Element (Dimensionless Ratio)
AF_i = Atom Fraction of isotope "i" in Element (Dimensionless Ratio)
m = Number of isotopes in Element

Example: Calculate the atom density of ^{235}U in U_3O_8 at a density of 5.0 g/cm^3.

$$WF_{235} = \left(\frac{0.7204 \times 235.0439}{(0.0054 \times 234.0410) + (0.7204 \times 235.0439) + (99.2742 \times 238.0508)}\right) = 0.7114$$

The materials listed in Tables 6.3-4 through 6.3-7 are insoluble in water and can therefore be combined using the volume additive method. All mixtures are composed of full-density water and one of the following uranium materials: U-metal, UO_2, UO_3, and U_3O_8. The uranium in all of the mixtures is 100% ^{235}U. The maximum theoretical densities of the uranium compounds, listed in Table 6.3-1, as corrected for 100% ^{235}U are used.

Each table lists the following data: uranium compound density, uranium density, water density, uranium volume fraction, water volume fraction, mixture density, hydrogen, oxygen, uranium and total atom densities, and hydrogen to uranium atom ratios (H/U). The tables contain uranium compound information ranging from 0 to maximum theoretical density for each of the compounds. The equations used to calculate the values in Tables 6.3-4 through 6.3-9 are in Sect. 6.3.1.4.

The tables can be used for modeling uranium-water mixtures as homogenous systems and running parametric studies to determine the optimum moderation level. Modeling material as homogenous mixtures at optimum moderation level with no diluents is typically conservative for all materials handled at UPF. However, heterogeneous effects can result in higher calculated k-effective values, especially for lumps of uranium metal distributed through a moderating liquid. CCG-425 [Ref. 4.3] contains some data and some conclusions on this subject, relative to the forms of uranium metal currently handled in existing Y-12 facilities.

Values between those explicitly shown in Tables 6.3-4 through 6.3-9 can be generated by multiple methods. For the insoluble Compound/Water mixtures listed in Tables 6.3-4 through 6.3-7 the methodology described above can be used with or without the accompanying EXCEL spreadsheet contained in ProjectWise. The data in Tables 6.3-4 through 6.3-7 were generated using the EXCEL spreadsheet contained in ProjectWise. Two other acceptable methods of generating intermediate values are the SCALE Standard Composition Library and Linear Interpolation, which is described below.

For Uranyl Nitrate and Uranyl Fluoride solutions contained in Tables 6.3-8 and 6.3-9 there are only two acceptable methods for generating intermediate values: the SCALE Standard Composition Library and the Linear Interpolation method described below. The data in Tables 6.3-8 and 6.3-9 were generated using the SCALE Standard Composition Library as described in section 6.3.2.

Any value between the explicit values listed in Tables 6.3-4 through 6.3-9 may be obtained by linearly interpolating between the next highest and lowest values as shown in equation 6.3-12. For consistency, it is best to use the “Material Density” or “Uranium Density” in the first or second columns of Tables 6.3-4 through 6.3-9 to calculate the interval step between the two adjacent points.

Linear Interpolation between 2 points

The standard equation used to linearly interpolate a new value (V_n) between two existing points (V_{n+1}, V_{n-1}) at Material Density (MD_n) is:

$$V_n = V_{n-1} + \left(\frac{MD_n - MD_{n-1}}{MD_{n+1} - MD_{n-1}}\right)(V_{n+1} - V_{n-1}) \qquad \text{Eq. 6.3.12}$$

where:
- V_n = Desired New Value to be interpolated
- V_{n+1} = Listed Value immediately following value to be interpolated
- V_{n-1} = Listed Value immediately before value to be interpolated
- MD_n = Material Density at which new value (V_n) is desired
- MD_{n+1} = Material Density at value immediately following value to be interpolated
- MD_{n-1} = Material Density at value immediately before value to be interpolated
- n = interval step

Example: Calculate the atom density of ^{235}U in a U-metal/Water Mixture from Table 6.3-4 at a Uranium Density of 2.5 gU/cm^3.

$$V_{2.5} = 0.0061491 + \left(\frac{2.500 - 2.400}{2.600 - 2.400}\right)(0.0066615 - 0.0061491) = 0.0064053$$

Table 6.3-4. U-Metal-Water Mixture Data

Uranium Density (g/cm^3) (Specified)	Uranium Volume Fraction (Eq. 6.3.4)	Water Volume Fraction (Eq. 6.3.5)	Water Density (g/cm^3) (Eq. 6.3.6)	Mixture Density (g/cm^3) (Eq. 6.3.7)	Hydrogen Density (atom/b-cm) (Eq. 6.3.8)	Oxygen Density (atom/b-cm) (Eq. 6.3.8)	^{235}U Density (atom/b-cm) (Eq. 6.3.8)	Total Density (atom/b-cm) (Eq. 6.3.9)	H/U ratio (Eq. 6.3.10)
0.000	0.0000	1.0000	0.9982	0.9982	6.6735E-02	3.3368E-02	0.0000E+00	1.0010E-01	∞
0.005	0.0003	0.9997	0.9979	1.0029	6.6718E-02	3.3359E-02	1.2811E-05	1.0009E-01	5208.0
0.010	0.0005	0.9995	0.9977	1.0077	6.6700E-02	3.3350E-02	2.5621E-05	1.0008E-01	2603.3
0.015	0.0008	0.9992	0.9974	1.0124	6.6682E-02	3.3341E-02	3.8432E-05	1.0006E-01	1735.1
0.020	0.0011	0.9989	0.9971	1.0171	6.6664E-02	3.3332E-02	5.1242E-05	1.0005E-01	1301.0
0.025	0.0013	0.9987	0.9969	1.0219	6.6647E-02	3.3323E-02	6.4053E-05	1.0003E-01	1040.5
0.030	0.0016	0.9984	0.9966	1.0266	6.6629E-02	3.3314E-02	7.6864E-05	1.0002E-01	866.85
0.035	0.0019	0.9981	0.9963	1.0313	6.6611E-02	3.3306E-02	8.9674E-05	1.0001E-01	742.81
0.040	0.0021	0.9979	0.9961	1.0361	6.6594E-02	3.3297E-02	1.0248E-04	9.9993E-02	649.79
0.045	0.0024	0.9976	0.9958	1.0408	6.6576E-02	3.3288E-02	1.1530E-04	9.9979E-02	577.44
0.050	0.0027	0.9973	0.9955	1.0455	6.6558E-02	3.3279E-02	1.2811E-04	9.9965E-02	519.55
0.055	0.0029	0.9971	0.9953	1.0503	6.6540E-02	3.3270E-02	1.4092E-04	9.9951E-02	472.20
0.060	0.0032	0.9968	0.9950	1.0550	6.6523E-02	3.3261E-02	1.5373E-04	9.9938E-02	432.73
0.065	0.0035	0.9965	0.9948	1.0598	6.6505E-02	3.3252E-02	1.6654E-04	9.9924E-02	399.34
0.070	0.0037	0.9963	0.9945	1.0645	6.6487E-02	3.3244E-02	1.7935E-04	9.9910E-02	370.72
0.075	0.0040	0.9960	0.9942	1.0692	6.6469E-02	3.3235E-02	1.9216E-04	9.9896E-02	345.91
0.080	0.0043	0.9957	0.9940	1.0740	6.6452E-02	3.3226E-02	2.0497E-04	9.9882E-02	324.20
0.085	0.0045	0.9955	0.9937	1.0787	6.6434E-02	3.3217E-02	2.1778E-04	9.9869E-02	305.05
0.090	0.0048	0.9952	0.9934	1.0834	6.6416E-02	3.3208E-02	2.3059E-04	9.9855E-02	288.03
0.094	0.0050	0.9950	0.9932	1.0872	6.6402E-02	3.3201E-02	2.4084E-04	9.9844E-02	275.71
0.095	0.0051	0.9949	0.9932	1.0882	6.6398E-02	3.3199E-02	2.4340E-04	9.9841E-02	272.79
0.100	0.0053	0.9947	0.9929	1.0929	6.6381E-02	3.3190E-02	2.5621E-04	9.9827E-02	259.09
0.110	0.0058	0.9942	0.9924	1.1024	6.6345E-02	3.3173E-02	2.8183E-04	9.9800E-02	235.41
0.120	0.0064	0.9936	0.9918	1.1118	6.6310E-02	3.3155E-02	3.0745E-04	9.9772E-02	215.67

Table 6.3-4. U-Metal-Water Mixture Data

Uranium Density (g/cm^3) (Specified)	Uranium Volume Fraction (Eq. 6.3.4)	Water Volume Fraction (Eq. 6.3.5)	Water Density (g/cm^3) (Eq. 6.3.6)	Mixture Density (g/cm^3) (Eq. 6.3.7)	Hydrogen Density (atom/b-cm) (Eq. 6.3.8)	Oxygen Density (atom/b-cm) (Eq. 6.3.8)	^{235}U Density (atom/b-cm) (Eq. 6.3.8)	Total Density (atom/b-cm) (Eq. 6.3.9)	H/U ratio (Eq. 6.3.10)
0.130	0.0069	0.9931	0.9913	1.1213	6.6274E-02	3.3137E-02	3.3308E-04	9.9744E-02	198.98
0.140	0.0074	0.9926	0.9908	1.1308	6.6239E-02	3.3119E-02	3.5870E-04	9.9717E-02	184.67
0.150	0.0080	0.9920	0.9902	1.1402	6.6203E-02	3.3102E-02	3.8432E-04	9.9689E-02	172.26
0.160	0.0085	0.9915	0.9897	1.1497	6.6168E-02	3.3084E-02	4.0994E-04	9.9662E-02	161.41
0.170	0.0090	0.9910	0.9892	1.1592	6.6132E-02	3.3066E-02	4.3556E-04	9.9634E-02	151.83
0.180	0.0096	0.9904	0.9886	1.1686	6.6097E-02	3.3048E-02	4.6118E-04	9.9606E-02	143.32
0.190	0.0101	0.9899	0.9881	1.1781	6.6061E-02	3.3031E-02	4.8680E-04	9.9579E-02	135.70
0.200	0.0106	0.9894	0.9876	1.1876	6.6026E-02	3.3013E-02	5.1242E-04	9.9551E-02	128.85
0.250	0.0133	0.9867	0.9849	1.2349	6.5848E-02	3.2924E-02	6.4053E-04	9.9413E-02	102.80
0.300	0.0159	0.9841	0.9823	1.2823	6.5671E-02	3.2836E-02	7.6864E-04	9.9275E-02	85.439
0.350	0.0186	0.9814	0.9796	1.3296	6.5494E-02	3.2747E-02	8.9674E-04	9.9137E-02	73.035
0.400	0.0213	0.9787	0.9770	1.3770	6.5316E-02	3.2658E-02	1.0248E-03	9.8999E-02	63.733
0.450	0.0239	0.9761	0.9743	1.4243	6.5139E-02	3.2569E-02	1.1530E-03	9.8861E-02	56.497
0.500	0.0266	0.9734	0.9717	1.4717	6.4961E-02	3.2481E-02	1.2811E-03	9.8723E-02	50.709
0.550	0.0292	0.9708	0.9690	1.5190	6.4784E-02	3.2392E-02	1.4092E-03	9.8585E-02	45.973
0.600	0.0319	0.9681	0.9664	1.5664	6.4607E-02	3.2303E-02	1.5373E-03	9.8447E-02	42.027
0.650	0.0346	0.9654	0.9637	1.6137	6.4429E-02	3.2215E-02	1.6654E-03	9.8309E-02	38.688
0.700	0.0372	0.9628	0.9611	1.6611	6.4252E-02	3.2126E-02	1.7935E-03	9.8171E-02	35.825
0.750	0.0399	0.9601	0.9584	1.7084	6.4075E-02	3.2037E-02	1.9216E-03	9.8033E-02	33.345
0.800	0.0425	0.9575	0.9557	1.7557	6.3897E-02	3.1949E-02	2.0497E-03	9.7895E-02	31.174
0.850	0.0452	0.9548	0.9531	1.8031	6.3720E-02	3.1860E-02	2.1778E-03	9.7757E-02	29.259
0.900	0.0478	0.9522	0.9504	1.8504	6.3542E-02	3.1771E-02	2.3059E-03	9.7619E-02	27.556
0.950	0.0505	0.9495	0.9478	1.8978	6.3365E-02	3.1682E-02	2.4340E-03	9.7481E-02	26.033
1.000	0.0532	0.9468	0.9451	1.9451	6.3188E-02	3.1594E-02	2.5621E-03	9.7343E-02	24.662

Table 6.3-4. U-Metal-Water Mixture Data

Uranium Density (g/cm^3) (Specified)	Uranium Volume Fraction (Eq. 6.3.4)	Water Volume Fraction (Eq. 6.3.5)	Water Density (g/cm^3) (Eq. 6.3.6)	Mixture Density (g/cm^3) (Eq. 6.3.7)	Hydrogen Density (atom/b-cm) (Eq. 6.3.8)	Oxygen Density (atom/b-cm) (Eq. 6.3.8)	^{235}U Density (atom/b-cm) (Eq. 6.3.8)	Total Density (atom/b-cm) (Eq. 6.3.9)	H/U ratio (Eq. 6.3.10)
1.100	0.0585	0.9415	0.9398	2.0398	6.2833E-02	3.1416E-02	2.8183E-03	9.7067E-02	22.294
1.200	0.0638	0.9362	0.9345	2.1345	6.2478E-02	3.1239E-02	3.0745E-03	9.6792E-02	20.321
1.300	0.0691	0.9309	0.9292	2.2292	6.2123E-02	3.1062E-02	3.3308E-03	9.6516E-02	18.651
1.400	0.0744	0.9256	0.9239	2.3239	6.1768E-02	3.0884E-02	3.5870E-03	9.6240E-02	17.220
1.500	0.0797	0.9203	0.9186	2.4186	6.1414E-02	3.0707E-02	3.8432E-03	9.5964E-02	15.980
1.600	0.0851	0.9149	0.9133	2.5133	6.1059E-02	3.0529E-02	4.0994E-03	9.5688E-02	14.895
1.700	0.0904	0.9096	0.9080	2.6080	6.0704E-02	3.0352E-02	4.3556E-03	9.5412E-02	13.937
1.800	0.0957	0.9043	0.9027	2.7027	6.0349E-02	3.0175E-02	4.6118E-03	9.5136E-02	13.086
1.881	0.1000	0.9000	0.8984	2.7794	6.0062E-02	3.0031E-02	4.8193E-03	9.4912E-02	12.463
1.900	0.1010	0.8990	0.8974	2.7974	5.9994E-02	2.9997E-02	4.8680E-03	9.4860E-02	12.324
2.000	0.1063	0.8937	0.8921	2.8921	5.9640E-02	2.9820E-02	5.1242E-03	9.4584E-02	11.639
2.200	0.1170	0.8830	0.8815	3.0815	5.8930E-02	2.9465E-02	5.6367E-03	9.4032E-02	10.455
2.400	0.1276	0.8724	0.8708	3.2708	5.8221E-02	2.9110E-02	6.1491E-03	9.3480E-02	9.4682
2.600	0.1382	0.8618	0.8602	3.4602	5.7511E-02	2.8755E-02	6.6615E-03	9.2928E-02	8.6333
2.800	0.1489	0.8511	0.8496	3.6496	5.6801E-02	2.8401E-02	7.1739E-03	9.2376E-02	7.9178
2.822	0.1500	0.8500	0.8484	3.6704	5.6723E-02	2.8362E-02	7.2303E-03	9.2315E-02	7.8452
3.000	0.1595	0.8405	0.8390	3.8390	5.6092E-02	2.8046E-02	7.6864E-03	9.1824E-02	7.2976
3.200	0.1701	0.8299	0.8284	4.0284	5.5382E-02	2.7691E-02	8.1988E-03	9.1272E-02	6.7549
3.400	0.1808	0.8192	0.8178	4.2178	5.4673E-02	2.7336E-02	8.7112E-03	9.0720E-02	6.2761
3.600	0.1914	0.8086	0.8072	4.4072	5.3963E-02	2.6982E-02	9.2236E-03	9.0168E-02	5.8505
3.762	0.2000	0.8000	0.7986	4.5606	5.3388E-02	2.6694E-02	9.6387E-03	8.9721E-02	5.5390
3.800	0.2020	0.7980	0.7965	4.5965	5.3254E-02	2.6627E-02	9.7360E-03	8.9616E-02	5.4697
4.000	0.2127	0.7873	0.7859	4.7859	5.2544E-02	2.6272E-02	1.0248E-02	8.9064E-02	5.1270
4.200	0.2233	0.7767	0.7753	4.9753	5.1834E-02	2.5917E-02	1.0761E-02	8.8512E-02	4.8169
4.400	0.2339	0.7661	0.7647	5.1647	5.1125E-02	2.5562E-02	1.1273E-02	8.7961E-02	4.5350

Table 6.3-4. U-Metal-Water Mixture Data

Uranium Density (g/cm^3) (Specified)	Uranium Volume Fraction (Eq. 6.3.4)	Water Volume Fraction (Eq. 6.3.5)	Water Density (g/cm^3) (Eq. 6.3.6)	Mixture Density (g/cm^3) (Eq. 6.3.7)	Hydrogen Density (atom/b-cm) (Eq. 6.3.8)	Oxygen Density (atom/b-cm) (Eq. 6.3.8)	^{235}U Density (atom/b-cm) (Eq. 6.3.8)	Total Density (atom/b-cm) (Eq. 6.3.9)	H/U ratio (Eq. 6.3.10)
4.600	0.2446	0.7554	0.7541	5.3541	5.0415E-02	2.5208E-02	1.1786E-02	8.7409E-02	4.2776
4.703	0.2500	0.7500	0.7486	5.4516	5.0050E-02	2.5025E-02	1.2050E-02	8.7124E-02	4.1536
4.800	0.2552	0.7448	0.7435	5.5435	4.9706E-02	2.4853E-02	1.2298E-02	8.6857E-02	4.0417
5.000	0.2658	0.7342	0.7329	5.7329	4.8996E-02	2.4498E-02	1.2811E-02	8.6305E-02	3.8247
5.200	0.2764	0.7236	0.7222	5.9222	4.8287E-02	2.4143E-02	1.3323E-02	8.5753E-02	3.6243
5.400	0.2871	0.7129	0.7116	6.1116	4.7577E-02	2.3788E-02	1.3835E-02	8.5201E-02	3.4388
5.600	0.2977	0.7023	0.7010	6.3010	4.6867E-02	2.3434E-02	1.4348E-02	8.4649E-02	3.2665
5.643	0.3000	0.7000	0.6987	6.3417	4.6715E-02	2.3357E-02	1.4458E-02	8.4530E-02	3.2311
5.800	0.3083	0.6917	0.6904	6.4904	4.6158E-02	2.3079E-02	1.4860E-02	8.4097E-02	3.1061
6.000	0.3190	0.6810	0.6798	6.6798	4.5448E-02	2.2724E-02	1.5373E-02	8.3545E-02	2.9564
6.200	0.3296	0.6704	0.6692	6.8692	4.4739E-02	2.2369E-02	1.5885E-02	8.2993E-02	2.8164
6.400	0.3402	0.6598	0.6586	7.0586	4.4029E-02	2.2015E-02	1.6398E-02	8.2441E-02	2.6851
6.584	0.3500	0.6500	0.6488	7.2328	4.3376E-02	2.1688E-02	1.6869E-02	8.1933E-02	2.5714
6.600	0.3509	0.6491	0.6480	7.2480	4.3319E-02	2.1660E-02	1.6910E-02	8.1889E-02	2.5618
6.800	0.3615	0.6385	0.6373	7.4373	4.2610E-02	2.1305E-02	1.7422E-02	8.1337E-02	2.4457
7.000	0.3721	0.6279	0.6267	7.6267	4.1900E-02	2.0950E-02	1.7935E-02	8.0785E-02	2.3363
7.200	0.3828	0.6172	0.6161	7.8161	4.1191E-02	2.0595E-02	1.8447E-02	8.0233E-02	2.2329
7.400	0.3934	0.6066	0.6055	8.0055	4.0481E-02	2.0241E-02	1.8960E-02	7.9681E-02	2.1351
7.524	0.4000	0.6000	0.5989	8.1229	4.0041E-02	2.0021E-02	1.9277E-02	7.9339E-02	2.0771
7.600	0.4040	0.5960	0.5949	8.1949	3.9772E-02	1.9886E-02	1.9472E-02	7.9130E-02	2.0425
7.800	0.4147	0.5853	0.5843	8.3843	3.9062E-02	1.9531E-02	1.9985E-02	7.8578E-02	1.9546
8.000	0.4253	0.5747	0.5737	8.5737	3.8352E-02	1.9176E-02	2.0497E-02	7.8026E-02	1.8711
8.200	0.4359	0.5641	0.5630	8.7630	3.7643E-02	1.8821E-02	2.1009E-02	7.7474E-02	1.7917
8.400	0.4466	0.5534	0.5524	8.9524	3.6933E-02	1.8467E-02	2.1522E-02	7.6922E-02	1.7161
8.464	0.4500	0.5500	0.5490	9.0130	3.6706E-02	1.8353E-02	2.1686E-02	7.6745E-02	1.6926

Table 6.3-4. U-Metal-Water Mixture Data

Uranium Density (g/cm^3) (Specified)	Uranium Volume Fraction (Eq. 6.3.4)	Water Volume Fraction (Eq. 6.3.5)	Water Density (g/cm^3) (Eq. 6.3.6)	Mixture Density (g/cm^3) (Eq. 6.3.7)	Hydrogen Density (atom/b-cm) (Eq. 6.3.8)	Oxygen Density (atom/b-cm) (Eq. 6.3.8)	^{235}U Density (atom/b-cm) (Eq. 6.3.8)	Total Density (atom/b-cm) (Eq. 6.3.9)	H/U ratio (Eq. 6.3.10)
8.600	0.4572	0.5428	0.5418	9.1418	3.6224E-02	1.8112E-02	2.2034E-02	7.6370E-02	1.6440
8.800	0.4678	0.5322	0.5312	9.3312	3.5514E-02	1.7757E-02	2.2547E-02	7.5818E-02	1.5751
9.000	0.4785	0.5215	0.5206	9.5206	3.4805E-02	1.7402E-02	2.3059E-02	7.5266E-02	1.5094
9.200	0.4891	0.5109	0.5100	9.7100	3.4095E-02	1.7048E-02	2.3571E-02	7.4714E-02	1.4465
9.400	0.4997	0.5003	0.4994	9.8994	3.3385E-02	1.6693E-02	2.4084E-02	7.4162E-02	1.3862
9.405	0.5000	0.5000	0.4991	9.9041	3.3368E-02	1.6684E-02	2.4097E-02	7.4148E-02	1.3847
9.600	0.5104	0.4896	0.4888	10.0888	3.2676E-02	1.6338E-02	2.4596E-02	7.3610E-02	1.3285
9.800	0.5210	0.4790	0.4781	10.2781	3.1966E-02	1.5983E-02	2.5109E-02	7.3058E-02	1.2731
10.000	0.5316	0.4684	0.4675	10.4675	3.1257E-02	1.5628E-02	2.5621E-02	7.2506E-02	1.2200
10.200	0.5423	0.4577	0.4569	10.6569	3.0547E-02	1.5274E-02	2.6134E-02	7.1954E-02	1.1689
10.345	0.5500	0.4500	0.4492	10.7942	3.0033E-02	1.5016E-02	2.6505E-02	7.1554E-02	1.1331
10.400	0.5529	0.4471	0.4463	10.8463	2.9838E-02	1.4919E-02	2.6646E-02	7.1402E-02	1.1198
10.600	0.5635	0.4365	0.4357	11.0357	2.9128E-02	1.4564E-02	2.7158E-02	7.0850E-02	1.0725
10.800	0.5742	0.4258	0.4251	11.2251	2.8418E-02	1.4209E-02	2.7671E-02	7.0299E-02	1.0270
11.000	0.5848	0.4152	0.4145	11.4145	2.7709E-02	1.3854E-02	2.8183E-02	6.9747E-02	0.9832
11.200	0.5954	0.4046	0.4038	11.6038	2.6999E-02	1.3500E-02	2.8696E-02	6.9195E-02	0.9409
11.286	0.6000	0.4000	0.3993	11.6853	2.6694E-02	1.3347E-02	2.8916E-02	6.8957E-02	0.9232
11.400	0.6061	0.3939	0.3932	11.7932	2.6290E-02	1.3145E-02	2.9208E-02	6.8643E-02	0.9001
11.600	0.6167	0.3833	0.3826	11.9826	2.5580E-02	1.2790E-02	2.9721E-02	6.8091E-02	0.8607
11.800	0.6273	0.3727	0.3720	12.1720	2.4871E-02	1.2435E-02	3.0233E-02	6.7539E-02	0.8226
12.000	0.6380	0.3620	0.3614	12.3614	2.4161E-02	1.2080E-02	3.0745E-02	6.6987E-02	0.7858
12.200	0.6486	0.3514	0.3508	12.5508	2.3451E-02	1.1726E-02	3.1258E-02	6.6435E-02	0.7503
12.226	0.6500	0.3500	0.3494	12.5754	2.3359E-02	1.1680E-02	3.1324E-02	6.6363E-02	0.7457
12.400	0.6592	0.3408	0.3402	12.7402	2.2742E-02	1.1371E-02	3.1770E-02	6.5883E-02	0.7158
12.600	0.6699	0.3301	0.3295	12.9295	2.2032E-02	1.1016E-02	3.2283E-02	6.5331E-02	0.6825

Table 6.3-4. U-Metal-Water Mixture Data

Uranium Density (g/cm^3) (Specified)	Uranium Volume Fraction (Eq. 6.3.4)	Water Volume Fraction (Eq. 6.3.5)	Water Density (g/cm^3) (Eq. 6.3.6)	Mixture Density (g/cm^3) (Eq. 6.3.7)	Hydrogen Density (atom/b-cm) (Eq. 6.3.8)	Oxygen Density (atom/b-cm) (Eq. 6.3.8)	^{235}U Density (atom/b-cm) (Eq. 6.3.8)	Total Density (atom/b-cm) (Eq. 6.3.9)	H/U ratio (Eq. 6.3.10)
12.800	0.6805	0.3195	0.3189	13.1189	2.1323E-02	1.0661E-02	3.2795E-02	6.4779E-02	0.6502
13.000	0.6911	0.3089	0.3083	13.3083	2.0613E-02	1.0307E-02	3.3308E-02	6.4227E-02	0.6189
13.167	0.7000	0.3000	0.2995	13.4665	2.0021E-02	1.0010E-02	3.3735E-02	6.3766E-02	0.5935
13.200	0.7018	0.2982	0.2977	13.4977	1.9904E-02	9.9518E-03	3.3820E-02	6.3675E-02	0.5885
13.400	0.7124	0.2876	0.2871	13.6871	1.9194E-02	9.5970E-03	3.4332E-02	6.3123E-02	0.5591
13.600	0.7230	0.2770	0.2765	13.8765	1.8484E-02	9.2422E-03	3.4845E-02	6.2571E-02	0.5305
13.800	0.7337	0.2663	0.2659	14.0659	1.7775E-02	8.8874E-03	3.5357E-02	6.2019E-02	0.5027
14.000	0.7443	0.2557	0.2553	14.2553	1.7065E-02	8.5326E-03	3.5870E-02	6.1468E-02	0.4758
14.108	0.7500	0.2500	0.2495	14.3575	1.6682E-02	8.3410E-03	3.6146E-02	6.1169E-02	0.4615
14.200	0.7549	0.2451	0.2446	14.4446	1.6356E-02	8.1778E-03	3.6382E-02	6.0916E-02	0.4496
14.400	0.7656	0.2344	0.2340	14.6340	1.5646E-02	7.8231E-03	3.6894E-02	6.0364E-02	0.4241
14.600	0.7762	0.2238	0.2234	14.8234	1.4937E-02	7.4683E-03	3.7407E-02	5.9812E-02	0.3993
14.800	0.7868	0.2132	0.2128	15.0128	1.4227E-02	7.1135E-03	3.7919E-02	5.9260E-02	0.3752
15.000	0.7974	0.2026	0.2022	15.2022	1.3517E-02	6.7587E-03	3.8432E-02	5.8708E-02	0.3517
15.048	0.8000	0.2000	0.1996	15.2476	1.3347E-02	6.6735E-03	3.8555E-02	5.8575E-02	0.3462
15.200	0.8081	0.1919	0.1916	15.3916	1.2808E-02	6.4039E-03	3.8944E-02	5.8156E-02	0.3289
15.400	0.8187	0.1813	0.1810	15.5810	1.2098E-02	6.0491E-03	3.9457E-02	5.7604E-02	0.3066
15.600	0.8293	0.1707	0.1703	15.7703	1.1389E-02	5.6943E-03	3.9969E-02	5.7052E-02	0.2849
15.800	0.8400	0.1600	0.1597	15.9597	1.0679E-02	5.3395E-03	4.0481E-02	5.6500E-02	0.2638
15.989	0.8500	0.1500	0.1497	16.1387	1.0009E-02	5.0043E-03	4.0966E-02	5.5979E-02	0.2443
16.000	0.8506	0.1494	0.1491	16.1491	9.9695E-03	4.9848E-03	4.0994E-02	5.5948E-02	0.2432
16.200	0.8612	0.1388	0.1385	16.3385	9.2599E-03	4.6300E-03	4.1506E-02	5.5396E-02	0.2231
16.400	0.8719	0.1281	0.1279	16.5279	8.5504E-03	4.2752E-03	4.2019E-02	5.4844E-02	0.2035
16.600	0.8825	0.1175	0.1173	16.7173	7.8408E-03	3.9204E-03	4.2531E-02	5.4292E-02	0.1844
16.800	0.8931	0.1069	0.1067	16.9067	7.1312E-03	3.5656E-03	4.3044E-02	5.3740E-02	0.1657

Table 6.3-4. U-Metal-Water Mixture Data

Uranium Density (g/cm^3) (Specified)	Uranium Volume Fraction (Eq. 6.3.4)	Water Volume Fraction (Eq. 6.3.5)	Water Density (g/cm^3) (Eq. 6.3.6)	Mixture Density (g/cm^3) (Eq. 6.3.7)	Hydrogen Density (atom/b-cm) (Eq. 6.3.8)	Oxygen Density (atom/b-cm) (Eq. 6.3.8)	^{235}U Density (atom/b-cm) (Eq. 6.3.8)	Total Density (atom/b-cm) (Eq. 6.3.9)	H/U ratio (Eq. 6.3.10)
16.929	0.9000	0.1000	0.0998	17.0288	6.6735E-03	3.3368E-03	4.3374E-02	5.3384E-02	0.1539
17.000	0.9038	0.0962	0.0961	17.0961	6.4216E-03	3.2108E-03	4.3556E-02	5.3188E-02	0.1474
17.200	0.9144	0.0856	0.0854	17.2854	5.7121E-03	2.8560E-03	4.4068E-02	5.2637E-02	0.1296
17.400	0.9250	0.0750	0.0748	17.4748	5.0025E-03	2.5012E-03	4.4581E-02	5.2085E-02	0.1122
17.600	0.9357	0.0643	0.0642	17.6642	4.2929E-03	2.1465E-03	4.5093E-02	5.1533E-02	0.0952
17.800	0.9463	0.0537	0.0536	17.8536	3.5833E-03	1.7917E-03	4.5606E-02	5.0981E-02	0.0786
17.869	0.9500	0.0500	0.0499	17.9189	3.3385E-03	1.6693E-03	4.5782E-02	5.0790E-02	0.0729
18.000	0.9569	0.0431	0.0430	18.0430	2.8738E-03	1.4369E-03	4.6118E-02	5.0429E-02	0.0623
18.200	0.9676	0.0324	0.0324	18.2324	2.1642E-03	1.0821E-03	4.6631E-02	4.9877E-02	0.0464
18.400	0.9782	0.0218	0.0218	18.4218	1.4546E-03	7.2731E-04	4.7143E-02	4.9325E-02	0.0309
18.600	0.9888	0.0112	0.0111	18.6111	7.4505E-04	3.7253E-04	4.7655E-02	4.8773E-02	0.0156
18.800	0.9995	0.0005	0.0005	18.8005	3.5479E-05	1.7739E-05	4.8168E-02	4.8221E-02	0.0007
18.810	1.0000	0.0000	0.0000	18.8100	0.0000E+00	0.0000E+00	4.8193E-02	4.8193E-02	0.0000

Table 6.3-5. UO_2-Water Mixture Data

UO_2 Density (g/cm^3) (Specified)	Uranium Density (g/cm^3) (Eq. 6.3.3)	UO_2 Volume Fraction (Eq. 6.3.4)	Water Volume Fraction (Eq. 6.3.5)	Water Density (g/cm^3) (Eq. 6.3.6)	Mixture Density (g/cm^3) (Eq. 6.3.7)	Hydrogen Density (atom/b-cm) (Eq. 6.3.8)	Oxygen Density (atom/b-cm) (Eq. 6.3.8)	^{235}U Density (atom/b-cm) (Eq. 6.3.8)	Total Density (atom/b-cm) (Eq. 6.3.9)	H/U ratio (Eq. 6.3.10)
0.000	0.0000	0.0000	1.0000	0.9982	0.9982	6.6735E-02	3.3368E-02	0.0000E+00	1.0010E-01	∞
0.010	0.0088	0.0009	0.9991	0.9973	1.0073	6.6674E-02	3.3382E-02	2.2551E-05	1.0008E-01	2956.6
0.020	0.0176	0.0018	0.9982	0.9964	1.0164	6.6612E-02	3.3396E-02	4.5102E-05	1.0005E-01	1476.9
0.030	0.0264	0.0028	0.9972	0.9954	1.0254	6.6551E-02	3.3411E-02	6.7653E-05	1.0003E-01	983.71
0.040	0.0352	0.0037	0.9963	0.9945	1.0345	6.6489E-02	3.3425E-02	9.0204E-05	1.0000E-01	737.10
0.050	0.0440	0.0046	0.9954	0.9936	1.0436	6.6428E-02	3.3439E-02	1.1276E-04	9.9980E-02	589.13

Table 6.3-5. UO_2-Water Mixture Data

UO_2 Density (g/cm^3) (Specified)	Uranium Density (g/cm^3) (Eq. 6.3.3)	UO_2 Volume Fraction (Eq. 6.3.4)	Water Volume Fraction (Eq. 6.3.5)	Water Density (g/cm^3) (Eq. 6.3.6)	Mixture Density (g/cm^3) (Eq. 6.3.7)	Hydrogen Density (atom/b-cm) (Eq. 6.3.8)	Oxygen Density (atom/b-cm) (Eq. 6.3.8)	^{235}U Density (atom/b-cm) (Eq. 6.3.8)	Total Density (atom/b-cm) (Eq. 6.3.9)	H/U ratio (Eq. 6.3.10)
0.060	0.0528	0.0055	0.9945	0.9927	1.0527	6.6366E-02	3.3454E-02	1.3531E-04	9.9955E-02	490.49
0.070	0.0616	0.0065	0.9935	0.9918	1.0618	6.6305E-02	3.3468E-02	1.5786E-04	9.9931E-02	420.03
0.080	0.0704	0.0074	0.9926	0.9908	1.0708	6.6243E-02	3.3483E-02	1.8041E-04	9.9906E-02	367.19
0.090	0.0792	0.0083	0.9917	0.9899	1.0799	6.6182E-02	3.3497E-02	2.0296E-04	9.9882E-02	326.08
0.100	0.0880	0.0092	0.9908	0.9890	1.0890	6.6120E-02	3.3511E-02	2.2551E-04	9.9857E-02	293.20
0.200	0.1760	0.0184	0.9816	0.9798	1.1798	6.5505E-02	3.3655E-02	4.5102E-04	9.9611E-02	145.24
0.300	0.2641	0.0276	0.9724	0.9706	1.2706	6.4890E-02	3.3798E-02	6.7653E-04	9.9365E-02	95.916
0.400	0.3521	0.0369	0.9631	0.9614	1.3614	6.4275E-02	3.3942E-02	9.0204E-04	9.9119E-02	71.255
0.500	0.4401	0.0461	0.9539	0.9522	1.4522	6.3660E-02	3.4085E-02	1.1276E-03	9.8873E-02	56.459
0.543	0.4779	0.0500	0.9500	0.9482	1.4912	6.3396E-02	3.4147E-02	1.2245E-03	9.8767E-02	51.772
0.600	0.5281	0.0553	0.9447	0.9430	1.5430	6.3045E-02	3.4229E-02	1.3531E-03	9.8627E-02	46.594
0.700	0.6161	0.0645	0.9355	0.9338	1.6338	6.2430E-02	3.4372E-02	1.5786E-03	9.8381E-02	39.548
0.800	0.7041	0.0737	0.9263	0.9246	1.7246	6.1815E-02	3.4516E-02	1.8041E-03	9.8135E-02	34.264
0.900	0.7922	0.0829	0.9171	0.9154	1.8154	6.1200E-02	3.4659E-02	2.0296E-03	9.7888E-02	30.154
1.000	0.8802	0.0922	0.9078	0.9062	1.9062	6.0585E-02	3.4803E-02	2.2551E-03	9.7642E-02	26.866
1.085	0.9550	0.1000	0.9000	0.8984	1.9834	6.0062E-02	3.4925E-02	2.4468E-03	9.7433E-02	24.547
1.200	1.0562	0.1106	0.8894	0.8878	2.0878	5.9355E-02	3.5090E-02	2.7061E-03	9.7150E-02	21.933
1.400	1.2322	0.1290	0.8710	0.8694	2.2694	5.8124E-02	3.5377E-02	3.1572E-03	9.6658E-02	18.410
1.600	1.4083	0.1475	0.8525	0.8510	2.4510	5.6894E-02	3.5663E-02	3.6082E-03	9.6166E-02	15.768
1.628	1.4329	0.1500	0.8500	0.8484	2.4764	5.6722E-02	3.5704E-02	3.6713E-03	9.6097E-02	15.450
1.800	1.5843	0.1659	0.8341	0.8326	2.6326	5.5664E-02	3.5950E-02	4.0592E-03	9.5674E-02	13.713
2.000	1.7603	0.1843	0.8157	0.8142	2.8142	5.4434E-02	3.6237E-02	4.5102E-03	9.5182E-02	12.069

Table 6.3-5. UO_2-Water Mixture Data

UO_2 Density (g/cm^3) (Specified)	Uranium Density (g/cm^3) (Eq. 6.3.3)	UO_2 Volume Fraction (Eq. 6.3.4)	Water Volume Fraction (Eq. 6.3.5)	Water Density (g/cm^3) (Eq. 6.3.6)	Mixture Density (g/cm^3) (Eq. 6.3.7)	Hydrogen Density (atom/b-cm) (Eq. 6.3.8)	Oxygen Density (atom/b-cm) (Eq. 6.3.8)	^{235}U Density (atom/b-cm) (Eq. 6.3.8)	Total Density (atom/b-cm) (Eq. 6.3.9)	H/U ratio (Eq. 6.3.10)
2.170	1.9100	0.2000	0.8000	0.7986	2.9686	5.3388E-02	3.6481E-02	4.8936E-03	9.4763E-02	10.910
2.200	1.9364	0.2028	0.7972	0.7958	2.9958	5.3204E-02	3.6524E-02	4.9612E-03	9.4689E-02	10.724
2.400	2.1124	0.2212	0.7788	0.7774	3.1774	5.1974E-02	3.6811E-02	5.4123E-03	9.4197E-02	9.6030
2.600	2.2885	0.2396	0.7604	0.7590	3.3590	5.0744E-02	3.7098E-02	5.8633E-03	9.3705E-02	8.6545
2.712	2.3870	0.2500	0.7500	0.7487	3.4607	5.0055E-02	3.7259E-02	6.1159E-03	9.3430E-02	8.1844
2.800	2.4645	0.2581	0.7419	0.7406	3.5406	4.9513E-02	3.7385E-02	6.3143E-03	9.3213E-02	7.8415
3.000	2.6405	0.2765	0.7235	0.7222	3.7222	4.8283E-02	3.7672E-02	6.7653E-03	9.2721E-02	7.1369
3.200	2.8166	0.2949	0.7051	0.7038	3.9038	4.7053E-02	3.7959E-02	7.2163E-03	9.2229E-02	6.5203
3.255	2.8650	0.3000	0.7000	0.6987	3.9537	4.6715E-02	3.8038E-02	7.3404E-03	9.2093E-02	6.3641
3.400	2.9926	0.3134	0.6866	0.6854	4.0854	4.5823E-02	3.8246E-02	7.6674E-03	9.1737E-02	5.9764
3.600	3.1686	0.3318	0.6682	0.6670	4.2670	4.4593E-02	3.8533E-02	8.1184E-03	9.1244E-02	5.4928
3.798	3.3429	0.3500	0.6500	0.6488	4.4468	4.3375E-02	3.8817E-02	8.5649E-03	9.0757E-02	5.0643
3.800	3.3447	0.3502	0.6498	0.6486	4.4486	4.3363E-02	3.8820E-02	8.5694E-03	9.0752E-02	5.0602
4.000	3.5207	0.3687	0.6313	0.6302	4.6302	4.2133E-02	3.9107E-02	9.0204E-03	9.0260E-02	4.6708
4.200	3.6967	0.3871	0.6129	0.6118	4.8118	4.0902E-02	3.9394E-02	9.4715E-03	8.9768E-02	4.3185
4.340	3.8200	0.4000	0.6000	0.5989	4.9389	4.0041E-02	3.9595E-02	9.7872E-03	8.9423E-02	4.0912
4.400	3.8728	0.4055	0.5945	0.5934	4.9934	3.9672E-02	3.9681E-02	9.9225E-03	8.9276E-02	3.9982
4.600	4.0488	0.4240	0.5760	0.5750	5.1750	3.8442E-02	3.9968E-02	1.0373E-02	8.8784E-02	3.7058
4.800	4.2248	0.4424	0.5576	0.5566	5.3566	3.7212E-02	4.0255E-02	1.0825E-02	8.8291E-02	3.4377
4.883	4.2979	0.4500	0.5500	0.5490	5.4320	3.6701E-02	4.0374E-02	1.1012E-02	8.8087E-02	3.3329
5.000	4.4009	0.4608	0.5392	0.5382	5.5382	3.5982E-02	4.0542E-02	1.1276E-02	8.7799E-02	3.1911
5.200	4.5769	0.4793	0.5207	0.5198	5.7198	3.4752E-02	4.0829E-02	1.1727E-02	8.7307E-02	2.9635

Table 6.3-5. UO_2-Water Mixture Data

UO_2 Density (g/cm^3) (Specified)	Uranium Density (g/cm^3) (Eq. 6.3.3)	UO_2 Volume Fraction (Eq. 6.3.4)	Water Volume Fraction (Eq. 6.3.5)	Water Density (g/cm^3) (Eq. 6.3.6)	Mixture Density (g/cm^3) (Eq. 6.3.7)	Hydrogen Density (atom/b-cm) (Eq. 6.3.8)	Oxygen Density (atom/b-cm) (Eq. 6.3.8)	^{235}U Density (atom/b-cm) (Eq. 6.3.8)	Total Density (atom/b-cm) (Eq. 6.3.9)	H/U ratio (Eq. 6.3.10)
5.400	4.7529	0.4977	0.5023	0.5014	5.9014	3.3521E-02	4.1116E-02	1.2178E-02	8.6815E-02	2.7527
5.425	4.7749	0.5000	0.5000	0.4991	5.9241	3.3368E-02	4.1152E-02	1.2234E-02	8.6753E-02	2.7275
5.600	4.9290	0.5161	0.4839	0.4830	6.0830	3.2291E-02	4.1403E-02	1.2629E-02	8.6323E-02	2.5570
5.800	5.1050	0.5346	0.4654	0.4646	6.2646	3.1061E-02	4.1690E-02	1.3080E-02	8.5831E-02	2.3748
5.967	5.2520	0.5500	0.4500	0.4492	6.4162	3.0034E-02	4.1929E-02	1.3456E-02	8.5420E-02	2.2320
6.000	5.2810	0.5530	0.4470	0.4462	6.4462	2.9831E-02	4.1977E-02	1.3531E-02	8.5338E-02	2.2047
6.200	5.4571	0.5714	0.4286	0.4278	6.6278	2.8601E-02	4.2264E-02	1.3982E-02	8.4846E-02	2.0456
6.400	5.6331	0.5899	0.4101	0.4094	6.8094	2.7371E-02	4.2551E-02	1.4433E-02	8.4354E-02	1.8964
6.510	5.7299	0.6000	0.4000	0.3993	6.9093	2.6694E-02	4.2709E-02	1.4681E-02	8.4084E-02	1.8183
6.600	5.8091	0.6083	0.3917	0.3910	6.9910	2.6141E-02	4.2838E-02	1.4884E-02	8.3862E-02	1.7563
6.800	5.9852	0.6267	0.3733	0.3726	7.1726	2.4910E-02	4.3125E-02	1.5335E-02	8.3370E-02	1.6244
7.000	6.1612	0.6452	0.3548	0.3542	7.3542	2.3680E-02	4.3412E-02	1.5786E-02	8.2878E-02	1.5001
7.052	6.2070	0.6500	0.3500	0.3494	7.4014	2.3360E-02	4.3486E-02	1.5903E-02	8.2750E-02	1.4689
7.200	6.3372	0.6636	0.3364	0.3358	7.5358	2.2450E-02	4.3699E-02	1.6237E-02	8.2386E-02	1.3827
7.400	6.5133	0.6820	0.3180	0.3174	7.7174	2.1220E-02	4.3986E-02	1.6688E-02	8.1893E-02	1.2716
7.595	6.6849	0.7000	0.3000	0.2995	7.8945	2.0021E-02	4.4265E-02	1.7128E-02	8.1414E-02	1.1689
7.600	6.6893	0.7005	0.2995	0.2990	7.8990	1.9990E-02	4.4273E-02	1.7139E-02	8.1401E-02	1.1664
7.800	6.8654	0.7189	0.2811	0.2806	8.0806	1.8760E-02	4.4560E-02	1.7590E-02	8.0909E-02	1.0665
8.000	7.0414	0.7373	0.2627	0.2622	8.2622	1.7530E-02	4.4847E-02	1.8041E-02	8.0417E-02	0.9717
8.137	7.1620	0.7500	0.2500	0.2496	8.3866	1.6687E-02	4.5043E-02	1.8350E-02	8.0080E-02	0.9094
8.200	7.2174	0.7558	0.2442	0.2438	8.4438	1.6299E-02	4.5133E-02	1.8492E-02	7.9925E-02	0.8814
8.400	7.3935	0.7742	0.2258	0.2254	8.6254	1.5069E-02	4.5420E-02	1.8943E-02	7.9433E-02	0.7955

Table 6.3-5. UO_2-Water Mixture Data

UO_2 Density (g/cm^3) (Specified)	Uranium Density (g/cm^3) (Eq. 6.3.3)	UO_2 Volume Fraction (Eq. 6.3.4)	Water Volume Fraction (Eq. 6.3.5)	Water Density (g/cm^3) (Eq. 6.3.6)	Mixture Density (g/cm^3) (Eq. 6.3.7)	Hydrogen Density (atom/b-cm) (Eq. 6.3.8)	Oxygen Density (atom/b-cm) (Eq. 6.3.8)	^{235}U Density (atom/b-cm) (Eq. 6.3.8)	Total Density (atom/b-cm) (Eq. 6.3.9)	H/U ratio (Eq. 6.3.10)
8.600	7.5695	0.7926	0.2074	0.2070	8.8070	1.3839E-02	4.5707E-02	1.9394E-02	7.8940E-02	0.7136
8.680	7.6399	0.8000	0.2000	0.1996	8.8796	1.3347E-02	4.5822E-02	1.9574E-02	7.8744E-02	0.6819
8.800	7.7455	0.8111	0.1889	0.1886	8.9886	1.2609E-02	4.5994E-02	1.9845E-02	7.8448E-02	0.6354
9.000	7.9216	0.8295	0.1705	0.1702	9.1702	1.1379E-02	4.6281E-02	2.0296E-02	7.7956E-02	0.5606
9.200	8.0976	0.8479	0.1521	0.1518	9.3518	1.0149E-02	4.6568E-02	2.0747E-02	7.7464E-02	0.4892
9.222	8.1170	0.8500	0.1500	0.1498	9.3718	1.0013E-02	4.6600E-02	2.0797E-02	7.7410E-02	0.4815
9.400	8.2736	0.8664	0.1336	0.1334	9.5334	8.9186E-03	4.6855E-02	2.1198E-02	7.6972E-02	0.4207
9.600	8.4497	0.8848	0.1152	0.1150	9.7150	7.6884E-03	4.7142E-02	2.1649E-02	7.6480E-02	0.3551
9.765	8.5949	0.9000	0.1000	0.0998	9.8648	6.6735E-03	4.7379E-02	2.2021E-02	7.6074E-02	0.3031
9.800	8.6257	0.9032	0.0968	0.0966	9.8966	6.4583E-03	4.7429E-02	2.2100E-02	7.5988E-02	0.2922
10.000	8.8017	0.9217	0.0783	0.0782	10.0782	5.2281E-03	4.7716E-02	2.2551E-02	7.5495E-02	0.2318
10.200	8.9778	0.9401	0.0599	0.0598	10.2598	3.9980E-03	4.8003E-02	2.3002E-02	7.5003E-02	0.1738
10.308	9.0728	0.9500	0.0500	0.0499	10.3579	3.3337E-03	4.8158E-02	2.3246E-02	7.4737E-02	0.1434
10.400	9.1538	0.9585	0.0415	0.0414	10.4414	2.7678E-03	4.8290E-02	2.3453E-02	7.4511E-02	0.1180
10.600	9.3298	0.9770	0.0230	0.0230	10.6230	1.5377E-03	4.8577E-02	2.3904E-02	7.4019E-02	0.0643
10.800	9.5059	0.9954	0.0046	0.0046	10.8046	3.0754E-04	4.8864E-02	2.4355E-02	7.3527E-02	0.0126
10.850	9.5499	1.0000	0.0000	0.0000	10.8500	0.0000E+00	4.8936E-02	2.4468E-02	7.3404E-02	0.0000

Table 6.3-6. UO_3-Water Mixture Data

UO_3 Density (g/cm^3) (Specified)	Uranium Density (g/cm^3) (Eq. 6.3.3)	UO_3 Volume Fraction (Eq. 6.3.4)	Water Volume Fraction (Eq. 6.3.5)	Water Density (g/cm^3) (Eq. 6.3.6)	Mixture Density (g/cm^3) (Eq. 6.3.7)	Hydrogen Density (atom/b-cm) (Eq. 6.3.8)	Oxygen Density (atom/b-cm) (Eq. 6.3.8)	^{235}U Density (atom/b-cm) (Eq. 6.3.8)	Total Density (atom/b-cm) (Eq. 6.3.9)	H/U ratio (Eq. 6.3.10)
0.000	0.0000	0.0000	1.0000	0.9982	0.9982	6.6735E-02	3.3368E-02	0.0000E+00	1.0010E-01	∞
0.010	0.0083	0.0014	0.9986	0.9968	1.0068	6.6643E-02	3.3385E-02	2.1276E-05	1.0005E-01	3132.3
0.020	0.0166	0.0028	0.9972	0.9954	1.0154	6.6551E-02	3.3403E-02	4.2553E-05	9.9996E-02	1564.0
0.030	0.0249	0.0042	0.9958	0.9941	1.0241	6.6458E-02	3.3421E-02	6.3829E-05	9.9943E-02	1041.2
0.040	0.0332	0.0055	0.9945	0.9927	1.0327	6.6366E-02	3.3438E-02	8.5105E-05	9.9889E-02	779.81
0.050	0.0415	0.0069	0.9931	0.9913	1.0413	6.6273E-02	3.3456E-02	1.0638E-04	9.9835E-02	622.98
0.060	0.0498	0.0083	0.9917	0.9899	1.0499	6.6181E-02	3.3473E-02	1.2766E-04	9.9782E-02	518.42
0.070	0.0581	0.0097	0.9903	0.9885	1.0585	6.6088E-02	3.3491E-02	1.4893E-04	9.9728E-02	443.74
0.080	0.0664	0.0111	0.9889	0.9871	1.0671	6.5996E-02	3.3509E-02	1.7021E-04	9.9675E-02	387.73
0.090	0.0747	0.0125	0.9875	0.9858	1.0758	6.5904E-02	3.3526E-02	1.9149E-04	9.9621E-02	344.17
0.100	0.0830	0.0139	0.9861	0.9844	1.0844	6.5811E-02	3.3544E-02	2.1276E-04	9.9568E-02	309.32
0.200	0.1661	0.0277	0.9723	0.9705	1.1705	6.4887E-02	3.3720E-02	4.2553E-04	9.9032E-02	152.49
0.300	0.2491	0.0416	0.9584	0.9567	1.2567	6.3962E-02	3.3896E-02	6.3829E-04	9.8497E-02	100.21
0.361	0.2998	0.0500	0.9500	0.9483	1.3093	6.3399E-02	3.4004E-02	7.6808E-04	9.8170E-02	82.542
0.400	0.3322	0.0554	0.9446	0.9429	1.3429	6.3038E-02	3.4072E-02	8.5105E-04	9.7961E-02	74.071
0.500	0.4152	0.0693	0.9307	0.9291	1.4291	6.2114E-02	3.4248E-02	1.0638E-03	9.7426E-02	58.388
0.600	0.4983	0.0831	0.9169	0.9152	1.5152	6.1190E-02	3.4425E-02	1.2766E-03	9.6891E-02	47.932
0.700	0.5813	0.0970	0.9030	0.9014	1.6014	6.0265E-02	3.4601E-02	1.4893E-03	9.6355E-02	40.464
0.722	0.5996	0.1000	0.9000	0.8984	1.6204	6.0062E-02	3.4639E-02	1.5362E-03	9.6237E-02	39.099
0.800	0.6643	0.1108	0.8892	0.8876	1.6876	5.9341E-02	3.4777E-02	1.7021E-03	9.5820E-02	34.863
0.900	0.7474	0.1247	0.8753	0.8738	1.7738	5.8417E-02	3.4953E-02	1.9149E-03	9.5284E-02	30.507
1.000	0.8304	0.1385	0.8615	0.8599	1.8599	5.7492E-02	3.5129E-02	2.1276E-03	9.4749E-02	27.022

Table 6.3-6. UO_3-Water Mixture Data

UO_3 Density (g/cm^3) (Specified)	Uranium Density (g/cm^3) (Eq. 6.3.3)	UO_3 Volume Fraction (Eq. 6.3.4)	Water Volume Fraction (Eq. 6.3.5)	Water Density (g/cm^3) (Eq. 6.3.6)	Mixture Density (g/cm^3) (Eq. 6.3.7)	Hydrogen Density (atom/b-cm) (Eq. 6.3.8)	Oxygen Density (atom/b-cm) (Eq. 6.3.8)	^{235}U Density (atom/b-cm) (Eq. 6.3.8)	Total Density (atom/b-cm) (Eq. 6.3.9)	H/U ratio (Eq. 6.3.10)
1.083	0.8993	0.1500	0.8500	0.8485	1.9315	5.6725E-02	3.5275E-02	2.3042E-03	9.4305E-02	24.618
1.200	0.9965	0.1662	0.8338	0.8323	2.0323	5.5644E-02	3.5481E-02	2.5532E-03	9.3678E-02	21.794
1.400	1.1626	0.1939	0.8061	0.8046	2.2046	5.3795E-02	3.5834E-02	2.9787E-03	9.2607E-02	18.060
1.444	1.1991	0.2000	0.8000	0.7986	2.2426	5.3388E-02	3.5911E-02	3.0723E-03	9.2372E-02	17.377
1.600	1.3287	0.2216	0.7784	0.7770	2.3770	5.1946E-02	3.6186E-02	3.4042E-03	9.1536E-02	15.259
1.800	1.4948	0.2493	0.7507	0.7493	2.5493	5.0098E-02	3.6538E-02	3.8297E-03	9.0466E-02	13.081
1.805	1.4989	0.2500	0.7500	0.7487	2.5537	5.0052E-02	3.6547E-02	3.8404E-03	9.0439E-02	13.033
2.000	1.6608	0.2770	0.7230	0.7217	2.7217	4.8249E-02	3.6890E-02	4.2553E-03	8.9395E-02	11.339
2.166	1.7987	0.3000	0.7000	0.6987	2.8647	4.6715E-02	3.7183E-02	4.6085E-03	8.8506E-02	10.137
2.200	1.8269	0.3047	0.6953	0.6940	2.8940	4.6401E-02	3.7243E-02	4.6808E-03	8.8324E-02	9.9130
2.400	1.9930	0.3324	0.6676	0.6664	3.0664	4.4552E-02	3.7595E-02	5.1063E-03	8.7253E-02	8.7249
2.527	2.0985	0.3500	0.6500	0.6488	3.1758	4.3378E-02	3.7819E-02	5.3765E-03	8.6573E-02	8.0680
2.600	2.1591	0.3601	0.6399	0.6387	3.2387	4.2703E-02	3.7947E-02	5.5318E-03	8.6182E-02	7.7195
2.800	2.3252	0.3878	0.6122	0.6111	3.4111	4.0855E-02	3.8299E-02	5.9574E-03	8.5111E-02	6.8578
2.888	2.3983	0.4000	0.6000	0.5989	3.4869	4.0041E-02	3.8454E-02	6.1446E-03	8.4640E-02	6.5165
3.000	2.4913	0.4155	0.5845	0.5834	3.5834	3.9006E-02	3.8652E-02	6.3829E-03	8.4041E-02	6.1110
3.200	2.6573	0.4432	0.5568	0.5558	3.7558	3.7157E-02	3.9004E-02	6.8084E-03	8.2970E-02	5.4576
3.249	2.6980	0.4500	0.5500	0.5490	3.7980	3.6704E-02	3.9090E-02	6.9127E-03	8.2707E-02	5.3097
3.400	2.8234	0.4709	0.5291	0.5281	3.9281	3.5309E-02	3.9356E-02	7.2340E-03	8.1899E-02	4.8810
3.600	2.9895	0.4986	0.5014	0.5005	4.1005	3.3460E-02	3.9709E-02	7.6595E-03	8.0828E-02	4.3685
3.610	2.9978	0.5000	0.5000	0.4991	4.1091	3.3368E-02	3.9726E-02	7.6808E-03	8.0775E-02	4.3443
3.800	3.1556	0.5263	0.4737	0.4728	4.2728	3.1612E-02	4.0061E-02	8.0850E-03	7.9757E-02	3.9099

Table 6.3-6. UO_3-Water Mixture Data

UO_3 Density (g/cm^3) (Specified)	Uranium Density (g/cm^3) (Eq. 6.3.3)	UO_3 Volume Fraction (Eq. 6.3.4)	Water Volume Fraction (Eq. 6.3.5)	Water Density (g/cm^3) (Eq. 6.3.6)	Mixture Density (g/cm^3) (Eq. 6.3.7)	Hydrogen Density (atom/b-cm) (Eq. 6.3.8)	Oxygen Density (atom/b-cm) (Eq. 6.3.8)	^{235}U Density (atom/b-cm) (Eq. 6.3.8)	Total Density (atom/b-cm) (Eq. 6.3.9)	H/U ratio (Eq. 6.3.10)
3.971	3.2976	0.5500	0.4500	0.4492	4.4202	3.0031E-02	4.0362E-02	8.4488E-03	7.8842E-02	3.5544
4.000	3.3217	0.5540	0.4460	0.4452	4.4452	2.9763E-02	4.0413E-02	8.5105E-03	7.8686E-02	3.4972
4.200	3.4878	0.5817	0.4183	0.4175	4.6175	2.7914E-02	4.0765E-02	8.9361E-03	7.7616E-02	3.1238
4.332	3.5974	0.6000	0.4000	0.3993	4.7313	2.6694E-02	4.0998E-02	9.2169E-03	7.6909E-02	2.8962
4.400	3.6538	0.6094	0.3906	0.3899	4.7899	2.6066E-02	4.1118E-02	9.3616E-03	7.6545E-02	2.7843
4.600	3.8199	0.6371	0.3629	0.3622	4.9622	2.4217E-02	4.1470E-02	9.7871E-03	7.5474E-02	2.4744
4.693	3.8972	0.6500	0.3500	0.3494	5.0424	2.3357E-02	4.1634E-02	9.9850E-03	7.4976E-02	2.3393
4.800	3.9860	0.6648	0.3352	0.3346	5.1346	2.2368E-02	4.1822E-02	1.0213E-02	7.4403E-02	2.1903
5.000	4.1521	0.6925	0.3075	0.3069	5.3069	2.0520E-02	4.2174E-02	1.0638E-02	7.3332E-02	1.9289
5.054	4.1969	0.7000	0.3000	0.2995	5.3535	2.0021E-02	4.2270E-02	1.0753E-02	7.3043E-02	1.8619
5.200	4.3182	0.7202	0.2798	0.2793	5.4793	1.8671E-02	4.2527E-02	1.1064E-02	7.2261E-02	1.6876
5.400	4.4843	0.7479	0.2521	0.2516	5.6516	1.6823E-02	4.2879E-02	1.1489E-02	7.1191E-02	1.4642
5.415	4.4967	0.7500	0.2500	0.2496	5.6646	1.6684E-02	4.2905E-02	1.1521E-02	7.1110E-02	1.4481
5.600	4.6504	0.7756	0.2244	0.2240	5.8240	1.4974E-02	4.3231E-02	1.1915E-02	7.0120E-02	1.2568
5.776	4.7965	0.8000	0.2000	0.1996	5.9756	1.3347E-02	4.3541E-02	1.2289E-02	6.9177E-02	1.0861
5.800	4.8164	0.8033	0.1967	0.1963	5.9963	1.3125E-02	4.3583E-02	1.2340E-02	6.9049E-02	1.0636
6.000	4.9825	0.8310	0.1690	0.1687	6.1687	1.1277E-02	4.3936E-02	1.2766E-02	6.7978E-02	0.8833
6.137	5.0963	0.8500	0.1500	0.1497	6.2867	1.0010E-02	4.4177E-02	1.3057E-02	6.7245E-02	0.7666
6.200	5.1486	0.8587	0.1413	0.1410	6.3410	9.4280E-03	4.4288E-02	1.3191E-02	6.6907E-02	0.7147
6.400	5.3147	0.8864	0.1136	0.1134	6.5134	7.5794E-03	4.4640E-02	1.3617E-02	6.5836E-02	0.5566
6.498	5.3961	0.9000	0.1000	0.0998	6.5978	6.6735E-03	4.4813E-02	1.3825E-02	6.5312E-02	0.4827
6.600	5.4808	0.9141	0.0859	0.0857	6.6857	5.7307E-03	4.4993E-02	1.4042E-02	6.4766E-02	0.4081

Table 6.3-6. UO_3-Water Mixture Data

UO_3 Density (g/cm^3) (Specified)	Uranium Density (g/cm^3) (Eq. 6.3.3)	UO_3 Volume Fraction (Eq. 6.3.4)	Water Volume Fraction (Eq. 6.3.5)	Water Density (g/cm^3) (Eq. 6.3.6)	Mixture Density (g/cm^3) (Eq. 6.3.7)	Hydrogen Density (atom/b-cm) (Eq. 6.3.8)	Oxygen Density (atom/b-cm) (Eq. 6.3.8)	^{235}U Density (atom/b-cm) (Eq. 6.3.8)	Total Density (atom/b-cm) (Eq. 6.3.9)	H/U ratio (Eq. 6.3.10)
6.800	5.6469	0.9418	0.0582	0.0581	6.8581	3.8821E-03	4.5345E-02	1.4468E-02	6.3695E-02	0.2683
6.859	5.6959	0.9500	0.0500	0.0499	6.9089	3.3368E-03	4.5449E-02	1.4593E-02	6.3379E-02	0.2286
7.000	5.8129	0.9695	0.0305	0.0304	7.0304	2.0335E-03	4.5697E-02	1.4893E-02	6.2624E-02	0.1365
7.200	5.9790	0.9972	0.0028	0.0028	7.2028	1.8486E-04	4.6049E-02	1.5319E-02	6.1553E-02	0.0121
7.220	5.9956	1.0000	0.0000	0.0000	7.2200	0.0000E+00	4.6085E-02	1.5362E-02	6.1446E-02	0.0000

Table 6.3-7. U_3O_8-Water Mixture Data

U_3O_8 Density (g/cm^3) (Specified)	Uranium Density (g/cm^3) (Eq. 6.3.3)	U_3O_8 Volume Fraction (Eq. 6.3.4)	Water Volume Fraction (Eq. 6.3.5)	Water Density (g/cm^3) (Eq. 6.3.6)	Mixture Density (g/cm^3) (Eq. 6.3.7)	Hydrogen Density (atom/b-cm) (Eq. 6.3.8)	Oxygen Density (atom/b-cm) (Eq. 6.3.8)	^{235}U Density (atom/b-cm) (Eq. 6.3.8)	Total Density (atom/b-cm) (Eq. 6.3.9)	H/U Ratio (Eq. 6.3.10)
0.000	0.0000	0.0000	1.0000	0.9982	0.9982	6.6735E-02	3.3368E-02	0.0000E+00	1.0010E-01	∞
0.010	0.0085	0.0012	0.9988	0.9970	1.0070	6.6655E-02	3.3385E-02	2.1685E-05	1.0006E-01	3073.8
0.020	0.0169	0.0024	0.9976	0.9958	1.0158	6.6574E-02	3.3403E-02	4.3370E-05	1.0002E-01	1535.0
0.030	0.0254	0.0036	0.9964	0.9946	1.0246	6.6494E-02	3.3420E-02	6.5055E-05	9.9979E-02	1022.1
0.040	0.0339	0.0048	0.9952	0.9934	1.0334	6.6413E-02	3.3438E-02	8.6740E-05	9.9938E-02	765.66
0.050	0.0423	0.0060	0.9940	0.9922	1.0422	6.6333E-02	3.3456E-02	1.0842E-04	9.9897E-02	611.79
0.060	0.0508	0.0072	0.9928	0.9910	1.0510	6.6252E-02	3.3473E-02	1.3011E-04	9.9856E-02	509.20
0.070	0.0592	0.0084	0.9916	0.9898	1.0598	6.6172E-02	3.3491E-02	1.5179E-04	9.9814E-02	435.93
0.080	0.0677	0.0097	0.9903	0.9886	1.0686	6.6091E-02	3.3508E-02	1.7348E-04	9.9773E-02	380.98
0.090	0.0762	0.0109	0.9891	0.9874	1.0774	6.6011E-02	3.3526E-02	1.9516E-04	9.9732E-02	338.23
0.100	0.0846	0.0121	0.9879	0.9862	1.0862	6.5930E-02	3.3543E-02	2.1685E-04	9.9691E-02	304.04

Table 6.3-7. U_3O_8-Water Mixture Data

U_3O_8 Density (g/cm^3) (Specified)	Uranium Density (g/cm^3) (Eq. 6.3.3)	U_3O_8 Volume Fraction (Eq. 6.3.4)	Water Volume Fraction (Eq. 6.3.5)	Water Density (g/cm^3) (Eq. 6.3.6)	Mixture Density (g/cm^3) (Eq. 6.3.7)	Hydrogen Density (atom/b-cm) (Eq. 6.3.8)	Oxygen Density (atom/b-cm) (Eq. 6.3.8)	^{235}U Density (atom/b-cm) (Eq. 6.3.8)	Total Density (atom/b-cm) (Eq. 6.3.9)	H/U Ratio (Eq. 6.3.10)
0.200	0.1693	0.0241	0.9759	0.9741	1.1741	6.5125E-02	3.3719E-02	4.3370E-04	9.9278E-02	150.16
0.300	0.2539	0.0362	0.9638	0.9621	1.2621	6.4320E-02	3.3895E-02	6.5055E-04	9.8866E-02	98.871
0.400	0.3385	0.0483	0.9517	0.9500	1.3500	6.3515E-02	3.4071E-02	8.6740E-04	9.8454E-02	73.225
0.4145	0.3508	0.0500	0.9500	0.9483	1.3628	6.3399E-02	3.4096E-02	8.9884E-04	9.8394E-02	70.534
0.500	0.4232	0.0603	0.9397	0.9380	1.4380	6.2710E-02	3.4247E-02	1.0842E-03	9.8041E-02	57.838
0.600	0.5078	0.0724	0.9276	0.9260	1.5260	6.1905E-02	3.4422E-02	1.3011E-03	9.7629E-02	47.579
0.700	0.5925	0.0844	0.9156	0.9139	1.6139	6.1100E-02	3.4598E-02	1.5179E-03	9.7216E-02	40.252
0.800	0.6771	0.0965	0.9035	0.9019	1.7019	6.0295E-02	3.4774E-02	1.7348E-03	9.6804E-02	34.756
0.829	0.7016	0.1000	0.9000	0.8984	1.7274	6.0062E-02	3.4825E-02	1.7977E-03	9.6684E-02	33.411
0.900	0.7617	0.1086	0.8914	0.8898	1.7898	5.9490E-02	3.4950E-02	1.9516E-03	9.6392E-02	30.482
1.000	0.8464	0.1206	0.8794	0.8778	1.8778	5.8685E-02	3.5125E-02	2.1685E-03	9.5979E-02	27.063
1.200	1.0156	0.1448	0.8552	0.8537	2.0537	5.7075E-02	3.5477E-02	2.6022E-03	9.5154E-02	21.934
1.2435	1.0525	0.1500	0.8500	0.8485	2.0920	5.6725E-02	3.5553E-02	2.6965E-03	9.4975E-02	21.036
1.400	1.1849	0.1689	0.8311	0.8296	2.2296	5.5465E-02	3.5828E-02	3.0359E-03	9.4330E-02	18.270
1.600	1.3542	0.1930	0.8070	0.8055	2.4055	5.3855E-02	3.6180E-02	3.4696E-03	9.3505E-02	15.522
1.658	1.4033	0.2000	0.8000	0.7986	2.4566	5.3388E-02	3.6282E-02	3.5954E-03	9.3266E-02	14.849
1.800	1.5235	0.2171	0.7829	0.7815	2.5815	5.2245E-02	3.6531E-02	3.9033E-03	9.2680E-02	13.385
2.000	1.6927	0.2413	0.7587	0.7574	2.7574	5.0635E-02	3.6883E-02	4.3370E-03	9.1855E-02	11.675
2.0725	1.7541	0.2500	0.7500	0.7487	2.8212	5.0052E-02	3.7010E-02	4.4942E-03	9.1556E-02	11.137
2.200	1.8620	0.2654	0.7346	0.7333	2.9333	4.9025E-02	3.7234E-02	4.7707E-03	9.1030E-02	10.276
2.400	2.0313	0.2895	0.7105	0.7092	3.1092	4.7415E-02	3.7586E-02	5.2044E-03	9.0205E-02	9.1106
2.487	2.1049	0.3000	0.7000	0.6987	3.1857	4.6715E-02	3.7739E-02	5.3930E-03	8.9847E-02	8.6620
2.600	2.2006	0.3136	0.6864	0.6851	3.2851	4.5805E-02	3.7937E-02	5.6381E-03	8.9381E-02	8.1242

Table 6.3-7. U_3O_8-Water Mixture Data

U_3O_8 Density (g/cm^3) (Specified)	Uranium Density (g/cm^3) (Eq. 6.3.3)	U_3O_8 Volume Fraction (Eq. 6.3.4)	Water Volume Fraction (Eq. 6.3.5)	Water Density (g/cm^3) (Eq. 6.3.6)	Mixture Density (g/cm^3) (Eq. 6.3.7)	Hydrogen Density (atom/b-cm) (Eq. 6.3.8)	Oxygen Density (atom/b-cm) (Eq. 6.3.8)	^{235}U Density (atom/b-cm) (Eq. 6.3.8)	Total Density (atom/b-cm) (Eq. 6.3.9)	H/U Ratio (Eq. 6.3.10)
2.800	2.3698	0.3378	0.6622	0.6611	3.4611	4.4195E-02	3.8289E-02	6.0718E-03	8.8556E-02	7.2788
2.9015	2.4557	0.3500	0.6500	0.6488	3.5503	4.3378E-02	3.8467E-02	6.2919E-03	8.8137E-02	6.8943
3.000	2.5391	0.3619	0.6381	0.6370	3.6370	4.2585E-02	3.8640E-02	6.5055E-03	8.7731E-02	6.5460
3.200	2.7084	0.3860	0.6140	0.6129	3.8129	4.0975E-02	3.8992E-02	6.9392E-03	8.6906E-02	5.9049
3.316	2.8066	0.4000	0.6000	0.5989	3.9149	4.0041E-02	3.9196E-02	7.1907E-03	8.6428E-02	5.5685
3.400	2.8777	0.4101	0.5899	0.5888	3.9888	3.9365E-02	3.9344E-02	7.3729E-03	8.6081E-02	5.3392
3.600	3.0469	0.4343	0.5657	0.5647	4.1647	3.7755E-02	3.9695E-02	7.8066E-03	8.5257E-02	4.8363
3.7305	3.1574	0.4500	0.5500	0.5490	4.2795	3.6704E-02	3.9924E-02	8.0896E-03	8.4718E-02	4.5373
3.800	3.2162	0.4584	0.5416	0.5406	4.3406	3.6145E-02	4.0047E-02	8.2403E-03	8.4432E-02	4.3864
4.000	3.3855	0.4825	0.5175	0.5166	4.5166	3.4535E-02	4.0398E-02	8.6740E-03	8.3607E-02	3.9814
4.145	3.5082	0.5000	0.5000	0.4991	4.6441	3.3368E-02	4.0653E-02	8.9884E-03	8.3009E-02	3.7123
4.200	3.5547	0.5066	0.4934	0.4925	4.6925	3.2925E-02	4.0750E-02	9.1077E-03	8.2782E-02	3.6151
4.400	3.7240	0.5308	0.4692	0.4684	4.8684	3.1315E-02	4.1101E-02	9.5414E-03	8.1957E-02	3.2820
4.5598	3.8593	0.5500	0.4500	0.4492	5.0090	3.0029E-02	4.1382E-02	9.8879E-03	8.1298E-02	3.0369
4.600	3.8933	0.5549	0.4451	0.4443	5.0443	2.9705E-02	4.1453E-02	9.9751E-03	8.1133E-02	2.9779
4.800	4.0626	0.5790	0.4210	0.4202	5.2202	2.8095E-02	4.1804E-02	1.0409E-02	8.0308E-02	2.6992
4.974	4.2098	0.6000	0.4000	0.3993	5.3733	2.6694E-02	4.2110E-02	1.0786E-02	7.9590E-02	2.4749
5.000	4.2318	0.6031	0.3969	0.3961	5.3961	2.6485E-02	4.2156E-02	1.0842E-02	7.9483E-02	2.4427
5.200	4.4011	0.6273	0.3727	0.3721	5.5721	2.4875E-02	4.2507E-02	1.1276E-02	7.8658E-02	2.2060
5.3888	4.5609	0.6500	0.3500	0.3493	5.7381	2.3355E-02	4.2839E-02	1.1686E-02	7.7880E-02	1.9986
5.400	4.5704	0.6514	0.3486	0.3480	5.7480	2.3265E-02	4.2859E-02	1.1710E-02	7.7833E-02	1.9868
5.600	4.7397	0.6755	0.3245	0.3239	5.9239	2.1655E-02	4.3210E-02	1.2144E-02	7.7009E-02	1.7832
5.800	4.9089	0.6996	0.3004	0.2998	6.0998	2.0045E-02	4.3562E-02	1.2577E-02	7.6184E-02	1.5937

Table 6.3-7. U_3O_8-Water Mixture Data

U_3O_8 Density (g/cm^3) (Specified)	Uranium Density (g/cm^3) (Eq. 6.3.3)	U_3O_8 Volume Fraction (Eq. 6.3.4)	Water Volume Fraction (Eq. 6.3.5)	Water Density (g/cm^3) (Eq. 6.3.6)	Mixture Density (g/cm^3) (Eq. 6.3.7)	Hydrogen Density (atom/b-cm) (Eq. 6.3.8)	Oxygen Density (atom/b-cm) (Eq. 6.3.8)	^{235}U Density (atom/b-cm) (Eq. 6.3.8)	Total Density (atom/b-cm) (Eq. 6.3.9)	H/U Ratio (Eq. 6.3.10)
5.803	4.9115	0.7000	0.3000	0.2995	6.1025	2.0021E-02	4.3567E-02	1.2584E-02	7.6171E-02	1.5910
6.000	5.0782	0.7238	0.2762	0.2757	6.2757	1.8435E-02	4.3913E-02	1.3011E-02	7.5359E-02	1.4169
6.200	5.2475	0.7479	0.2521	0.2517	6.4517	1.6825E-02	4.4265E-02	1.3445E-02	7.4534E-02	1.2514
6.2175	5.2623	0.7500	0.2500	0.2496	6.4671	1.6684E-02	4.4296E-02	1.3483E-02	7.4462E-02	1.2374
6.400	5.4168	0.7720	0.2280	0.2276	6.6276	1.5215E-02	4.4616E-02	1.3878E-02	7.3709E-02	1.0963
6.600	5.5860	0.7961	0.2039	0.2035	6.8035	1.3605E-02	4.4968E-02	1.4312E-02	7.2885E-02	0.9506
6.632	5.6131	0.8000	0.2000	0.1996	6.8316	1.3347E-02	4.5024E-02	1.4381E-02	7.2753E-02	0.9281
6.800	5.7553	0.8203	0.1797	0.1794	6.9794	1.1995E-02	4.5319E-02	1.4746E-02	7.2060E-02	0.8134
7.000	5.9246	0.8444	0.1556	0.1553	7.1553	1.0385E-02	4.5671E-02	1.5179E-02	7.1235E-02	0.6841
7.0465	5.9639	0.8500	0.1500	0.1497	7.1962	1.0010E-02	4.5753E-02	1.5280E-02	7.1043E-02	0.6551
7.200	6.0938	0.8685	0.1315	0.1312	7.3312	8.7746E-03	4.6022E-02	1.5613E-02	7.0410E-02	0.5620
7.400	6.2631	0.8926	0.1074	0.1072	7.5072	7.1646E-03	4.6374E-02	1.6047E-02	6.9585E-02	0.4465
7.461	6.3147	0.9000	0.1000	0.0998	7.5608	6.6735E-03	4.6481E-02	1.6179E-02	6.9334E-02	0.4125
7.600	6.4324	0.9168	0.0832	0.0831	7.6831	5.5546E-03	4.6725E-02	1.6481E-02	6.8761E-02	0.3370
7.800	6.6017	0.9409	0.0591	0.0590	7.8590	3.9446E-03	4.7077E-02	1.6914E-02	6.7936E-02	0.2332
7.8755	6.6656	0.9500	0.0500	0.0499	7.9254	3.3368E-03	4.7210E-02	1.7078E-02	6.7624E-02	0.1954
8.000	6.7709	0.9650	0.0350	0.0349	8.0349	2.3345E-03	4.7428E-02	1.7348E-02	6.7111E-02	0.1346
8.200	6.9402	0.9891	0.0109	0.0108	8.2108	7.2451E-04	4.7780E-02	1.7782E-02	6.6286E-02	0.0407
8.290	7.0164	1.0000	0.0000	0.0000	8.2900	0.0000E+00	4.7938E-02	1.7977E-02	6.5915E-02	0.0000

6.3.2 Uranium Solution Guidelines

In systems that use organic solvents to purify uranium solutions, studies must be done to compare the reactivity of uranium-laden organic solvents to optimally moderated uranyl fluoride and uranyl nitrate. Of the two, uranyl fluoride is often the most reactive (i.e. can produce the higher system k_{eff} for a given uranium concentration) and is able to reach higher uranium concentrations. However, currently there is no plan on uranyl fluoride systems being present in UPF. There are many operations at UPF that use uranyl nitrate solutions. For a given operation the most reactive form of uranium solution present is used as the material model for solution in these systems. Uranium concentrations in organic solvents can be based on the maximum concentration of uranyl nitrate in the solvent provided that analysis of distribution coefficients and extraction efficiency supports such a limit. Otherwise, an optimum concentration is determined for uranyl nitrate mixed with the organic solvent.

The SCALE computer code was used to determine solution properties given a specified solution chemistry, uranium density, excess acid molarity, and solution temperature. Once these values are specified, SCALE will calculate total solution density and atom densities for the component elements using a method described in Sect. M7.A of ORNL/TM-2005/39 [Ref. 4.16]. Representative solution compositions for $UO_2(NO_3)_2$ and UO_2F_2 were processed using the Material Information Processor (MIP) in SCALE6.1.1. The Material Information Processor uses the Pitzer method to determine nitrate content, water content and solution density for a given uranium concentration. SCALE6.1.1 along with the Material Information Processor are validated in Ref. 4.55. The codes and computing platforms are maintained under configuration control by the Y-12 NCS organization. The resulting solution and atom densities are presented in Tables 6.3-8 and 6.3-9. These values were determined using the specified uranium concentration in g U/L, an excess acid molarity of 0, and a temperature of 20°C (293K). Using the output data from SCALE, the H/U ratio was calculated using Eq. 6.3.10, and the total atom density was calculated using Eq. 6.3.9.

Table 6.3-8. Uranyl Nitrate Solution Data

Uranium Density (g U/L)	Solution Density (g/cm^3)	H/U ratio	Hydrogen (atom/b-cm)	Oxygen (atom/b-cm)	Nitrogen (atom/b-cm)	^{235}U (atom/b-cm)	Total (atom/b-cm)
5	1.005	5202	6.6641E-02	3.3423E-02	2.5621E-05	1.2811E-05	1.0010E-01
10	1.012	2597	6.6543E-02	3.3476E-02	5.1243E-05	2.5621E-05	1.0010E-01
15	1.019	1729	6.6442E-02	3.3528E-02	7.6864E-05	3.8432E-05	1.0009E-01
20	1.025	1295	6.6340E-02	3.3580E-02	1.0249E-04	5.1243E-05	1.0007E-01
25	1.032	1034	6.6237E-02	3.3631E-02	1.2811E-04	6.4053E-05	1.0006E-01
30	1.039	860.4	6.6133E-02	3.3681E-02	1.5373E-04	7.6864E-05	1.0004E-01
35	1.046	736.3	6.6028E-02	3.3731E-02	1.7935E-04	8.9675E-05	1.0003E-01
40	1.052	643.2	6.5923E-02	3.3781E-02	2.0497E-04	1.0249E-04	1.0001E-01
45	1.059	570.8	6.5817E-02	3.3831E-02	2.3059E-04	1.1530E-04	9.9994E-02
50	1.066	512.9	6.5711E-02	3.3880E-02	2.5621E-04	1.2811E-04	9.9975E-02
55	1.073	465.5	6.5604E-02	3.3929E-02	2.8184E-04	1.4092E-04	9.9956E-02
60	1.079	426.1	6.5497E-02	3.3978E-02	3.0746E-04	1.5373E-04	9.9936E-02
65	1.086	392.6	6.5390E-02	3.4027E-02	3.3308E-04	1.6654E-04	9.9917E-02
70	1.093	364.0	6.5283E-02	3.4076E-02	3.5870E-04	1.7935E-04	9.9897E-02
75	1.099	339.2	6.5175E-02	3.4125E-02	3.8432E-04	1.9216E-04	9.9876E-02

Table 6.3-8. Uranyl Nitrate Solution Data

Uranium Density (g U/L)	Solution Density (g/cm^3)	H/U ratio	Hydrogen (atom/b-cm)	Oxygen (atom/b-cm)	Nitrogen (atom/b-cm)	^{235}U (atom/b-cm)	Total (atom/b-cm)
80	1.106	317.5	6.5068E-02	3.4174E-02	4.0994E-04	2.0497E-04	9.9857E-02
85	1.113	298.3	6.4961E-02	3.4223E-02	4.3556E-04	2.1778E-04	9.9837E-02
90	1.120	281.2	6.4853E-02	3.4271E-02	4.6118E-04	2.3059E-04	9.9816E-02
95	1.126	266.0	6.4746E-02	3.4320E-02	4.8681E-04	2.4340E-04	9.9796E-02
100	1.133	252.3	6.4638E-02	3.4369E-02	5.1243E-04	2.5621E-04	9.9776E-02
110	1.146	228.6	6.4424E-02	3.4467E-02	5.6367E-04	2.8184E-04	9.9737E-02
120	1.160	208.8	6.4210E-02	3.4564E-02	6.1491E-04	3.0746E-04	9.9696E-02
130	1.173	192.1	6.3996E-02	3.4662E-02	6.6616E-04	3.3308E-04	9.9657E-02
140	1.187	177.8	6.3782E-02	3.4761E-02	7.1740E-04	3.5870E-04	9.9619E-02
150	1.200	165.4	6.3569E-02	3.4859E-02	7.6864E-04	3.8432E-04	9.9581E-02
160	1.214	154.6	6.3357E-02	3.4958E-02	8.1988E-04	4.0994E-04	9.9545E-02
170	1.227	145.0	6.3145E-02	3.5057E-02	8.7113E-04	4.3556E-04	9.9509E-02
180	1.241	136.5	6.2933E-02	3.5156E-02	9.2237E-04	4.6118E-04	9.9473E-02
190	1.254	128.8	6.2723E-02	3.5256E-02	9.7361E-04	4.8681E-04	9.9439E-02
200	1.268	122.0	6.2513E-02	3.5356E-02	1.0249E-03	5.1243E-04	9.9406E-02
210	1.281	115.8	6.2303E-02	3.5456E-02	1.0761E-03	5.3805E-04	9.9373E-02
220	1.295	110.2	6.2095E-02	3.5557E-02	1.1273E-03	5.6367E-04	9.9343E-02
230	1.308	105.0	6.1886E-02	3.5657E-02	1.1786E-03	5.8929E-04	9.9311E-02
240	1.322	100.3	6.1679E-02	3.5759E-02	1.2298E-03	6.1491E-04	9.9283E-02
250	1.335	95.97	6.1471E-02	3.5860E-02	1.2811E-03	6.4053E-04	9.9253E-02
260	1.349	91.97	6.1265E-02	3.5962E-02	1.3323E-03	6.6616E-04	9.9225E-02
270	1.362	88.26	6.1059E-02	3.6063E-02	1.3836E-03	6.9178E-04	9.9197E-02
280	1.376	84.82	6.0853E-02	3.6166E-02	1.4348E-03	7.1740E-04	9.9171E-02
290	1.389	81.62	6.0647E-02	3.6268E-02	1.4860E-03	7.4302E-04	9.9144E-02
300	1.403	78.63	6.0442E-02	3.6370E-02	1.5373E-03	7.6864E-04	9.9118E-02
310	1.417	75.84	6.0238E-02	3.6473E-02	1.5885E-03	7.9426E-04	9.9094E-02
320	1.430	73.22	6.0033E-02	3.6576E-02	1.6398E-03	8.1988E-04	9.9069E-02
330	1.444	70.76	5.9829E-02	3.6679E-02	1.6910E-03	8.4550E-04	9.9045E-02
340	1.457	68.45	5.9625E-02	3.6782E-02	1.7423E-03	8.7113E-04	9.9020E-02
350	1.471	66.26	5.9421E-02	3.6885E-02	1.7935E-03	8.9675E-04	9.8996E-02
360	1.484	64.20	5.9217E-02	3.6988E-02	1.8447E-03	9.2237E-04	9.8972E-02
370	1.498	62.25	5.9013E-02	3.7091E-02	1.8960E-03	9.4799E-04	9.8948E-02
380	1.512	60.40	5.8809E-02	3.7194E-02	1.9472E-03	9.7361E-04	9.8924E-02
390	1.525	58.65	5.8605E-02	3.7296E-02	1.9985E-03	9.9923E-04	9.8899E-02
400	1.539	56.98	5.8401E-02	3.7399E-02	2.0497E-03	1.0249E-03	9.8875E-02
410	1.552	55.40	5.8196E-02	3.7502E-02	2.1010E-03	1.0505E-03	9.8849E-02
420	1.566	53.89	5.7991E-02	3.7604E-02	2.1522E-03	1.0761E-03	9.8823E-02
430	1.579	52.45	5.7786E-02	3.7707E-02	2.2034E-03	1.1017E-03	9.8798E-02
440	1.593	51.08	5.7580E-02	3.7809E-02	2.2547E-03	1.1273E-03	9.8771E-02
450	1.607	49.76	5.7373E-02	3.7910E-02	2.3059E-03	1.1530E-03	9.8742E-02

Table 6.3-8. Uranyl Nitrate Solution Data

Uranium Density (g U/L)	Solution Density (g/cm^3)	H/U ratio	Hydrogen (atom/b-cm)	Oxygen (atom/b-cm)	Nitrogen (atom/b-cm)	^{235}U (atom/b-cm)	Total (atom/b-cm)
460	1.620	48.50	5.7166E-02	3.8012E-02	2.3572E-03	1.1786E-03	9.8714E-02
470	1.634	47.30	5.6958E-02	3.8113E-02	2.4084E-03	1.2042E-03	9.8684E-02
480	1.647	46.14	5.6749E-02	3.8213E-02	2.4597E-03	1.2298E-03	9.8651E-02
490	1.661	45.03	5.6539E-02	3.8313E-02	2.5109E-03	1.2555E-03	9.8618E-02
500	1.674	43.97	5.6329E-02	3.8413E-02	2.5621E-03	1.2811E-03	9.8585E-02
510	1.688	42.95	5.6117E-02	3.8512E-02	2.6134E-03	1.3067E-03	9.8549E-02
520	1.701	41.96	5.5903E-02	3.8610E-02	2.6646E-03	1.3323E-03	9.8510E-02
530	1.714	41.01	5.5689E-02	3.8708E-02	2.7159E-03	1.3579E-03	9.8471E-02
540	1.728	40.09	5.5473E-02	3.8805E-02	2.7671E-03	1.3836E-03	9.8429E-02
550	1.741	39.21	5.5255E-02	3.8901E-02	2.8184E-03	1.4092E-03	9.8384E-02
560	1.755	38.36	5.5036E-02	3.8997E-02	2.8696E-03	1.4348E-03	9.8337E-02
570	1.768	37.53	5.4815E-02	3.9091E-02	2.9208E-03	1.4604E-03	9.8287E-02
580	1.781	36.74	5.4591E-02	3.9184E-02	2.9721E-03	1.4860E-03	9.8233E-02
590	1.795	35.96	5.4366E-02	3.9276E-02	3.0233E-03	1.5117E-03	9.8177E-02
593*	1.798	35.74	5.4298E-02	3.9304E-02	3.0387E-03	1.5194E-03	9.8160E-02

*This is the highest U density that will stay in solution per MIP in SCALE6.1.

Table 6.3-9. Uranyl Fluoride Solution Data

Uranium Density (g U/L)	Solution Density (g/cm^3)	H/U ratio	Hydrogen (atom/b-cm)	Oxygen (atom/b-cm)	Fluorine (atom/b-cm)	^{235}U (atom/b-cm)	Total (atom/b-cm)
5	1.004	5205	6.6683E-02	3.3367E-02	2.5621E-05	1.2811E-05	1.0009E-01
10	1.009	2601	6.6633E-02	3.3368E-02	5.1243E-05	2.5621E-05	1.0008E-01
15	1.015	1733	6.6585E-02	3.3369E-02	7.6864E-05	3.8432E-05	1.0007E-01
20	1.021	1298	6.6539E-02	3.3372E-02	1.0249E-04	5.1243E-05	1.0006E-01
25	1.027	1038	6.6496E-02	3.3376E-02	1.2811E-04	6.4053E-05	1.0006E-01
30	1.033	864.6	6.6453E-02	3.3380E-02	1.5373E-04	7.6864E-05	1.0006E-01
35	1.039	740.6	6.6412E-02	3.3386E-02	1.7935E-04	8.9675E-05	1.0007E-01
40	1.044	647.6	6.6373E-02	3.3391E-02	2.0497E-04	1.0249E-04	1.0007E-01
45	1.050	575.3	6.6334E-02	3.3397E-02	2.3059E-04	1.1530E-04	1.0008E-01
50	1.056	517.5	6.6295E-02	3.3404E-02	2.5621E-04	1.2811E-04	1.0008E-01
55	1.062	470.2	6.6258E-02	3.3411E-02	2.8184E-04	1.4092E-04	1.0009E-01
60	1.068	430.8	6.6221E-02	3.3418E-02	3.0746E-04	1.5373E-04	1.0010E-01
65	1.074	397.4	6.6184E-02	3.3425E-02	3.3308E-04	1.6654E-04	1.0011E-01
70	1.080	368.8	6.6148E-02	3.3433E-02	3.5870E-04	1.7935E-04	1.0012E-01
75	1.086	344.0	6.6112E-02	3.3440E-02	3.8432E-04	1.9216E-04	1.0013E-01
80	1.092	322.4	6.6076E-02	3.3448E-02	4.0994E-04	2.0497E-04	1.0014E-01
85	1.098	303.2	6.6041E-02	3.3456E-02	4.3556E-04	2.1778E-04	1.0015E-01
90	1.104	286.2	6.6005E-02	3.3464E-02	4.6118E-04	2.3059E-04	1.0016E-01
95	1.110	271.0	6.5969E-02	3.3472E-02	4.8681E-04	2.4340E-04	1.0017E-01

Table 6.3-9. Uranyl Fluoride Solution Data

Uranium Density (g U/L)	Solution Density (g/cm^3)	H/U ratio	Hydrogen (atom/b-cm)	Oxygen (atom/b-cm)	Fluorine (atom/b-cm)	^{235}U (atom/b-cm)	Total (atom/b-cm)
100	1.116	257.3	6.5934E-02	3.3479E-02	5.1243E-04	2.5621E-04	1.0018E-01
110	1.128	233.7	6.5863E-02	3.3495E-02	5.6367E-04	2.8184E-04	1.0020E-01
120	1.140	214.0	6.5791E-02	3.3510E-02	6.1491E-04	3.0746E-04	1.0022E-01
130	1.151	197.3	6.5719E-02	3.3526E-02	6.6616E-04	3.3308E-04	1.0024E-01
140	1.163	183.0	6.5646E-02	3.3540E-02	7.1740E-04	3.5870E-04	1.0026E-01
150	1.175	170.6	6.5572E-02	3.3555E-02	7.6864E-04	3.8432E-04	1.0028E-01
160	1.187	159.8	6.5498E-02	3.3569E-02	8.1988E-04	4.0994E-04	1.0030E-01
170	1.199	150.2	6.5422E-02	3.3582E-02	8.7113E-04	4.3556E-04	1.0031E-01
180	1.211	141.7	6.5345E-02	3.3595E-02	9.2237E-04	4.6118E-04	1.0032E-01
190	1.223	134.1	6.5268E-02	3.3607E-02	9.7361E-04	4.8681E-04	1.0034E-01
200	1.234	127.2	6.5188E-02	3.3619E-02	1.0249E-03	5.1243E-04	1.0034E-01
210	1.246	121.0	6.5107E-02	3.3630E-02	1.0761E-03	5.3805E-04	1.0035E-01
220	1.258	115.4	6.5025E-02	3.3640E-02	1.1273E-03	5.6367E-04	1.0036E-01
230	1.270	110.2	6.4942E-02	3.3650E-02	1.1786E-03	5.8929E-04	1.0036E-01
240	1.281	105.5	6.4857E-02	3.3658E-02	1.2298E-03	6.1491E-04	1.0036E-01
250	1.293	101.1	6.4771E-02	3.3667E-02	1.2811E-03	6.4053E-04	1.0036E-01
260	1.305	97.10	6.4683E-02	3.3674E-02	1.3323E-03	6.6616E-04	1.0036E-01
270	1.316	93.37	6.4594E-02	3.3681E-02	1.3836E-03	6.9178E-04	1.0035E-01
280	1.328	89.91	6.4504E-02	3.3687E-02	1.4348E-03	7.1740E-04	1.0034E-01
290	1.340	86.69	6.4411E-02	3.3692E-02	1.4860E-03	7.4302E-04	1.0033E-01
300	1.351	83.68	6.4318E-02	3.3696E-02	1.5373E-03	7.6864E-04	1.0032E-01
310	1.363	80.86	6.4223E-02	3.3700E-02	1.5885E-03	7.9426E-04	1.0031E-01
320	1.374	78.21	6.4126E-02	3.3703E-02	1.6398E-03	8.1988E-04	1.0029E-01
330	1.386	75.73	6.4028E-02	3.3705E-02	1.6910E-03	8.4551E-04	1.0027E-01
340	1.397	73.39	6.3928E-02	3.3706E-02	1.7423E-03	8.7113E-04	1.0025E-01
350	1.409	71.17	6.3826E-02	3.3707E-02	1.7935E-03	8.9675E-04	1.0022E-01
360	1.420	69.09	6.3723E-02	3.3706E-02	1.8447E-03	9.2237E-04	1.0020E-01
370	1.432	67.11	6.3619E-02	3.3705E-02	1.8960E-03	9.4799E-04	1.0017E-01
380	1.443	65.23	6.3513E-02	3.3704E-02	1.9472E-03	9.7361E-04	1.0014E-01
390	1.454	63.45	6.3405E-02	3.3701E-02	1.9985E-03	9.9923E-04	1.0010E-01
400	1.466	61.76	6.3295E-02	3.3697E-02	2.0497E-03	1.0249E-03	1.0007E-01
410	1.477	60.15	6.3185E-02	3.3693E-02	2.1010E-03	1.0505E-03	1.0003E-01
420	1.488	58.61	6.3072E-02	3.3688E-02	2.1522E-03	1.0761E-03	9.9988E-02
430	1.500	57.15	6.2958E-02	3.3683E-02	2.2034E-03	1.1017E-03	9.9946E-02
440	1.511	55.75	6.2843E-02	3.3676E-02	2.2547E-03	1.1273E-03	9.9901E-02
450	1.522	54.40	6.2726E-02	3.3669E-02	2.3059E-03	1.1530E-03	9.9854E-02
460	1.533	53.12	6.2607E-02	3.3661E-02	2.3572E-03	1.1786E-03	9.9804E-02
470	1.544	51.89	6.2487E-02	3.3652E-02	2.4084E-03	1.2042E-03	9.9752E-02
480	1.556	50.71	6.2365E-02	3.3642E-02	2.4597E-03	1.2298E-03	9.9697E-02
490	1.567	49.57	6.2241E-02	3.3632E-02	2.5109E-03	1.2555E-03	9.9639E-02

Table 6.3-9. Uranyl Fluoride Solution Data

Uranium Density (g U/L)	Solution Density (g/cm^3)	H/U ratio	Hydrogen (atom/b-cm)	Oxygen (atom/b-cm)	Fluorine (atom/b-cm)	^{235}U (atom/b-cm)	Total (atom/b-cm)
500	1.578	48.49	6.2116E-02	3.3620E-02	2.5621E-03	1.2811E-03	9.9579E-02
510	1.589	47.44	6.1990E-02	3.3608E-02	2.6134E-03	1.3067E-03	9.9518E-02
520	1.600	46.43	6.1862E-02	3.3596E-02	2.6646E-03	1.3323E-03	9.9455E-02
530	1.611	45.46	6.1732E-02	3.3582E-02	2.7159E-03	1.3579E-03	9.9388E-02
540	1.622	44.52	6.1601E-02	3.3568E-02	2.7671E-03	1.3836E-03	9.9320E-02
550	1.633	43.62	6.1468E-02	3.3552E-02	2.8184E-03	1.4092E-03	9.9248E-02
560	1.644	42.75	6.1334E-02	3.3536E-02	2.8696E-03	1.4348E-03	9.9174E-02
570	1.655	41.90	6.1198E-02	3.3520E-02	2.9208E-03	1.4604E-03	9.9099E-02
580	1.666	41.09	6.1060E-02	3.3502E-02	2.9721E-03	1.4860E-03	9.9020E-02
590	1.677	40.30	6.0921E-02	3.3484E-02	3.0233E-03	1.5117E-03	9.8940E-02
600	1.688	39.54	6.0780E-02	3.3465E-02	3.0746E-03	1.5373E-03	9.8857E-02
610	1.698	38.80	6.0638E-02	3.3445E-02	3.1258E-03	1.5629E-03	9.8772E-02
620	1.709	38.08	6.0494E-02	3.3424E-02	3.1771E-03	1.5885E-03	9.8684E-02
630	1.720	37.39	6.0349E-02	3.3403E-02	3.2283E-03	1.6141E-03	9.8594E-02
640	1.731	36.71	6.0202E-02	3.3381E-02	3.2795E-03	1.6398E-03	9.8502E-02
650	1.742	36.06	6.0054E-02	3.3358E-02	3.3308E-03	1.6654E-03	9.8408E-02
660	1.752	35.43	5.9904E-02	3.3334E-02	3.3820E-03	1.6910E-03	9.8311E-02
670	1.763	34.81	5.9752E-02	3.3309E-02	3.4333E-03	1.7166E-03	9.8211E-02
680	1.774	34.21	5.9599E-02	3.3284E-02	3.4845E-03	1.7423E-03	9.8110E-02
690	1.784	33.62	5.9444E-02	3.3258E-02	3.5358E-03	1.7679E-03	9.8006E-02
700	1.795	33.06	5.9288E-02	3.3231E-02	3.5870E-03	1.7935E-03	9.7900E-02
710	1.806	32.51	5.9130E-02	3.3203E-02	3.6382E-03	1.8191E-03	9.7790E-02
720	1.816	31.97	5.8970E-02	3.3175E-02	3.6895E-03	1.8447E-03	9.7679E-02
730	1.827	31.44	5.8810E-02	3.3145E-02	3.7407E-03	1.8704E-03	9.7566E-02
740	1.837	30.93	5.8647E-02	3.3116E-02	3.7920E-03	1.8960E-03	9.7451E-02
750	1.848	30.43	5.8483E-02	3.3085E-02	3.8432E-03	1.9216E-03	9.7333E-02
760	1.858	29.95	5.8317E-02	3.3053E-02	3.8944E-03	1.9472E-03	9.7212E-02
770	1.869	29.48	5.8150E-02	3.3021E-02	3.9457E-03	1.9728E-03	9.7090E-02
780	1.879	29.01	5.7982E-02	3.2988E-02	3.9969E-03	1.9985E-03	9.6965E-02
790	1.890	28.56	5.7812E-02	3.2954E-02	4.0482E-03	2.0241E-03	9.6838E-02
800	1.900	28.12	5.7640E-02	3.2919E-02	4.0994E-03	2.0497E-03	9.6708E-02
810	1.911	27.69	5.7467E-02	3.2884E-02	4.1507E-03	2.0753E-03	9.6577E-02
820	1.921	27.27	5.7292E-02	3.2848E-02	4.2019E-03	2.1010E-03	9.6443E-02
830	1.931	26.86	5.7115E-02	3.2811E-02	4.2531E-03	2.1266E-03	9.6306E-02
840	1.942	26.46	5.6938E-02	3.2773E-02	4.3044E-03	2.1522E-03	9.6168E-02
850	1.952	26.06	5.6758E-02	3.2735E-02	4.3556E-03	2.1778E-03	9.6026E-02
860	1.962	25.68	5.6577E-02	3.2696E-02	4.4069E-03	2.2034E-03	9.5883E-02
870	1.972	25.30	5.6395E-02	3.2656E-02	4.4581E-03	2.2291E-03	9.5738E-02
880	1.983	24.93	5.6211E-02	3.2615E-02	4.5094E-03	2.2547E-03	9.5590E-02
890	1.993	24.57	5.6025E-02	3.2573E-02	4.5606E-03	2.2803E-03	9.5439E-02

Table 6.3-9. Uranyl Fluoride Solution Data

Uranium Density (g U/L)	Solution Density (g/cm^3)	H/U ratio	Hydrogen (atom/b-cm)	Oxygen (atom/b-cm)	Fluorine (atom/b-cm)	^{235}U (atom/b-cm)	Total (atom/b-cm)
900	2.003	24.22	5.5838E-02	3.2531E-02	4.6118E-03	2.3059E-03	9.5287E-02
910	2.013	23.87	5.5650E-02	3.2488E-02	4.6631E-03	2.3315E-03	9.5133E-02
920	2.023	23.53	5.5460E-02	3.2444E-02	4.7143E-03	2.3572E-03	9.4976E-02
930	2.033	23.19	5.5269E-02	3.2400E-02	4.7656E-03	2.3828E-03	9.4817E-02
940	2.044	22.87	5.5075E-02	3.2354E-02	4.8168E-03	2.4084E-03	9.4654E-02
950	2.054	22.55	5.4881E-02	3.2309E-02	4.8681E-03	2.4340E-03	9.4492E-02
960	2.064	22.23	5.4685E-02	3.2262E-02	4.9193E-03	2.4597E-03	9.4326E-02
970	2.074	21.92	5.4488E-02	3.2214E-02	4.9705E-03	2.4853E-03	9.4158E-02
980	2.084	21.62	5.4289E-02	3.2166E-02	5.0218E-03	2.5109E-03	9.3988E-02
990	2.094	21.32	5.4089E-02	3.2117E-02	5.0730E-03	2.5365E-03	9.3816E-02
1000	2.104	21.03	5.3887E-02	3.2068E-02	5.1243E-03	2.5621E-03	9.3641E-02

*Uranium densities go higher than 1000 g/L.

6.3.3 Chemicals in Liquid Form

The densities in g/cm^3 taken from the references as shown in Table 2.3-2 [Design Input 2.15] do not require adjustment. While the temperatures associated with these densities range from 20°C to 25°C, this falls within the normal range of ambient temperatures.

The values reported in units of specific gravity are all given with a reference water temperature of 4°C, which is the temperature at which the density of water reaches its maximum value of 0.9999749 g/cm^3 [Design Input 2.14]. The specific gravity of a material is the ratio of its density to the density of water at the specified temperature. Since the density of water at 4°C is so close to 1.0000, multiplying the given specific gravity by this water density does not change the numerical value within the reported number of digits. The temperatures reported for the measurement of the specific gravities range from 15°C to 20°C, which also falls within the normal range of ambient temperatures. Therefore, the specific gravity values given in Table 2.3-2 will be taken as density values in g/cm^3 without any adjustment.

Table 6.3-10 contains several chemicals in liquid form that are used regularly in processes. The table contains the chemical name, concentrations in water, molecular formulas, and densities. Some chemicals are listed at several concentrations in water.

Table 6.3-10. Chemicals in Liquid Form

Chemical	Concentration [mass %]	Formula	Density [g/cm^3]
Acetic acid	100	CH_3COOH	1.0498
Acetone	100	$(CH_3)_2CO$	0.7845
Acetonitrile	100	CH_3CN	0.7857
Aluminum nitrate	32	$Al(NO_3)_3$	1.3036
Ammonia	30	NH_3	0.8920
Chromic acid	50	H_2CrO_4	1.505
Dibutyl Carbitol	100	$C_{12}H_{26}O_3$	0.885

Table 6.3-10. Chemicals in Liquid Form

Chemical	Concentration [mass %]	Formula	Density [g/cm^3]
(diethylene glycol dibutyl ether)			
Dodecane	100	$CH_3(CH_2)_{10}CH_3$	0.7495
Hydrochloric acid	40	HCl	1.1980
Hydrochloric acid	38	HCl	1.1885
Hydrochloric acid	30	HCl	1.1493
Hydrofluoric acid	50	HF	1.155
Hydrogen peroxide	55	H_2O_2	1.2188
Hydrogen peroxide	35	H_2O_2	1.1327
Nitric acid	70	HNO_3	1.4134
Nitric acid	50	HNO_3	1.3100
Nitric acid	30	HNO_3	1.1800
Phosphoric acid	100	H_3PO_4	1.870
Sodium hydroxide	50	NaOH	1.5253
Sodium nitrate	45	$NaNO_3$	1.3683
Sulfuric acid	50	H_2SO_4	1.3951
Sulfuric acid	98	H_2SO_4	1.8361
Tributyl phosphate	100	$(C_4H_9O)_3PO$	0.9727

6.3.4 Chemicals in Solid Form

Several compounds, mixtures, and alloys have been predefined in the SCALE computer code. These include many standard materials used in most criticality safety analyses. Other mixtures not included in SCALE6.1, such as the machine coolant, had their atomic weight percentages changed to sum to 100. The material compounds, mixtures, and alloys from the SCALE6.1 Standard Composition Library [Ref. 4.18] were not modified.

6.3.4.1 Molecular Data for Pure Compounds

The following compounds and graphite represent many of the materials that may be used at UPF. Table 6.3-11 contains the name, molecular formula, and theoretical density for standard compounds from Table 2.3-3. All these materials can be used directly in SCALE by entering either the molecular formula or the name in the standard composition section of the SCALE input file. For benzene, graphite, plexiglass, and polyethylene, the name is entered; all other materials are specified using the molecular formula. For consistency, the same densities should also be used in MCNP calculations.

Table 6.3-11. Pure Non-Fissile Material Data (Table 2.3-3)

Name	Molecular Formula	Theoretical Density (g/cm^3)
Aluminum Oxide	Al_2O_3	3.97
Boron Carbide	B_4C	2.52

Table 6.3-11. Pure Non-Fissile Material Data (Table 2.3-3)

Name	Molecular Formula	Theoretical Density (g/cm^3)
Benzene	C_6H_6	0.8765
Beryllium Oxide	BeO	3.0
Gadolinium Oxide	Gd_2O_3	7.07
Graphite	C	2.3
Plexiglass	$C_5H_8O_2$	1.18
Polyethylene	CH_2	0.92
Polyvinyl chloride	C_2H_3Cl	1.6
Water	H_2O	0.9982
Bubble-alumina	>99% Al_2O_3	0.96
SALI low-density alumina)	80 wt% Al_2O_3 20 wt% SiO_2	0.48
Silicon Carbide	SiC	3.16
Silicon Dioxide	SiO_2 (α-quartz) (β-quartz) (tridymite) (cristobalite) (vitreous)	 2.648 2.533 2.265 2.334 2.196

6.3.4.2 Molecular Data for Mixtures and Alloys

The following material data contains many of the materials used in standard criticality safety analyses. The information in Table 6.3-12 contains weight fraction of each element in the mixture and its theoretical density. All these materials can be used directly in SCALE by entering their name in the standard composition section of the SCALE input file.

Table 6.3-12. Alloy and Mixture Data (Ref. 4.18, Table M8.2.5)

Name	Element: Wt %	Density (g/cm^3)	Name	Element: Wt %	Density (g/cm^3)
CarbonSteel	Fe: 99.0 C: 1.0	7.8212	u(.27)metal [1]	^{235}U: 0.27 ^{238}U: 99.73	19.05
Dry-Air	C: 0.0126 N: 76.5081 O: 23.4793	0.0012	kerosene	C: 84.0 H: 16.0	0.82

Table 6.3-12. Alloy and Mixture Data (Ref. 4.18, Table M8.2.5)

Name	Element: Wt %	Density (g/cm^3)	Name	Element: Wt %	Density (g/cm^3)
Granite	H: 0.0336 O: 47.8286 F: 0.0901 Na: 2.2501 Mg: 0.1449 Al: 7.4752 Si: 32.8046 P: 0.0393 K: 5.0108 Ca: 1.1876 Ti: 0.2520 Mn: 0.0465 Fe: 2.8367	2.66	Mgconcrete [2]	Fe: 0.5595 H: 0.3319 C: 10.5321 O: 49.9430 Na: 0.1411 Mg: 9.4200 Al: 0.7859 Si: 4.2101 S: 0.2483 Cl: 0.0523 K: 0.9445 Ca: 22.6318 Ti: 0.1488 Mn: 0.0512	2.147
Inconel	Si: 2.5 Ti: 2.5 Cr: 15.0 Fe: 7.0 Ni: 73.0	8.3	SS304	C: 0.08 Si: 1.0 P: 0.045 Cr: 19.0 Mn: 2.0 Fe: 68.375 Ni: 9.5	7.94
Limestone	H: 0.0863 C: 11.3548 O: 49.6925 Na: 0.0371 Mg: 4.7656 Al: 0.4294 Si: 2.4299 P: 0.0175 S: 0.0251 K: 0.2744 Ca: 30.4731 Ti: 0.0360 Fe: 0.3783	2.15	SS316	C: 0.08 Si: 1.0 P: 0.045 Cr: 17.0 Mn: 2.0 Fe: 65.375 Ni: 12.0 Mo: 2.5	8.03
Pyrex	B: 3.7 Al: 1.0 O: 53.5 Si: 37.7 Na: 4.1	2.23	Zirc4	Zr: 98.23 Sn: 1.45 Fe: 0.21 Cr: 0.10 Hf: 0.01	6.56

[1] Depleted Uranium
[2] Magnuson's Concrete

6.3.5 BoroBond4

The following material data contains data for BoroBond4 as cast and with the water content decreased by 5, 40, 50, and 60 lbs to account for decreased water due to aging or fire. The information in Table 6.3-13 contains atom densities of each element in the mixture and its calculated density.

Table 6.3-13 BoroBond4 Data (Ref. 4.48, App. A))

Element	Base H_2O content Atom density (at/b-cm)	5 lb decrease in H_2O content Atom density (at/b-cm)	40 lb decrease in H_2O content Atom density (at/b-cm)	50 lb decrease in H_2O content Atom density (at/b-cm)	60 lb decrease in H_2O content Atom density (at/b-cm)
Mg	0.003247	0.003247	0.003247	0.003247	0.003247
O	0.039400	0.039340	0.038915	0.038794	0.038672
K	0.002971	0.002971	0.002971	0.002971	0.002971
H	0.030314	0.030193	0.029344	0.029101	0.028858
P	0.002971	0.002971	0.002971	0.002971	0.002971
Fe	0.000500	0.000500	0.000500	0.000500	0.000500
Al	0.003130	0.003130	0.003130	0.003130	0.003130
Si	0.003320	0.003320	0.003320	0.003320	0.003320
B-10	0.000616	0.000616	0.000616	0.000616	0.000616
B-11	0.002478	0.002478	0.002478	0.002478	0.002478
C	0.000773	0.000773	0.000773	0.000773	0.000773

6.3.6 Machine Coolant

The element values from the Y-12 ACL report (Table 2.3-6) were used to determine the weight percent of the hydrogen, carbon, and oxygen in C350 [Ref. 4.26]. Since the hydrogen and carbon weight percent were listed with very tight confidence values, the reported values were used. The oxygen results were reported with no confidence levels. Therefore, the remaining C350 weight percent is taken to be oxygen. Using the volume additive method, a mixture composed of 10 vol% C350-90 vol% full-density water mixture has a density of 1.0038 g/cm^3. The Y-12 ACL report lists a density of 1.0007 g/cm^3 for a mixture of 10 vol% C350 and 90 vol% water. Since the mixture density calculated using the volume additive method is more conservative (1.0038 g/cm^3), it is used as the mixture density.

Based on the Y-12 ACL report, the following specifications are used for modeling:

- Density: 1.0542 g/cm^3
- Hydrogen: 10.49 wt %
- Carbon: 32.60 wt %
- Oxygen: 56.91 wt %

Using the volume additive method, a mixture composed of 10 vol% C350-90 vol% full-density water mixture has a density of 1.0038 g/cm^3.

6.3.7 Concrete Composition

The results of a calculational study [Ref. 4.5, Design Input 2.20] showed that the SCALE composition Magnuson's concrete produced the highest k_{eff} results when used as a reflector of various thicknesses on slabs of wet and dry uranium materials. Since the study included a wide variety of eight concrete compositions, it is assumed that Magnuson's concrete is an appropriate composition for use in UPF calculations [Assumption 3.2].

The specific form of concrete used in UPF will be analyzed for density, water content, and concentration of constituents. The variation of water content as the concrete cures and dries over time may also need to be taken into consideration for configurations that are particularly sensitive to the concrete (such as concrete between interacting units of fissile material).

Until the details of the UPF concrete are known, SCALE's standard composition for Magnuson's concrete, listed in Table 6.3-12 (in Sect. 6.3.4.2), is used to model concrete in all UPF computations [Design Input 2.19]. However, depending on how the concrete is used, the choice of Magnuson's concrete as a bounding reflector may need to be carried as an assumption requiring confirmation in NCS DACs until the UPF concrete is characterized.

Section 6.4.1.5 gives guidance on thickness of concrete that should be used when modeled as a reflector.

6.3.8 Isotopic Composition of Selected Compounds/Alloys

MCNP requires material data to be entered by isotope with either the associated atom fraction or weight fraction. The elements in all compounds/alloys in Table 6.3-11, Table 6.3-12 and Table 6.3-13 have been broken down into their constituent isotopes. Table 6.3-14 contains the elemental breakdown as a function of weight fraction and total density. If the weight fraction of an isotope in the material is less than $1{\times}10^{-6}$ that isotope is not included. This may result in some isotopes in some stable isotopes that occur in an element in the material being eliminated. In those cases a footnote is included in Table 6.3-14 for that material. The isotopic weight fractions of each material sums to 1.0. A negative sign is added to the front of the weight fraction so that the data may be used as listed in an MCNP input file material list. Note that for the ENDF/B-VII library SCALE (v7-238) treats graphite as a homogenized material (6000) whereas MCNP (default from the xsdir file) breaks out graphite into its constituent isotopes (6012 and 6013).

Table 6.3-14 Weight Fractions of Isotopes in Materials

Material	List of Isotopes and Weight Fractions in Material	Total Density (g/cm^3)
Aluminum Oxide (Al_2O_3)	8016 -0.47075 13027 -0.52925	3.97
Boron Carbide (B_4C)	5010 -0.14425 5011 -0.63838 6000 -0.21737	2.52
Benzene (C_6H_6)	1001 -0.07742 6000 -0.92258	0.8765
Beryllium Oxide (BeO)	4009 -0.36032 8016 -0.63968	3.0
Gadolinium Oxide (Gd_2O_3)	8016 -0.13241 64152 -0.00168 64154 -0.01851 64155 -0.12650 64156 -0.17609 64157 -0.13549 64158 -0.21643 64160 -0.19288	7.07
Graphite	6000 -1.0	2.3
Plexiglas ($C_5H_8O_2$)	1001 -0.08054 6000 -0.59984 8016 -0.31962	1.18
Polyethylene (CH_2)	1001 -0.14371 6000 -0.85629	0.92
Polyvinyl Chloride (C_2H_3Cl)	1001 -0.04838 6000 -0.38435 17035 -0.42389 17037 -0.14337	1.6
Water	1001 -0.11189 8016 -0.88811	0.9982

Table 6.3-14 Weight Fractions of Isotopes in Materials

Material	List of Isotopes and Weight Fractions in Material	Total Density (g/cm^3)
Bubble Alumina	8016 -0.47075 13027 -0.52925	0.96
SALI-Spec. 80 wt% Al_2O_3 20 wt% SiO_2 (low-density alumina)	8016 -0.48311 13027 -0.42340 14028 -0.08588 14029 -0.00452 14030 -0.00308	0.48
SALI-Generic 55 wt% Al_2O_3 45 wt% SiO_2 (low-density alumina)	8016 -0.49857 13027 -0.29109 14028 -0.19324 14029 -0.01017 14030 -0.00694	0.60
Silicon Carbide (SiC)	6000 -0.29955 14028 -0.64348 14029 -0.03386 14030 -0.02311	3.16
Silicon Dioxide (SiO_2) (α-quartz) (β-quartz) (cristobalite) (tridymite) (vitreous)	8016 -0.53257 14028 -0.42942 14029 -0.02259 14030 -0.01542	2.648 2.533 2.334 2.265 2.196
CarbonSteel	6000 -0.01000 26054 -0.05589 26056 -0.90984 26057 -0.02138 26058 -0.00289	7.8212
U(0.27)metal	92235 -0.00267 92238 -0.99733	19.05
Dry Air	6000 -0.00013 7014 -0.76508 8016 -0.23479	0.0012
Kerosene	1001 -0.16000 6000 -0.84000	0.82
Granite	1001 -0.00034 8016 -0.47829 9019 -0.00090 11023 -0.02250 12024 -0.00113 12025 -0.00015 12026 -0.00017 13027 -0.07475 14028 -0.30136 14029 -0.01586 14030 -0.01083 15031 -0.00039 19039 -0.04657 19040 -0.00001 19041 -0.00353 20040 -0.01148 20042 -0.00008 20043 -0.00002 20044 -0.00027 20048 -0.00003 22046 -0.00020 22047 -0.00018 22048 -0.00186 22049 -0.00014 22050 -0.00014 25055 -0.00046 26054 -0.00160 26056 -0.02607 26057 -0.00061 26058 -0.00008 *Due to number of significant figure 20046 is zero and not included.	2.66
mgconcrete	1001 -0.00332 6000 -0.10532 8016 -0.49943 11023 -0.00141 12024 -0.07343 12025 -0.00968 12026 -0.01109 13027 -0.00786 14028 -0.03868 14029 -0.00203 14030 -0.00139 16032 -0.00235 16033 -0.00002 16034 -0.00011 17035 -0.00039 17037 -0.00013 19039 -0.00878 19041 -0.00067 20040 -0.21875 20042 -0.00153 20043 -0.00033 20044 -0.00518 20046 -0.00001 20048 -0.00051 22046 -0.00012 22047 -0.00011 22048 -0.00110 22049 -0.00008 22050 -0.00008 25055 -0.00051 26054 -0.00032 26056 -0.00514 26057 -0.00012 26058 -0.00002 * Due to number of significant figures 16036 and 19040 are zero and not included.	2.147

Table 6.3-14 Weight Fractions of Isotopes in Materials

Material	List of Isotopes and Weight Fractions in Material	Total Density (g/cm^3)
Inconel	14028 -0.02297 14029 -0.00121 14030 -0.00082 22046 -0.00198 22047 -0.00182 22048 -0.01846 22049 -0.00138 22050 -0.00135 24050 -0.00626 24052 -0.12555 24053 -0.01451 24054 -0.00368 26054 -0.00395 26056 -0.06433 26057 -0.00151 26058 -0.00020 28058 -0.49057 28060 -0.19546 28061 -0.00864 28062 -0.02799 28064 -0.00736	8.3
SS304	6000 -0.00080 14028 -0.00919 14029 -0.00048 14030 -0.00033 15031 -0.00045 24050 -0.00793 24052 -0.15903 24053 -0.01838 24054 -0.00466 25055 -0.02000 26054 -0.03860 26056 -0.62838 26057 -0.01477 26058 -0.00200 28058 -0.06384 28060 -0.02544 28061 -0.00112 28062 -0.00364 28064 -0.00096	7.94
Limestone	1001 -0.00086 6000 -0.11355 8016 -0.49693 11023 -0.00037 12024 -0.03715 12025 -0.00490 12026 -0.00561 13027 -0.00429 14028 -0.02232 14029 -0.00117 14030 -0.00080 15031 -0.00018 16032 -0.00024 16034 -0.00001 19039 -0.00255 19041 -0.00019 20040 -0.29456 20042 -0.00206 20043 -0.00044 20044 -0.00697 20046 -0.00001 20048 -0.00068 22046 -0.00003 22047 -0.00003 22048 -0.00027 22049 -0.00002 22050 -0.00002 26054 -0.00021 26056 -0.00348 26057 -0.00008 26058 -0.00002 * Due to number of significant figures 16033, 16036, and 19040 are zero and not included.	2.15
SS316	6000 -0.00080 14028 -0.00919 14029 -0.00048 14030 -0.00033 15031 -0.00045 24050 -0.00710 24052 -0.14229 24053 -0.01645 24054 -0.00417 25055 -0.02000 26054 -0.03691 26056 -0.60080 26057 -0.01412 26058 -0.00191 28058 -0.08064 28060 -0.03213 28061 -0.00142 28062 -0.00460 28064 -0.00121 42092 -0.00354 42094 -0.00226 42095 -0.00393 42096 -0.00417 42097 -0.00241 42098 -0.00617 42100 -0.00252	8.03
Pyrex	5010 -0.00682 5011 -0.03018 8016 -0.53500 11023 -0.04100 13027 -0.01000 14028 -0.34634 14029 -0.01822 14030 -0.01244	2.23
Zirc4	24050 -0.00004 24052 -0.00084 24053 -0.00010 24054 -0.00002 26054 -0.00012 26056 -0.00193 26057 -0.00005 26058 -0.00001 40090 -0.49806 40091 -0.10983 40092 -0.16972 40094 -0.17574 40096 -0.02892 50112 -0.00013 50114 -0.00009 50115 -0.00005 50116 -0.00206 50117 -0.00110 50118 -0.00349 50119 -0.00125 50120 -0.00477 50122 -0.00069 50124 -0.00088 72176 -0.00001 72177 -0.00002 72178 -0.00003 72179 -0.00001 72180 -0.00004 * Due to number of significant figures 70174 is zero and not included.	6.56

Table 6.3-14 Weight Fractions of Isotopes in Materials

Material	List of Isotopes and Weight Fractions in Material	Total Density (g/cm^3)
BoroBond4	1001 -0.02554 5010 -0.00516 5011 -0.02280 6000 -0.00776 8016 -0.52690 12024 -0.05142 12025 -0.00678 12026 -0.00776 13027 -0.07059 14028 -0.07160 14029 -0.00377 14030 -0.00257 15031 -0.07692 19039 -0.09024 19041 -0.00685 26054 -0.00132 26056 -0.02145 26057 -0.00050 26058 -0.00007 mtn lwtr S(α,β) input record needed. * Due to number of significant figures 19040 is zero and not included.	1.98666
BoroBond4 (5 lbs. of water removed from RCSB)	1001 -0.02546 5010 -0.00516 5011 -0.02282 6000 -0.00777 8016 -0.52658 12024 -0.05147 12025 -0.00679 12026 -0.00777 13027 -0.07065 14028 -0.07166 14029 -0.00377 14030 -0.00257 15031 -0.07699 19039 -0.09032 19040 -0.00001 19041 -0.00685 26054 -0.00132 26056 -0.02147 26057 -0.00050 26058 -0.00007 mtn lwtr S(α,β) input record needed.	1.98486
BoroBond4 (40 lbs. of water removed from RCSB)	1001 -0.02490 5010 -0.00519 5011 -0.02297 6000 -0.00782 8016 -0.52424 12024 -0.05180 12025 -0.00683 12026 -0.00782 13027 -0.07111 14028 -0.07213 14029 -0.00379 14030 -0.00259 15031 -0.07748 19039 -0.09090 19040 -0.00001 19041 -0.00690 26054 -0.00133 26056 -0.02161 26057 -0.00051 26058 -0.00007 mtn lwtr S(α,β) input record needed.	1.97215
BoroBond4 (50 lbs. of water removed from RCSB)	1001 -0.02474 5010 -0.00520 5011 -0.02301 6000 -0.00783 8016 -0.52358 12024 -0.05189 12025 -0.00684 12026 -0.00784 13027 -0.07124 14028 -0.07226 14029 -0.00380 14030 -0.00260 15031 -0.07763 19039 -0.09107 19041 -0.00691 26054 -0.00133 26056 -0.02165 26057 -0.00051 26058 -0.00007 mtn lwtr S(α,β) input record needed. * Due to number of significant figures 19040 is zero and not included.	1.96853
BoroBond4 (60 lbs. of water removed from RCSB)	1001 -0.02458 5010 -0.00521 5011 -0.02306 6000 -0.00785 8016 -0.52290 12024 -0.05199 12025 -0.00686 12026 -0.00785 13027 -0.07137 14028 -0.07239 14029 -0.00381 14030 -0.00260 15031 -0.07777 19039 -0.09124 19041 -0.00692 26054 -0.00133 26056 -0.02169 26057 -0.00051 26058 -0.00007 mtn lwtr S(α,β) input record needed. * Due to number of significant figures 19040 is zero and not included.	1.96488

Table 6.3-15 contains the elemental breakdown as a function of atom fractions (atom/b-cm) and a total atom density of the materials in Table 6.3-11, Table 6.3-12, and Table 6.3-13. The total atom density is the sum of the individual atom densities for each material.

Table 6.3-15 Atom Densities of Isotopes in Materials

Material	List of Isotopes and Isotopic Atom Density (Atoms/b-cm) in Material	Total Atom Density (atoms/b-cm)
Aluminum Oxide (Al_2O_3)	8016 0.070344 13027 0.046896	0.117240
Boron Carbide (B_4C)	5010 0.021862 5011 0.087998 6000 0.027465	0.137325
Benzene (C_6H_6)	1001 0.040545 6000 0.040545	0.081090
Beryllium Oxide (BeO)	4009 0.072232 8016 0.072232 mtn beo S(α,β) input record needed.	0.144464
Gadolinium Oxide (Gd_2O_3)	8016 0.035235 64152 0.000047 64154 0.000512 64155 0.003477 64156 0.004808 64157 0.003676 64158 0.005835 64160 0.005135	0.058725
Graphite	6000 0.115321 mtn grph S(α,β) input record needed.	0.115321
Plexiglas ($C_5H_8O_2$)	1001 0.056783 6000 0.035489 8016 0.014196 mtn poly grph S(α,β) input record needed	0.106468
Polyethylene (CH_2)	1001 0.078998 6000 0.039499 mtn poly grph S(α,β) input record needed.	0.118497
Polyvinyl Chloride (C_2H_3Cl)	1001 0.046251 6000 0.030834 17035 0.011680 17037 0.003737 mtn poly grph S(α,β) input record needed.	0.092502
Water	1001 0.066735 8016 0.033368 mtn lwtr S(α,β) input record needed.	0.100103
Bubble Alumina (Al_2O_3)	8016 0.017010 13027 0.011340	0.028350
SALI 80% Al_2O_3 20% SiO_2 (low-density alumina)	8016 0.008728 13027 0.004536 14028 0.000887 14029 0.000045 14030 0.000030	0.014226
SALI 55% Al_2O_3 45% SiO_2 (low-density alumina)	8016 0.011259 13027 0.003898 14028 0.002496 14029 0.000127 14030 0.000084	0.017864
Silicon Carbide SiC	6000 0.047460 14028 0.043769 14029 0.002224 14030 0.001467 mtn grph S(α,β) input record needed.	0.094920
Silicon Dioxide (SiO_2) (α-quartz)	8016 0.053081 14028 0.024476 14029 0.001243 14030 0.000821	0.079621
Silicon Dioxide (SiO_2) (β-quartz)	8016 0.050775 14028 0.023413 14029 0.001189 14030 0.000785	0.076162
Silicon Dioxide (SiO_2) (cristobalite)	8016 0.046786 14028 0.021574 14029 0.001096 14030 0.000723	0.070179
Silicon Dioxide (SiO_2) (tridymite)	8016 0.045403 14028 0.020936 14029 0.001064 14030 0.000702	0.068105
Silicon Dioxide (SiO_2) (vitreous)	8016 0.044020 14028 0.020298 14029 0.001031 14030 0.000681	0.066030

Table 6.3-15 Atom Densities of Isotopes in Materials

Material	List of Isotopes and Isotopic Atom Density (Atoms/b-cm) in Material	Total Atom Density (atoms/b-cm)
CarbonSteel	6000 0.003922 26054 0.004880 26056 0.076612 26057 0.001769 26058 0.000235	0.087418
U(.27)metal	92235 0.000130 92238 0.048063	0.048193
Dry Air	7014 0.000039 8016 0.000011 * Due to number of significant figures 6000 is zero and not included.	0.000050
Kerosene	1001 0.078391 6000 0.034536 mtn poly grph S(α,β) input record needed.	0.112927
Granite	1001 0.000534 8016 0.047887 9019 0.000076 11023 0.001568 12024 0.000075 12025 0.000010 12026 0.000011 13027 0.004438 14028 0.017255 14029 0.000877 14030 0.000579 15031 0.000020 19039 0.001915 19041 0.000138 20040 0.000460 20042 0.000003 20043 0.000001 20044 0.000010 20048 0.000001 22046 0.000007 22047 0.000006 22048 0.000062 22049 0.000005 22050 0.000004 25055 0.000014 26054 0.000048 26056 0.000747 26057 0.000017 26058 0.000002 mtn lwtr S(α,β) input record needed. *Due to number of significant figures 19040 and 20046 are zero and not included.	0.076770
mgconcrete	1001 0.004258 6000 0.011338 8016 0.040360 11023 0.000079 12024 0.003958 12025 0.000501 12026 0.000552 13027 0.000377 14028 0.001787 14029 0.000091 14030 0.000060 16032 0.000095 16033 0.000001 16034 0.000004 17035 0.000014 17037 0.000005 19039 0.000291 19041 0.000021 20040 0.007078 20042 0.000047 20043 0.000010 20044 0.000152 20048 0.000014 22046 0.000003 22047 0.000003 22048 0.000030 22049 0.000002 22050 0.000002 25055 0.000012 26054 0.000008 26056 0.000119 26057 0.000003 mtn lwtr S(α,β) input record needed. * Due to number of significant figures 16036, 19040, 20046, and 26058 are zero and not included.	0.071275
Inconel	14028 0.004103 14029 0.000208 14030 0.000138 22046 0.000215 22047 0.000194 22048 0.001924 22049 0.000141 22050 0.000135 24050 0.000627 24052 0.012082 24053 0.001370 24054 0.000341 26054 0.000366 26056 0.005749 26057 0.000133 26058 0.000018 28058 0.042321 28060 0.016302 28061 0.000709 28062 0.002259 28064 0.000575	0.089910
SS304	6000 0.000318 14028 0.001570 14029 0.000080 14030 0.000053 15031 0.000069 24050 0.000759 24052 0.014640 24053 0.001660 24054 0.000413 25055 0.001741 26054 0.003422 26056 0.053716 26057 0.001241 26058 0.000165 28058 0.005269 28060 0.002029 28061 0.000088 28062 0.000281 28064 0.000072	0.087586

Table 6.3-15 Atom Densities of Isotopes in Materials

Material	List of Isotopes and Isotopic Atom Density (Atoms/b-cm) in Material	Total Atom Density (atoms/b-cm)
Limestone	1001 0.001109 6000 0.012240 8016 0.040214 11023 0.000021 12024 0.002005 12025 0.000254 12026 0.000280 13027 0.000206 14028 0.001033 14029 0.000052 14030 0.000035 15031 0.000007 16032 0.000010 19039 0.000085 19041 0.000006 20040 0.009543 20042 0.000064 20043 0.000013 20044 0.000205 20048 0.000018 22046 0.000001 22047 0.000001 22048 0.000007 22049 0.000001 22050 0.000001 26054 0.000005 26056 0.000080 26057 0.000001 mtn lwtr S(α,β) input record needed. * Due to number of significant figures 16033. 16034, 16036, 19040, 20046, and 26058 are zero and not included.	0.067498
SS316	6000 0.000322 14028 0.001588 14029 0.000081 14030 0.000053 15031 0.000070 24050 0.000687 24052 0.013247 24053 0.001502 24054 0.000374 25055 0.001760 26054 0.003309 26056 0.051942 26057 0.001200 26058 0.000160 28058 0.006731 28060 0.002593 28061 0.000113 28062 0.000359 28064 0.000092 42092 0.000186 42094 0.000116 42095 0.000200 42096 0.000210 42097 0.000120 42098 0.000305 42100 0.000122	0.087442
Pyrex	5010 0.000915 5011 0.003681 8016 0.044906 11023 0.002395 13027 0.000498 14028 0.016625 14029 0.000845 14030 0.000557	0.070422
Zirc4	24050 0.000003 24052 0.000064 24053 0.000007 24054 0.000002 26054 0.000009 26056 0.000136 26057 0.000003 40090 0.021886 40091 0.004773 40092 0.007295 40094 0.007393 40096 0.001191 50112 0.000005 50114 0.000003 50115 0.000002 50116 0.000070 50117 0.000037 50118 0.000117 50119 0.000041 50120 0.000157 50122 0.000022 50124 0.000028 72178 0.000001 72180 0.000001 * Due to number of significant figures 26058, 72174, 72176, 72177 and 72179 are zero and not included.	0.043246
BoroBond4 (Base H_2O Content)	1001 0.030314 5010 0.000616 5011 0.002478 6000 0.000773 8016 0.039400 12024 0.002565 12025 0.000325 12026 0.000357 13027 0.003130 14028 0.003062 14029 0.000156 14030 0.000103 15031 0.002971 19039 0.002771 19041 0.000200 26054 0.000029 26056 0.000459 26057 0.000011 26058 0.000001 mtn lwtr S(α,β) input record needed. * Due to number of significant figures 19040 is zero and not included.	0.089721

Table 6.3-15 Atom Densities of Isotopes in Materials

Material	List of Isotopes and Isotopic Atom Density (Atoms/b-cm) in Material	Total Atom Density (atoms/b-cm)
BoroBond4 (5 lbs. of water removed from RCSB)	1001 0.030193 5010 0.000616 5011 0.002478 6000 0.000773 8016 0.039340 12024 0.002565 12025 0.000325 12026 0.000357 13027 0.003130 14028 0.003062 14029 0.000156 14030 0.000103 15031 0.002971 19039 0.002771 19041 0.000200 26054 0.000029 26056 0.000459 26057 0.000011 26058 0.000001 mtn lwtr S(α,β) input record needed. * Due to number of significant figures 19040 is zero and not included.	0.089540
BoroBond4 (40 lbs. of water removed from RCSB)	1001 0.029344 5010 0.000616 5011 0.002478 6000 0.000773 8016 0.038915 12024 0.002565 12025 0.000325 12026 0.000357 13027 0.003130 14028 0.003062 14029 0.000156 14030 0.000103 15031 0.002971 19039 0.002771 19041 0.000200 26054 0.000029 26056 0.000459 26057 0.000011 26058 0.000001 mtn lwtr S(α,β) input record needed. * Due to number of significant figures 19040 is zero and not included.	0.088266
BoroBond4 (50 lbs. of water removed from RCSB)	1001 0.029101 5010 0.000616 5011 0.002478 6000 0.000773 8016 0.038794 12024 0.002565 12025 0.000325 12026 0.000357 13027 0.003130 14028 0.003062 14029 0.000156 14030 0.000103 15031 0.002971 19039 0.002771 19041 0.000200 26054 0.000029 26056 0.000459 26057 0.000011 26058 0.000001 mtn lwtr S(α,β) input record needed. * Due to number of significant figures 19040 is zero and not included.	0.087902
BoroBond4 (60 lbs. of water removed from RCSB)	1001 0.028858 5010 0.000616 5011 0.002478 6000 0.000773 8016 0.038672 12024 0.002565 12025 0.000325 12026 0.000357 13027 0.003130 14028 0.003062 14029 0.000156 14030 0.000103 15031 0.002971 19039 0.002771 19041 0.000200 26054 0.000029 26056 0.000459 26057 0.000011 26058 0.000001 mtn lwtr S(α,β) input record needed. * Due to number of significant figures 19040 is zero and not included.	0.087537

6.4 STANDARD DIMENSIONAL DATA

6.4.1 Reflection Guidelines

The following standardized reflection conditions should be used to the extent practical in the absence of specific NCS requirements and/or specific design information. These specified reflection conditions represent conservative conditions that are expected to be bounding of most anticipated reflection conditions in the facility. Judgment must be exercised to determine if any specific materials or conditions could create more effective reflection than that specified in this section.

6.4.1.1 Full Reflection

For purposes of meeting the Y70-150 [Ref. 4.31] full water reflection requirement, some guidance is developed here.

Y70-150 [Ref. 4.31] requires in Appendix B, item 9 that "Any single fissile unit shall be shown to be subcritical under full (12 inch thick) tight fitting water reflection" [Design Input 2.22]. Appendix A of that procedure gives a definition for *fissile unit*, which includes single parts, single process containers, and most groups of portable items that are controlled as a single item under container handling requirements [Design Input 2.23]. The Y70-150 requirement, along with the fissile unit definition, indicates that the concern is for portable items that are moved around the facility outside of single processes, such that the reflection conditions present at any time may not be completely known. It also indicates that a group of items handled as a single unit does not need to have the reflecting material present in-between the items, where it may act as a moderator. A single item with reentrant surfaces should be examined using various configurations of water reflection, including various amounts of water inside the reentrant volumes, to determine the most conservative reflection conditions.

For implementation of the Y70-150 requirement, the thickness is specified, so 12 in. must be used. This is considered effectively infinite water reflection, as discussed in Refs. 4.14 and 4.19, which list 300 mm (11.8 in.) thickness of water reflection as effectively infinite [Design Input 2.24]. Therefore, further thickness of water reflection should have no effect. In the same reference section, it is stated that the effectiveness of hydrocarbons saturates at about 100 mm (4 in.) and is illustrated in Fig. 21 of the reference. [Fig. 2.4-1, Design Input 2.25]. That original figure is misleading, due to plotting errors. The data from Fig. 21 of Ref. 4.19 is replotted in Fig. 6.4-1, with the thickest reflector point correctly shown at 25.0 or 25.4 cm thickness, as given in the data of Table XX on page 42 of Ref. 4.19, rather than as erroneously shown in the original figure (at 20.0 cm thickness). Reflector effectiveness is indicated by the critical mass to bare critical mass ratio shown in Figure 6.4-1. From this graph, it is clear that the slope does not change when the reflector is more than 15 cm (5.90 in.) thick, so it is concluded that 6 in. thickness of close-fitting water reflection can be considered effectively infinite.

Note that any displacement (off-setting) of a reflector from an item will result in some additional neutron leakage and absorption that will reduce the calculated k_{eff} of the system. This may be acceptable for situations in which documented analysis determines it is not credible to have a thick reflector that matches the fissile unit contours.

Guidance for implementation of the Y70-150 requirement that full water reflection on a single fissile unit shall be shown to be subcritical:

- This need only be applied to portable items that are moved around the facility outside of the bounds of a specific process location or process enclosure/glovebox system.
- The requirement should also be applied to a group of items that are handled as a single unit, such as a group of sample bottles.
- For groups of items that are handled as a single unit, there is no need to include water between the units, such that it is an interstitial moderator.
- 12 in. thickness of water is considered effectively infinite water reflection.
- Calculations with close-fitting water approximately 12 in. thick (i.e., 30 cm) are judged to satisfy the full water reflection requirement from Y70-150. Thicknesses greater than 6 in. could also be argued to meet the intent of the requirement but do not meet the 12 in. that is specified.
- Displacement (off-setting) of a reflector will result in some additional neutron leakage and absorption and will reduce the calculated k-effective of the system. This may be acceptable for situations in

which documented analysis determines it is not credible to have a thick reflector that matches the fissile unit contours.

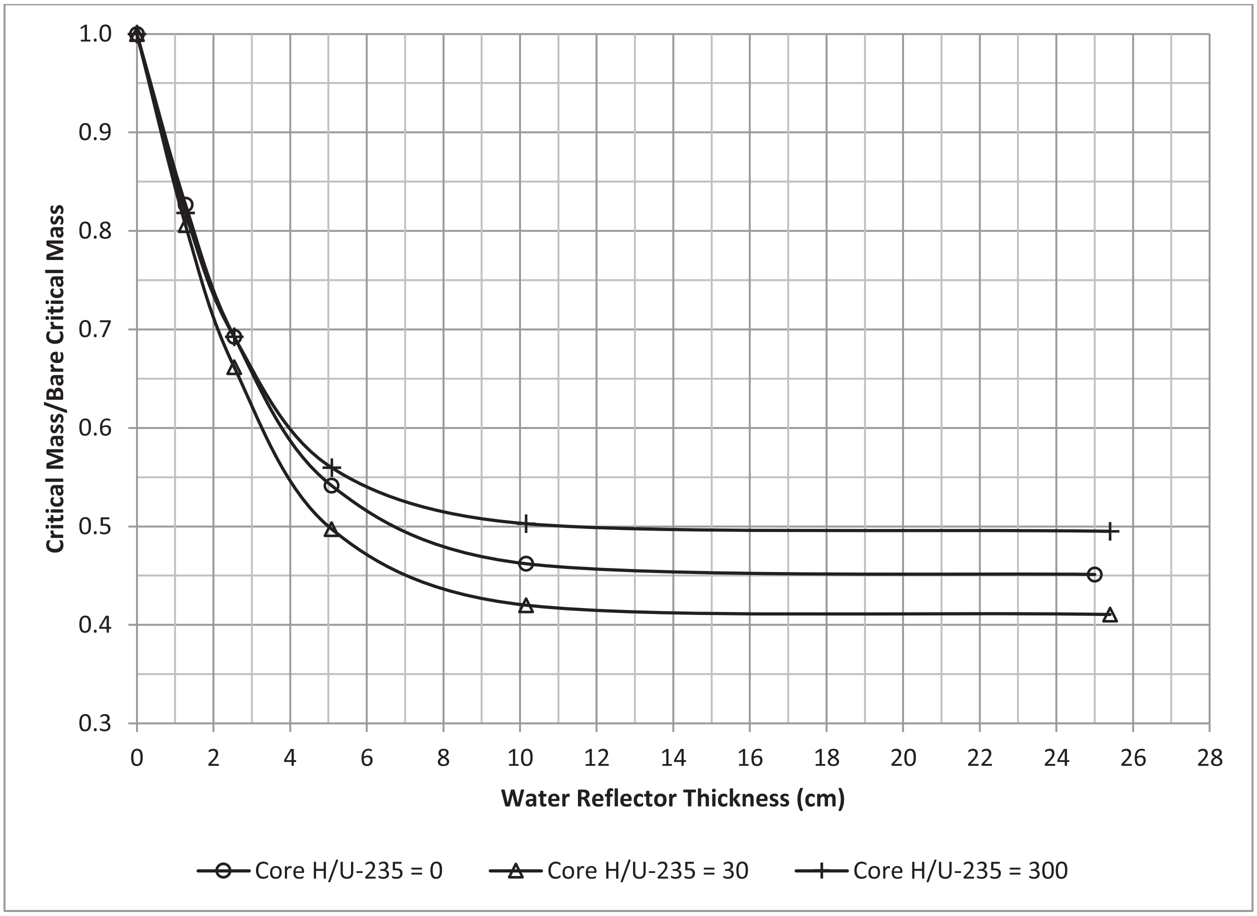


Fig. 6.4-1. Reflected critical mass vs. water reflector thickness [Ref. 4.19].

6.4.1.2 Reflection from Hands on Small Items

An operator's hands around a small item, such as a fissile container are considered bounded by 0.5-in.-thick tight-fitting contiguous water. Although parts of the hands may be thicker than this, hands cannot completely surround a can with no leakage paths. This is illustrated by Fig. 6.4-2, which is excerpted from Ref. 4.11. This shows results of experimental data collected for various combinations of operator hands on spherical systems of uranium metal and Lucite. The spherical system contained 23 kg U (93% enriched) with an OD of 6.24 in. The data shows that 0.9-cm (0.354-in.)-thick water reflection bounds any pair of operator hands and most sets of three or four hands in the experiment. This indicates that ½-in.-thick water reflection is a conservative reflection condition for a hand-held item.

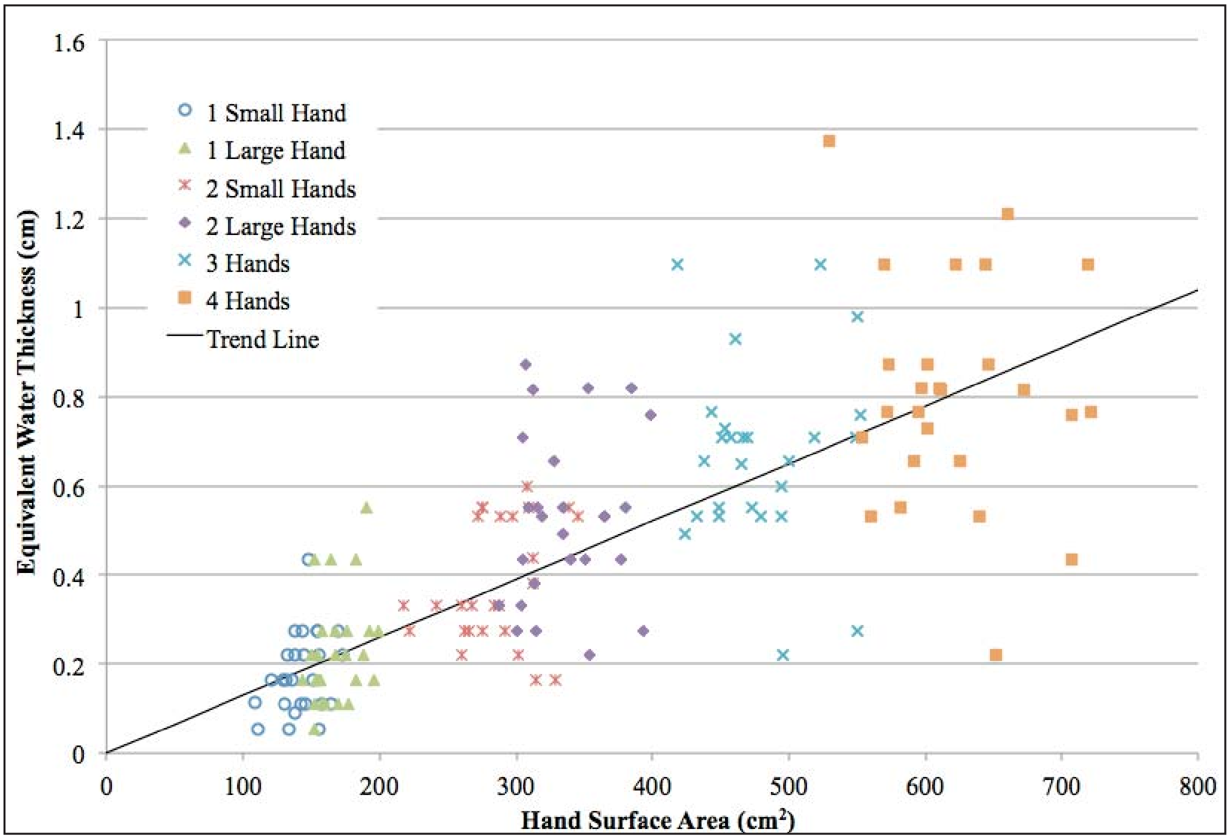


Fig. 6.4-2. Reflector value of operator hands.

(Source: Percher and Heinrichs)

6.4.1.3 Standard Glovebox, Airlock, and Hood (Enclosure)

Several design inputs and assumptions are used to develop standardized model guidance for gloveboxes. This guidance generally applies to all gloveboxes, airlocks, and hoods. If specific design inputs are available, then specific models should be developed that are conservative with respect to those design inputs. This guidance is only applicable in the absence of process-specific information.

Floors

The steel floors of gloveboxes and associated enclosures are controlled to at least 7 ga. thickness by a design criterion [Design Input 2.33]. This is equal to 3/16 in. (0.1875 in.) for steel [Design Input 2.34]. For conservatism, this value was rounded up to ¼ in. thickness recommended for NCS calculations early in the project [Assumption 3.8]. However, note that this is a minimum thickness, and gloveboxes that must hold heavy equipment, contain Magna-motion carts, or withstand vibrations or large shock forces will be designed with thicker floors. The designs also have varying amounts of additional structural bracing and process equipment, such as motors and pumps, under the glovebox floors. Therefore, actual process-specific designs should be used, if available, with additional reflection included for support structure and equipment under the glovebox. In the absence of specific process-based justifications, a minimum ½-in.-thick floor is now recommended for general use.

In Ref. 4.32, Figs. 44 and 46 [Design Input 2.36], the thickness of various reflectors around uranium spheres are plotted against the critical mass of 93.5% enriched metal (in Fig. 44) and against the critical volume of low-enriched uranium that is well-moderated (in Fig. 46). Both figures indicate that the same thickness of water is is approximately equal to steel at thicknesses under about 2 in. Therefore, water can be substituted for the same thickness of steel on the floor of the gloveboxes. If steel in an important reflector for the system being analyzed specific computations using both steel and water should be performed to understand the differences.

The floor of gloveboxes should be modeled as follows:

- Thickness of the model should be based on specific process designs. Additional thickness can be included to account for structural beams and equipment under the glovebox floor, if these items are not specifically modeled.
- In the absence of specific thickness data, a thickness of 0.25 in. can be used only for light-duty processes (those with no heavy equipment, no Magna-motion carts, and no large shock forces). In addition, highly reflecting items such as pumps and reservoirs under the glovebox must be accounted for.
- In the absence of specific thickness data, a thickness of 0.5 in. should be used. Additional thickness or specific additional items should be added to the model, when highly reflecting equipment such as pumps and liquid tanks are present under the floor.

Walls and Roof

The standard for windows is 3/8 in. Lexan, which is a polycarbonate [Design Input 2.35]. It is assumed that this material is bounded by a slab of 1-in.-thick full-density water [Assumption 3.6]. The remaining parts of the glovebox walls and roof are relatively thinner sheet metal, compared to the floor, since they do not withstand the same load distributions [Assumption 3.9]. From the discussion of Ref. 4.32 figures showing reflection effects, the steel walls are clearly bounded by 1-in. thick water reflection. The exact configuration of window versus metal for the walls and roofs may not be known, but it is concluded that the average reflection to items inside gloveboxes is bounded by a slab of 1-in.-thick full-density water at the location of all sides and roofs [Assumption 3.6].

The walls, windows, and roof of gloveboxes and other enclosures can be modelled as 1-in.-thick full-density water. Note that presence of significant highly reflecting items on glovebox roofs must be accounted for, especially for operations that may be near the roof of a glovebox.

6.4.1.4 Reflection around Enclosures and Other Equipment

Rooms and Building Structure

The concrete reflection from the floors, walls, and ceilings of rooms surrounding fissile operations must be considered. As discussed in Sect. 2.4.1.4, current building design shows the concrete rooms are about 120 ft × 100 ft × 20 ft high. Thus, any specific process system (such as a glovebox/enclosure, a bank of tanks, a solution vessel and associated pumps and equipment, or a set of storage racks) will only be significantly reflected by one corner of the typical concrete room. Therefore, it is not necessary to fully enclose equipment in a small concrete room, and the bounding concrete reflection should be a corner with two thick concrete walls and a floor and ceiling separated by up to 20 ft. Guidance on the thickness of concrete to use is given in Sect. 6.4.1.5. Room size determined from preliminary drawings is acceptable, because bounding and conservative concrete thicknesses are used.

When the entire room is not enclosed in concrete other walls and equipment become much more important as reflecting materials (or possibly fissile-interactions) for the other two sides. The composition and thickness of the Hazardous Liquid Processing Room (HLPR) walls or other non-structural gypsum-covered metal stud walls is not clear from the referenced drawings, so an assumption is made that these can be bounded by 2-in.-thick water [Assumption 3.3]. The 2-in. thickness is chosen to be bounding of two glovebox walls and is the thickness of water that is essentially infinite as a close fitting reflector as shown in Section 2.4.1.1, Fig. 2.4-1. The intent of this is to provide sufficient reflection to mimic the walls but not isolate the components in the room. Therefore, in the absence of specific information, 2-in.-thick water walls can substitute for non-concrete walls in the vicinity of a process.

Equipment layout drawings (ELDs) show the locations of gloveboxes within rooms and should be used to justify room dimensions and spacing from the room structure. In general, closer reflection from concrete is more conservative than farther away. In the absence of specific design information (and associated CSPS controls), the following spacing can be relied upon from the design criteria [Design Input 2.37]:

- Spacing from walls: minimum 35 in. for gloveboxes,
- Spacing from floor: minimum: 35 in. for gloveboxes and other equipment unless otherwise specified for the process.

Spacing from walls should be based on design information and controlled with CSPS controls. Other components in the vicinity of the process produce reflection that should be considered. To represent extraneous room reflection 1 in. water walls can be modeled 35-in. from the edge of the fissile containing component; e.g. tank, glovebox, pump, seal pot, etc. These walls should be on the two sides of the component that is not reflected by concrete. It is not necessary to model any portion of the room or other components beyond the 1-in. water walls.

Operators

Operators are good reflectors for fissile materials, since humans are composed largely of water. The model for a standard operator is discussed in Sect. 6.4.1.6. An assumption [Assumption 3.7] is made for the numbers of operator reflectors that are considered bounding of typical UPF operations as follows:

- Number per workstation: 2
- Number by storage rack: 2
- Number per bank of up to 10 tanks: 1

For workstations and racks, fissile material items typically only need one operator at a time. Operations should not require help in manual lifting at glovebox workstations because hoists are available for items more than 15 lb per design criteria [Design Input 2.38]. For workstations within gloveboxes, two operators will typically cover the area in front of a workstation, so there is no need to model more. Similarly, standard fissile container racks have hoists for lifting containers. Two operators should be included since one may be operating the lift and the other may be pulling the shelf out or entering storage data. Note that this is considered for typical operations, and each process should make a determination whether special conditions exist that would introduce more operators.

Tanks will be contained within gloveboxes or MAEs, so operators will not have routine access to stand close to them. The non-routine operations involving access to tanks within MAEs will typically focus on just one tank. In addition, these non-routine operations frequently are for maintenance, which is performed on drained equipment.

Standard Atmosphere

By volume, standard atmosphere is approximately 77% Nitrogen and 23% Oxygen with other trace elements and compounds (including water vapor) at a total air density of approximately 0.0012 g/cm^3. This is approximately 830 times less dense than water, which is composed of oxygen and hydrogen [Ref. 4.18]. Hydrogen, Oxygen and Nitrogen all have similar total cross sections. A neutron has an average mean free path in water of ~2 cm so the mean free path of a neutron in air would be about 50 feet. Given the large mean free path relative to the size of the UPF building there is no measurable difference between modeling room atmosphere as air or void.

In all UPF buildings, under normal conditions and for consistency, the preferred method is to model standard air as void.

6.4.1.5 Standard Concrete Room Wall Thickness

The standard UPF room has structural walls, ceiling, and floor of varying concrete thicknesses, but most walls and the building foundation are at least 24 in. thick. The use of structure thicknesses from preliminary drawings is acceptable, because bounding and conservative concrete thicknesses are recommended. For concrete floors, ceilings, and walls as planar reflectors, at least 18 in. is sufficient (effectively infinite), and thicker structures need not be specifically modelled.

Section 6.3.7 gives justification for using Magnuson concrete mixture in models. The effects of 45-cm (18-in.)-thick concrete may be considered effectively infinite [Design Input 2.21]. The range of concrete types indicates that the data should be applicable to all concrete mixtures and should apply to UPF concrete [Assumption 3.10]. Therefore, models for concrete floors, ceilings, and walls as planar reflectors that are at least 18 in. thick are sufficient, and thicker structures need not be specifically modelled.

Some items penetrate or protrude through the concrete surfaces, such as multi-story tanks that extend through room ceilings, transfer pipes and drains that penetrate walls, and drains embedded in floors. For these items, a thicker or thinner concrete slab may be needed in the model due to competing effects. The thickness of the concrete slab is the length of the item that is reflected radially by the concrete, so a thicker slab will have more reflection around the items penetrating it. Tanks that penetrate concrete ceilings are typically designed with an air space around the tank or bank of tanks. The space is typically a rectangular opening, prompting the common nickname of “toaster slot.” The airspace offsets may make the thickness of the slab for reflection more important, since a large air space offset could cause more neutron losses than a more close-fitting slab of lesser thickness. The opposite effect is seen for thicker concrete that may be isolating interaction of items that are below the slab (such as tanks or equipment that are near the penetration) from items above the slab (such as the tops of the penetrating tanks or other equipment nearby).

The slab thickness and offset should be determined by parametric studies to find optimum reflection conditions and limited by controls (CSPS requirements or design criteria) for cases where optimum conditions are not acceptable.

6.4.1.6 Standard Person

A standard water person model was developed in Ref. 4.1. It was a cuboid of full-density water with dimensions 183 cm tall, 37.13 cm wide, and 12.38 cm deep [Design Input 2.32]. For conservatism and simplicity in modeling, the width is rounded up to 38 cm and the depth is rounded up to 15 cm.

A standard person is modeled as a cuboid of full-density water that is 183 cm tall, 38 cm wide, and 15 cm deep (~104 kg).

6.5 SPRINKLER EFFECTS

When performing computer calculations that address the effects from sprinkler activation, water density in air and water film thickness on items must be considered.

A few precautions should be considered when performing criticality calculations for arrays of fissile units. First, it should be recognized that the most significant effect of sprinkler discharge on array reactivity is most likely that from the water film. When using limited values of interspersed water density in criticality calculations (in lieu of analysis over the full range of water densities), it is imperative that the effects from the water film not be neglected. Although inclusion of the water film will most likely increase array reactivity, there are numerous competing effects that impact interaction between units and single unit reactivity, so comparison cases with and without the water film should be modeled to confirm that its inclusion is indeed conservative. Consideration must be given to fissile items and surrounding surfaces or structures that have the ability to retain water, such as insulation. Finally, the calculation results should be examined to ensure that sufficient margin in k_{eff} exists to demonstrate subcriticality.

6.5.1 Evaluating Atmospheric Water from Sprinklers

The maximum sprinkler water density achieved in experiments [Ref. 4.13, 4.54] was less than 0.0005 g/cm^3 [Design Input 2.28]. The reference report data provide a basis for specifying 0.10 g/cm^3 (approximately 10% of theoretical water density) as an upper limit for the evaluation of water densities from fire sprinkler activation. Interstitial sprinkler water density shall be evaluated from 0.0 g/cm^3 through 0.9982 g/cm^3. To understand the effects of interstitial moderation, sprinkler water densities will be evaluated between 0 (void) and 0.1 g/cm^3 using a sufficient number of points to clearly discern inflections points in the k_{eff} as a function of water density and between 0.1 g/cm^3 and full density water using a sufficient number of points to clearly identify the shape of the curve. If the range from zero to 0.10 g/cm^3 is shown to be acceptable, no assumptions regarding sprinkler water density are needed in the analysis (CSPS). If the results are not below 0.9 for any part of the range below 0.10 g/cm^3, this fact should be highlighted in the results of the DAC, so that an assumption on maximum sprinkler density can be included in the analysis (CSPS).

6.5.2 Water Film Thickness from Fire Sprinklers

Fire sprinkler activation results in interspersed water moderation but also forms a film or coating of water on items. Y/DD-762 [Ref. 4.12] concludes that a film thickness of 3.5 mm (0.35 cm) is the maximum expected for non-horizontal surfaces [Design Input 2.29]. A water film thickness of 7 mm (0.7 cm) should be used on horizontal surfaces [Design Input 2.29].

When modeling the results of fire sprinkler activation, a water film thickness of 0.35 cm is placed on non-horizontal surfaces, and a water film thickness of 0.70 cm is placed on horizontal surfaces.

6.5.3 Liquid Level on Room Floor due to spill and Water from Sprinklers

DAC-EN-801768-A119 [Ref. 4.56] contains a study of all fissile liquids in the Main Production Building (MPB), Salvage and Accountability Building (SAB), and Personnel Support Building (PSB). All tanks and carts that could contain fissile liquids are included at the maximum uranium content anticipated for the item. [Ref. 4.33] CSPS-EN-801768-ARAY-B001, Rev. A, control 6.3.2 [Ref. 4.58] limits the liquid fissile contents of a vestibule to a maximum of 2 Liquid Transfer Carts (LTCs). For batches of tanks the maximum uranium concentration in any tank is assumed to be in all tanks. The MPB is then divided into areas based on processes (i.e. SOX, Pickling NDA, Chemical Recovery, etc.)

Floor areas are determined based on Rev. B drawings of the buildings. Two different methods were then used to reduce the floor area available due to placement of skids and equipment. Method 1 uses a plan view of the process area and subtracts the areas occupied by skids and equipment from the total area. The free space is then either the free area (total – equipment) or 55% of the total process area, whichever is smaller.

Method 2 is based on white space report COI-ED-801768-A139, *White Space count for Criticality Safety in support of liquid management* [Ref. 4.88] that excludes areas occupied by equipment 1-in. above the floor. The free space is then set to either the listed free area of 75% of the total area, whichever is smaller. Since many tanks and skids are raised above the floor method 2 results in larger areas for the spill to accumulate thus reducing the spill height. In both method 1 & 2 vestibules have an assumed free space of 95% since they contain no permanent equipment. All fissile liquids on the 2nd and 3rd floors are assumed to drain to the main floor and add to the spill depth there. All fissile liquids in the area are simultaneously released to the floor.

The results of a calculational study in DAC-EN-801768-A119 [Ref. 4.56, Design Input 2.45] showed that the fissile liquid spill from all tanks, components, and liquid transfer carts in an area has a maximum level in all but 2 instances of less than 0.5 inch. In those 2 instances the uranium concentration in the spill was approximately 20 gU/l.

In all other cases for the spill to exceed a depth of 0.5-in. it needs to be diluted with fire sprinkler water. The study examines the result of increasing the spill depth by maintaining the amount of uranium and adding sprinkler water resulting in various depths from 0.75 –in. to 5-in. at diluted uranium concentrations. The study showed that, with the exception of two vestibules, fissile material spills in all areas result in uranium concentrations less than 40 g U/l at 1-in deep, 20 g U/l at 2-in. deep and 15 g U/l at 3-in. deep. Since the study assumed all fissile material in an area spilled to the floor with the highest system concentration, the spill scenarios listed in Table 6.5-1 conservatively cover all possible spill scenarios.

Table 6.5-1 Fissile Liquid Spill Depth and U Concentration

Spill Depth (in.)	Uranium Concentration (gU/cm^3)
0.5	200 or highest normal U-Concentration for process being modeled
1.0	40
2.0	20
3.0	15

Until the details of the UPF room sizes and fissile liquid inventory are known, the spill model shall use the spill depths and uranium concentrations from Table 6.5-1 in all UPF computations involving fissile material spills on room floors [Design Input 2.45]. However, since the current room sizes and fissile liquid inventory data are preliminary, the spill scenarios need to be carried as an assumption requiring confirmation in NCS DACs until the UPF room sizes and fissile material inventory are finalized.

6.6 STRUCTURAL MATERIALS INCLUDING PIPING AND TUBING

The methods for dealing with structural material are to ignore them between fissile material, include them as external reflectors (such as concrete or water walls), and include them in the analysis if uncertain. The use of structural materials introduces competing effects with respect to the overall k_{eff} of interacting fissile materials. In some cases, structural materials between units increase neutron multiplication because they can be effective reflectors for single units or moderators between units. In other cases, structural materials between units decrease neutron multiplication because they isolate units by absorbing neutrons. The overall effects of structural materials are often counterproductive and counterintuitive. Examples include close contact between pipes and thick structural steel posts or beams, or sheet steel walls. If the effects of structural materials are uncertain, models should be included that both contain and eliminate the structural material so that their overall reactivity effects on the system are understood.

When using any structural material, the sensitivity to material properties and dimensions needs to be addressed and understood. Analysts should refer to the computer code validations for all materials of construction and be especially vigilant for chlorine and other uncommon materials of construction that may not be adequately covered in the benchmark cases. Using a less conservative method for modeling the system may require periodic inspection to ensure the structural material has not degraded beyond the values considered.

The UPF project will not rely on neutron absorbers for criticality control unless specifically pre-approved by the UPF NCS Chief Engineer. Reliance on strong neutron absorbers in the structural material (e.g., B and Cd) may invoke one of the NCS Program's Fundamental Criteria [Y70-150, Appendix B], which states that "the use of neutron absorbers as a primary criticality safety control should receive review and concurrence by the Y-12 Nuclear Criticality Safety Committee and shall be approved by the Y-12 NCS functional area manager."

6.6.1 Pipe and Tube Dimensions

The pipe and tube dimensions are listed in Tables 6.6-1, 6.6-2, and 6.6-3, which are generated from the raw data in Table 2.6-1, 2.6-2, and 2.6-3. Maximum outer diameters in inches and maximum outer radii in cm are calculated based on nominal inner diameters, wall thickness and tolerances or outer diameters and tolerances. When the inner diameter and wall thickness are specified the maximum outer diameter is determined by adding the inside diameter and tolerance to twice the sum of the wall thickness and tolerance. When the outer diameter is specified the maximum outer diameter is determined by adding the nominal outside diameter and the tolerance. The maximum outer diameter is then converted to the maximum outer radius since most computer codes use the radius as an input.

When modeling tanks, pipes, trays, containers and other fissile-bearing items, the displacement of uranium material and the neutron absorption of structural material are ignored in computer calculations. Fissile material is modeled to the outer dimension of the item plus tolerance. This will ensure that the fissile geometry will be adequately conservative with allowance for corrosion and erosion.

Pipe size is specified by the NPS Designator. Specification ASTM A312 [Ref. 4.7] contains the specifications and tolerances for stainless steel tubing. Table 6.6-1 contains the NPS Designator, outer diameter, nominal wall thickness for schedule 40 pipe, outer diameter tolerance, maximum outer diameter in inches, and maximum outer radius in cm. Note that all columns except column 3 apply to all pipe schedules.

Table 6.6-1. Pipe Dimensions per ASTM 312

NPS Designator	Outer Diameter (in.)	Nominal Wall Thickness Sch 40 (in.)	Outer Diameter Tolerance[1] (in.)	Maximum Outer Diameter (in.)	Maximum Outer Radius (cm)
1⁄8	0.405	0.068	1/64	0.421	0.534
1⁄4	0.540	0.088	1/64	0.556	0.705
3⁄8	0.675	0.091	1/64	0.691	0.877
1⁄2	0.840	0.109	1/64	0.856	1.086
3⁄4	1.050	0.113	1/64	1.066	1.353
1	1.315	0.133	1/64	1.331	1.689
1 1⁄4	1.660	0.140	1/64	1.676	2.128
1 1⁄2	1.900	0.145	1/64	1.916	2.432
2	2.375	0.154	1/32	2.406 (2.5)[2]	3.055 (3.175)[2]
2 1⁄2	2.875	0.203	1/32	2.906	3.690
3	3.500	0.216	1/32	3.531	4.484
3 1⁄2	4.000	0.226	1/32	4.031	5.119
4	4.500	0.237	1/32	4.531	5.754

Table 6.6-1. Pipe Dimensions per ASTM 312

NPS Designator	Outer Diameter (in.)	Nominal Wall Thickness Sch 40 (in.)	Outer Diameter Tolerance[1] (in.)	Maximum Outer Diameter (in.)	Maximum Outer Radius (cm)
5	5.563	0.258	1/16	5.626 (5.65)[3]	7.144 (7.1755)[3]
6	6.625	0.280	1/16	6.688	8.493
8	8.625	0.322	1/16	8.688	11.033
10	10.750	0.365	3/32	10.844	13.771
12	12.750	0.375	3/32	12.844	16.311

[1]The tolerance is added to the outside dimension to determine the maximum outer dimension.
[2]Value increased to be in agreement with Design Criteria DC-2-302.8.10.1 & DC-2-302.10.2.2.4 [Ref. 4.35].
[3]Value increased to be in agreement with Design Criteria DC-2-302.9.1.3.2 & DC-2-302.10.1.1 [Ref. 4.35].

Tubing size is specified by its nominal outer diameter in inches. Specification ASTM A554 [Ref. 4.8] contains the specifications and tolerances for stainless steel tubing. Table 6.6-2 contains the outer diameter, tolerance, maximum outer diameter in inches, and maximum outer radius in cm.

Table 6.6-2. Tube Dimensions per ASTM 554

Outer Diameter (in.)	Outer Diameter Tolerance (in.)	Maximum Outer Diameter (in.)	Maximum Outer Radius (cm)
0.25	0.004	0.254	0.323
0.375	0.004	0.379	0.481
0.5	0.010	0.510	0.647
1.0	0.010	1.010	1.282
1.5	0.010	1.510	1.917
2.0	0.012	2.012	2.555
2.5	0.014	2.514	3.192
3.0	0.020	3.020	3.835
3.5	0.020	3.520	4.470
4.0	0.025	4.025	5.111
4.5	0.025	4.525	5.746
5.0	0.025	5.025	6.381
5.5	0.030	5.530	7.023
6.0	0.030	6.030	7.658
6.5	0.030	6.530	8.293
7.0	0.030	7.030	8.928
7.5	0.030	7.530	9.563
8.0	0.031	8.031	10.199
8.5	0.033	8.533	10.836
9.0	0.035	9.035	11.474
9.5	0.037	9.537	12.111
10.0	0.039	10.039	12.749

Glass Tubing size is specified by its inner diameter, wall thickness, and tolerances. Ref. 4.47 contains the specifications and tolerances for Precision Bore Glass Tubing from the Duran Group. Table 6.6-3 contains the inner diameter ± tolerance in mm, wall thickness ± tolerance in mm, maximum outer diameter in inches, and maximum outer radius in cm.

Table 6.6-3 Glass Tube Dimensions per Ref. 4.47

Inner Diameter (mm)	ID Tolerance (mm)	Wall Thickness (mm)	Wall Thickness Tolerance (mm)	Maximum Outer Diameter (in.)	Maximum Outer Radius (cm)
70	0.03	9.20	0.90	3.5524	4.5115
75	0.03	9.70	0.90	3.7886	4.8115
80	0.03	9.20	1.00	3.9539	5.0215
85	0.03	9.60	1.00	4.1823	5.3115
90	0.03	10.00	1.00	4.4106	5.6015
95	0.03	9.60	1.00	4.5760	5.8115
100	0.04	9.50	1.00	4.7654	6.0520
110	0.04	7.30	1.00	4.9858	6.3320
120	0.04	9.80	1.10	5.5843	7.0920
140	0.04	9.70	1.20	6.3717	8.0920
150	0.05	9.60	1.30	6.7657	8.5925
160	0.05	7.20	1.10	6.9547	8.8325
200	0.07	9.30	1.40	8.7193	11.0735
210	0.07	9.50	1.40	9.1287	11.5935
225	0.08	9.30	2.00	9.7512	12.3840

6.6.2 Piping System Specifications

Pipe used within UPF is classified based on the type of service it will encounter as found in Table 6.6-3. The different classifications of pipe are depicted on drawings as a number associated with the section of pipe (the line specification). Some of the more common UPF pipe specifications are given in Table 6.6-4.

Table 6.6-4 Pipe Systems Material, Service, and Scope

Line Specification	Systems	Service Requirements
400513.19	STAINLESS STEEL SYSTEMS (UTILITY SERVICE)	Stainless steel (schedule 40S) Normal Fluid Service Piping (as defined by ASME B31.3). This piping does not contain uranium or nitric acid solutions during normal operations. The maximum temperature and pressure for this specification is 375°F (190.6°C) and 165 psig.
400513.20	STAINLESS STEEL SYSTEMS (CATEGORY D SERVICE)	Stainless steel (schedule 10S) Normal Fluid Service Piping (as defined by ASME B31.3) for the process exhaust and process off-gas systems. In vacuum service for gases, the maximum temperature and vacuum pressure for this specification is 300°F (148.9°C) and 28-in. Hg (vacuum).

Table 6.6-4 Pipe Systems Material, Service, and Scope

Line Specification	Systems	Service Requirements
400513.21	STAINLESS STEEL SYSTEMS (CATEGORY D SERVICE)	Stainless steel (schedule 40S) Category D Service Piping (as defined by ASME B31.3). The maximum temperature and pressure for this specification is 300°F (148.9°C) and 150 psig.
402513.30	STAINLESS STEEL SYSTEMS (NITRIC ACID, SEVERE SERVICE SYSTEMS)	Stainless steel (schedule 40S) Normal Fluid Service Piping (as defined by ASME B31.3) for severe service nitric acid and/or uranium-bearing solutions greater than 40% nitric acid concentration by weight or less than 40% nitric acid but with elevated temperatures greater than 120°F (48.9°C). The maximum temperature and pressure for this specification is 375°F (190.6°C) and 165 psig.
402513.31	STAINLESS STEEL SYSTEMS (MODERATE SERVICE NITRIC ACID AND URANIUM PROCESS SYSTEMS)	Stainless steel (schedule 40S) Normal Fluid Service Piping (as defined by ASME B31.3) for nitric acid and/or uranium-bearing solutions with up to 40% nitric acid concentration by weight. The maximum temperature and pressure for this specification is 120°F (48.9°C) and 200 psig for process solutions above 10% HNO_3 and sodium hydroxide; while a solution having a HNO_3 concentration at or below 10% may have a maximum temperature and pressure of 220°F (104.4°C) and 200 psig. In vacuum service for gases, the maximum temperature and vacuum pressure for this specification is 220°F (104.4°C) and 1×10^{-8} torr (vacuum).
402513.32	STAINLESS STEEL SYSTEMS (MODERATE SERVICE NITRIC ACID AND URANIUM PROCESS SYSTEMS LOCATED IN NON-LGEAS)	Stainless steel (schedule 40S) Normal Fluid Service Piping (as defined by ASME B31.3) for nitric acid and/or uranium-bearing solutions with up to 40% nitric acid concentration by weight. The maximum temperature and pressure for this specification is 120°F (48.9°C) and 200 psig for process solutions above 10% HNO_3; while a solution having a HNO_3 concentration at or below 10% may have a maximum temperature and pressure of 220°F (104.4°C) and 200 psig. This specification includes the piping that runs between MAEs and/or LGEAs through non- LGEAs.
400513.43	HASTELLOY C-276 SYSTEMS	Hastelloy (schedule 40) Category M Fluid Service Piping (as defined by ASME B31.3) for highly corrosive process solutions low carbon nickel-molybdenum-chromium Alloy UNS N10276 Hastelloy (a registered trademark of Cabot Corporation) C-276 piping systems is the material utilized for this service. The maximum temperature and pressure for this specification is 400°F (204.4°C) and 150 psig.
402513.60	STAINLESS STEEL SYSTEMS (HIGH TEMPERATURE SERVICES)	Stainless steel (schedule 40S) Normal Fluid Service (severe cyclic conditions) (as defined by ASME B31.3) for nitric acid and/or uranium-bearing process exhaust gases. The maximum temperature and pressure for this specification is to 1200°F (648.9°C) and up to 150 psig. The specification is rated for Process Vacuum (VPR) levels of 10^{-8} torr.

6.7 AVOGADRO'S CONSTANT

Table 6.7-1 contains the value listed in Table 3.7-1 rounded to four figures past the decimal.

Table 6.7-1. Miscellaneous Physics Constants

Description	Symbol	Value	Units
Avogadro's Constant	N_A	6.0221×10^{23}	Entities/Mole

6.8 CONTAINERS

There are 7 containers currently being analyzed for use in UPF: #3 inner can, #4 inner can, #5 inner can, tube vault can, #3 outer container, #4 outer container, and #5 outer container. The inner cans are used inside gloveboxes, hoods, and other places materials are processed. The inner cans generally do not move outside gloveboxes or hoods without being placed inside an appropriate outer container. Material will not directly be placed inside any of the outer containers. Instead, material will be placed in the inner can, which will then be placed inside an outer container. As indicated by the names: the #3 inner can is placed in the #3 outer container and the #4 inner can is place in the #4 outer container. Either the #5 inner can or the tube vault can may be placed in the #5 outer container.

6.8.1 Inner Cans

The #3 can, #4 can, #5 can, and tube vault can will be used to move and hold processed uranium at UPF. It is common NCS practice to model containers to their outer dimensions including tolerances. In keeping with that practice containers are modeled to their Outer Diameter (OD) plus tolerance and the height is modeled from the outside bottom to the outside top of the can with the lid. The applicable dimensions and tolerances are contained in Table 2.8-1. These values are used to determine the diameter and height of a right circular cylinder used to model the containers in NCS analyses. The sections below describe how the dimensions for each can are derived using the data in Table 2.8-1.

The #3, #4, and #5 inner cans all have a bead protruding outward around the circumference of the can that is approximately 0.44-in. wide and starts about 0.5-in. below the top rim. There is no specification on the drawings [Ref. 4.59, 4.60, and 4.61] showing how far it extends beyond the diameter of the can. Its purpose is simply to provide an extension around the can so the when the can is lifted, the lifting ring will not slide off the can. Based on a visual examination of the drawing it does not appear that this ring extends more than about 0.25-in. beyond the outer radius of the can and is therefore ignored.

The tube vault can has four small beads that protrude inward spaced along its height. Each of these beads is smaller than the bead in the #3, #4, and #5 cans and is similarly ignored.

The drawings which specify the inner cans [Ref. 4.59, 4.60, and 4.61] have can dimensions and tolerances in inches. The computer codes used to model these containers require dimensions in cm. Table 6.8-1 therefore contains the diameters and heights in inches as specified on the drawings and converted from inches to the radii and heights in cm, with 4 significant figures past the decimal point. Figure 6.8-1 shows an inner container with the limits for each of the dimensions listed in Table 6.8-1.

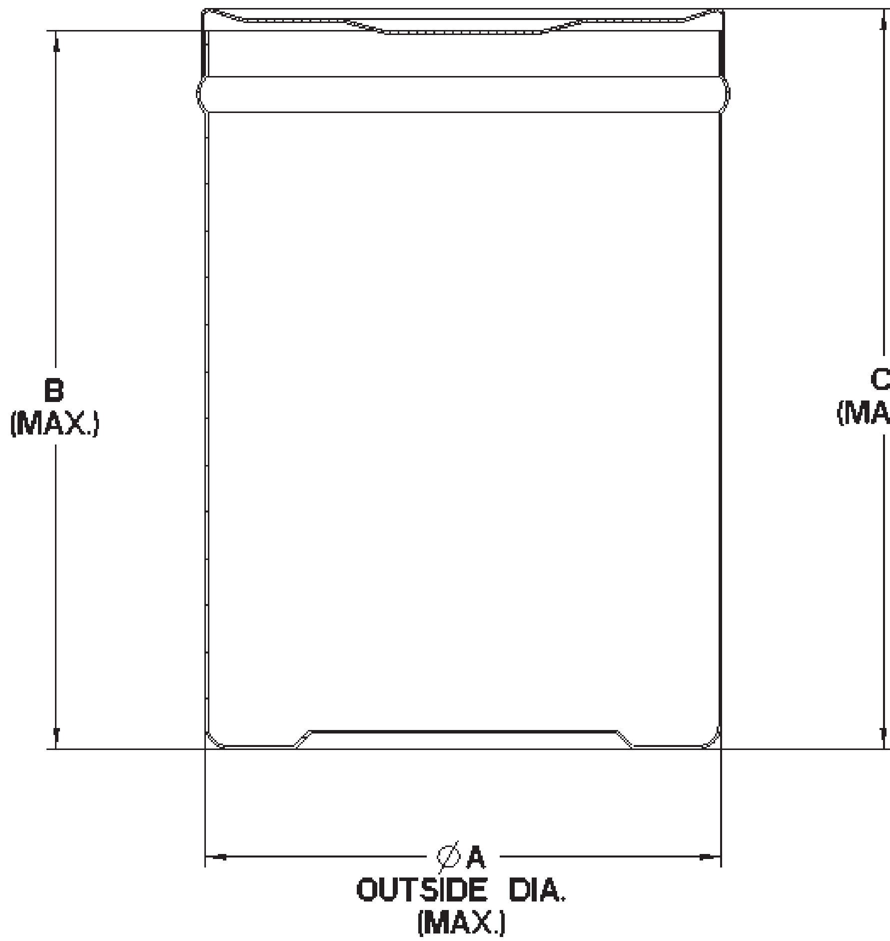


Fig. 6.8-1 Inner Container Dimensions for Table 6.8-1

6.8.1.1 #3 Inner Can

The diameter of the #3 inner can is determined by adding the nominal outside diameter (5.94-in.) to the tolerance (0.06-in.) in Table 2.8-1 plus an additional 0.06-in. to account for added uncertainties summing to a total diameter of 6.06-inches. The can height without lid is determined by adding the can height (4.40-in.) to the tolerance (0.06-in.) in Table 2.8-1 plus an additional 0.06-in. to account for added uncertainties, summing to a total height without lid of 4.52-inches. [Design Input 2.46] The maximum height of the #3 inner can listed in Table 2.8-1 (4.95-in.) is listed in the drawing M802228-0031. [Ref. 4.59] The outside diameter and height with lid were are used to determine the radius and height (cm) and the total volume (liters) listed in Table 6.8-1.

6.8.1.2 #4 Inner Can

The diameter of the #4 inner can is determined by adding the nominal outside diameter (4.84-in.) to the tolerance (0.06-in.) in Table 2.8-1 plus an additional 0.06-in. to account for added uncertainties, summing to a total diameter of 4.96-inches. The can height without lid is determined by adding the can height (10.00-in.) to the tolerance (0.06-in.) in Table 2.8-1 plus an additional 0.06-in. to account for added uncertainties, summing to a total height without lid of 10.12-inches. [Design Input 2.47]

The maximum height of the #4 inner can listed in Table 2.8-1 (10.59-in.) is listed in the drawing M802228-0036. [Ref. 4.60] The outside diameter and height with lid were are used to determine the radius and height (cm) and the total volume (liters) listed in Table 6.8-1.

6.8.1.3 #5 Inner Can

The diameter of the #5 inner can is determined by adding the nominal outside diameter (5.94-in.) to the tolerance (0.06-in.) in Table 2.8-1 plus an additional 0.06-in. to account for added uncertainties, summing to a total diameter of 6.06-inches. The can height without lid is determined by adding the can height (8.25-in.) to the tolerance (0.06-in.) in Table 2.8-1 plus an additional 0.06-in. to account for added uncertainties, summing to a total height without lid of 8.37-inches. [Design Input 2.48] The maximum height of the #5 inner can listed in Table 2.8-1 (8.78-in.) is listed in the drawing M802228-0041. [Ref. 4.61] The outside diameter and height with lid were are used to determine the radius and height (cm) and the total volume (liters) listed in Table 6.8-1.

6.8.1.4 Tube Vault Can (TVC)

The diameter of the tube vault can is determined by adding the nominal outside diameter (6.059-in.) to the tolerance (0.031-in.) in Table 2.8-1 plus an additional 0.06-in. to account for added uncertainties, summing to a total diameter of 6.15-inches. Since the tube vault can has a crimp sealed lid, there is no separate slip fit lid that adds to the overall Tube Vault Can (TVC) height. [Design Input 2.49, Ref. 4.62] The height of the tube vault can is determined by adding the nominal outside height (8.750-in.) to the tolerance (0.031-in.) in Table 2.8-1 plus an additional 0.06-in. to account for added uncertainties, summing to a total height of 8.841-inches. The outside diameter and height with lid were used to determine the radius and height (cm) and the total volume (liters) listed in Table 6.8-1.

6.8.1.5 #5 Inner Can / Tube Vault Can Combined Model

Since both the #5 inner can and the tube vault can will fit inside the #5 outer container it is often advisable to use the maximum outer dimensions that are common to both when performing NCS analyses. Since the tube vault can has both a larger diameter and height both cans can be considered to be conservatively modeled by the tube vault can.

Table 6.8-1 Fissile Material Inner Container Dimensions

Container	(A) Outside Diameter (in.)	(B) Height w/o lid (in.)	(C) Height with lid (in.)	Radius (cm)	Height with lid (cm)	Volume (L)
#3 Inner Can	6.06	4.52	4.95	7.6962	12.5730	2.340
#4 Inner Can	4.96	10.12	10.59	6.2992	26.8986	3.353
#5 Inner Can	6.06	8.37	8.78	7.6962	22.3012	4.150
Tube Vault Can (TVC)	6.15	---	8.841	7.8105	22.4561	4.304
#5 Inner Can / TVC Combined Model	6.15	---	8.841	7.8105	22.4561	4.304

6.8.2 Outer Containers

The #3, #4, and #5 outer containers are used to move and hold processed uranium within #3, #4, and #5 cans and tube vault cans contained therein. The NCS model for outer containers is a right circular cylinder filled with the contents of the applicable inner can to the outer diameter of the container body. The maximum outer diameter is from the container bases [Ref. 4.65, 4.68, and 4.70]. The working diameter is the nominal outer dimension plus tolerance. The maximum container height is calculated using the overall height plus tolerance. For the #3 and #4 containers these values are explicitly provided on the drawings. For the #5 container the total maximum height needs to be derived by adding together component heights plus tolerances. All dimensions are from Table 2.8-2. Figure 6.8-2 shows an outer container with the limits for each of the dimensions listed in Table 6.8-2.

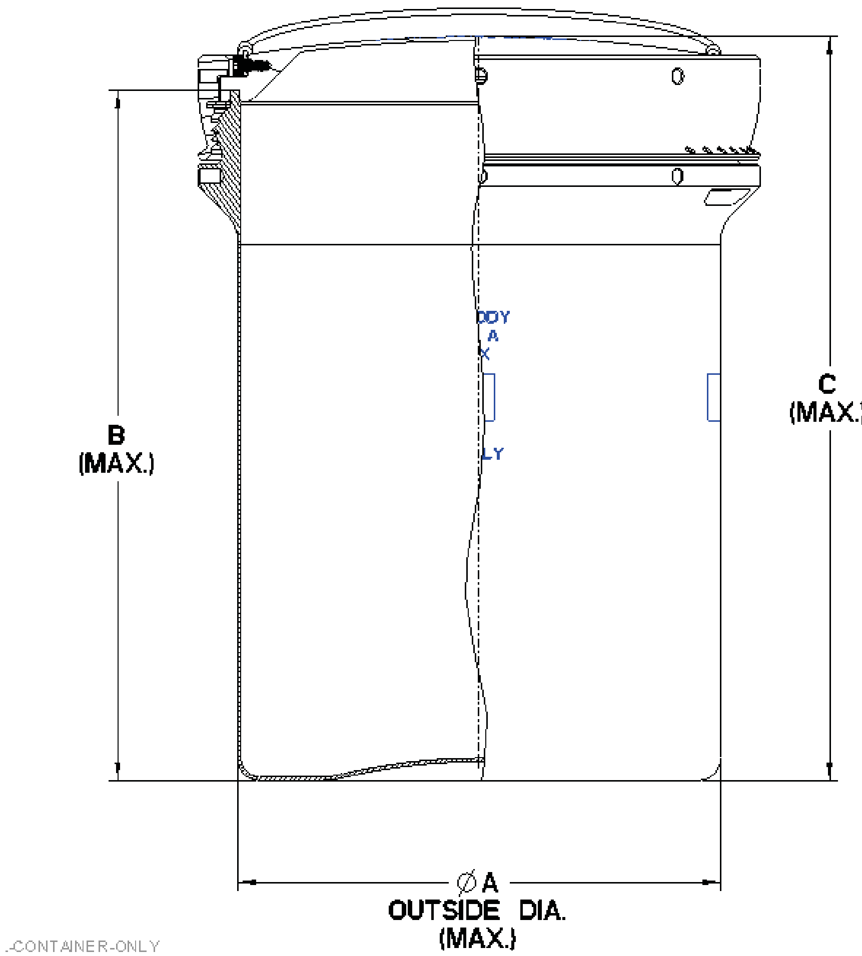


Fig. 6.8-2 Outer Container Dimensions for Table 6.8-2

Both the maximum diameter and height are rounded up to the nearest 0.1 inch. Since the computer codes used to model these containers require dimensions in cm these values are then converted from inches to cm with 4 significant figures past the decimal point. All values are listed below in Table 6.8-2.

6.8.2.1 #3 Outer Container

The maximum outer diameter is the sum of the outer diameter (6.536-in.), its tolerance (0.06-in.) resulting in 6.596 inches. This value is then rounded up to 6.6 inches. An additional 0.01-in. is added to account for uncertainties, resulting in an outside diameter of 6.61 inches. The can height w/o lid is the sum of its height (5.25-in.), its tolerance (0.02-in.) and an additional 0.06-in. to account for added uncertainties, resulting in a height of 5.33 inches. The overall height with lid is a sum of the outer height (5.96-in.) and its tolerance (0.01-in.) from Ref. 4.63, resulting in a height of 5.97 inches, which was rounded up to 6.0 inches. An additional 0.06-in. is then added to account for uncertainties, which results in a final outside height with lid of 6.06 inches. These values are listed in Table 6.8-2 below.

6.8.2.2 #4 Outer Container

The maximum outer diameter is the sum of the outer diameter (5.376-in.), its tolerance (0.06-in.) and an additional 0.06-in. to account for added uncertainties resulting in 5.496 inches. This value is then rounded up to 5.5 inches. The can height w/o lid is the sum of its height (11.00-in.), its tolerance (0.02-in.) and an additional 0.06-in. to account for added uncertainties, resulting in a height of 11.08 inches. The overall height is a sum of the outer height (11.60 in.) and its tolerance (0.01 in.) from Ref. 4.66, resulting in 11.61 inches, which is rounded up to 11.7 inches. An additional 0.06-in. is then added to account for uncertainties, which results in a final outside height with lid of 11.76 inches. These values are listed in Table 6.8-2 below.

6.8.2.3 #5 Outer Container

The maximum outer diameter is the sum of the outer diameter (6.536-in.) and its tolerance (0.06-in.) resulting in 6.596 inches. This value is then rounded up to 6.6 inches. An additional 0.01-in. is added to account for uncertainties, resulting in an outside diameter of 6.61 inches. The can height w/o lid is the sum of its height (9.35-in.), its tolerance (0.02-in.) and an additional 0.06-in. to account for added uncertainties, resulting in a height of 9.43 inches.

Unlike the #3 and #4 containers, the overall maximum height of the #5 container needs to be derived from the sum of several heights plus tolerances. The overall maximum height is a sum of the maximum inner height (9.72-in.), the distance from the top of the bottom curved section plus tolerance plus wall thickness plus tolerance, and the thickness of the top of can lid plus tolerance resulting in 10.153 inches, which is rounded up to 10.20 inches. An additional 0.06-in. is then added to account for uncertainties, which results in a final outside height with lid of 10.26 inches. These values are listed in Table 6.8-2 below.

Table 6.8-2 Fissile Material Outer Container Dimensions

Container	(A) Outside Diameter (in.)	(B) Height w/o lid (in.)	(C) Height with lid (in.)	Radius (cm)	Height with lid (cm)	Volume (L)
#3 Outer Container	6.61	5.33	6.06	8.3947	15.3924	3.408
#4 Outer Container	5.5	11.08	11.76	6.9850	29.8704	4.579
#5 Outer Container	6.61	9.43	10.26	8.3947	26.0604	5.770

The values in Table 6.8-2 are conservative, since they contain maximum dimensions, tolerances and additional margin to account for added uncertainties. These values should therefore be used as listed. For standard container models the outside diameter and height with lid should be used.

7. RESULTS

7.1 RESULTS SUMMARY

Table 7.1-1 summarizes the values developed for use as design inputs in typical NCS DACs.

Table 7.1-1 Summary Table of Results

Result Number	Description	Value	Units	Result Section
7.1	Elemental Atomic Mass and Densities, except uranium	As specified	g/mole, g/cm^3	Sect. 6.2.1, Table 6.2-1
7.2	Isotopic Atomic Mass , Isotopic Atom Percent and Isotopic Weight Percent for Natural Elements	As specified	g/mole Atom %	Sect. 6.2.2, Table 6.2-2
7.3	Uranium Enrichment (unless controlled by specification)	100	^{235}U %	Sect. 6.2.3
7.4	Uranium Density (^{235}U, theoretical)	18.81	g/cm^3	Sect. 6.3.1.1, Table 6.3-1
7.5	^{235}U Compound Densities—Theoretical UO_2 - Material, (Uranium) UO_3 - Material, (Uranium) U_3O_8 - Material, (Uranium) UF_4 - Material, (Uranium)	 10.85, (9.55) 7.22, (6.00) 8.29, (7.02) 6.64, (5.02)	g/cm^3, (gU/cm^3)	Sect. 6.3.1.1, Table 6.3-1
7.6	Hydration for "Dry" Material (H/U) UO_2 UO_3 U_3O_8 UF_4	 0.0 2.0 0.94 1.0	H/U atom ratio	Sect. 6.3.1.2, Table 6.3-2
7.7	Uranium Compound Bulk Density UO_2 UO_3 U_3O_8 UF_4	 4.0– 6.63 3.44 – 4.3 2.4 – 4.3 3.0 – 3.5	g/cm^3	Sect 6.3.1.3, Table 6.3-3
7.8	Optimum Moderation Values for Typical Bulk Powders for Volume-Limited Systems: UO_2 UO_3 U_3O_8 UF_4	 1.74 10.4 7.1 6.3	H/U atom ratio	Sect. 6.3.1.3, Table 6.3-3
7.9	Mixtures with several compounds can use highest density paired with highest credible H/U value.	Highest	N/A	Sect. 6.3.1.3
7.10	U-metal–Water Mixture Data	As specified	As specified	Sect. 6.3.1.4, Table 6.3-4
7.11	UO_2–Water Mixture Data	As specified	As specified	Sect. 6.3.1.4, Table 6.3-5
7.12	UO_3–Water Mixture Data	As specified	As specified	Sect. 6.3.1.4, Table 6.3-6
7.13	U_3O_8–Water Mixture Data	As specified	As specified	Sect. 6.3.1.4, Table 6.3-7
7.14	Uranyl Nitrate Solution Data	As specified	As specified	Sect. 6.3.2, Table 6.3-8
7.15	Uranyl Fluoride Solution Data	As specified	As specified	Sect. 6.3.2, Table 6.3-9

Table 7.1-1 Summary Table of Results

Result Number	Description	Value	Units	Result Section
7.16	Chemicals in Liquid Form	As specified	As specified	Sect. 6.3.3, Table 6.3-10
7.17	Non-Fissile Material Data	As specified	As specified	Sect. 6.3.4.1, Table 6.3-11
7.18	Alloy and Mixture Data	As specified	As specified	Sect. 6.3.4.2, Table 6.3-12
7.19	C-350 Specification: Hydrogen Carbon Oxygen Density	 10.49 32.60 56.91 1.0542	 wt % wt % wt % g/cm^3	Sect. 6.3.5
7.20	10 vol% C350–90 vol% Water Density	1.0038	g/cm^3	Sect. 6.3.5
7.21	Magnuson's Concrete Composition	As specified	As specified	Sect. 6.3.4.2,Table 6.3-12
7.22	Full Reflection Guidelines	As specified	As specified	Sect. 6.4.1.1
7.23	Effectively infinite water reflection thickness for close-fitting, contiguous reflection around a small item	≥ 6	in.	Sect. 6.4.1.1
7.24	Effectively infinite water reflection thickness (all situations)	≥ 12	in.	Sect. 6.4.1.1
7.25	Hand Reflection Thickness, Water	0.5	in.	Sect. 6.4.1.2
7.26	Effectively infinite concrete reflection thickness	≥ 18	in.	Sect. 6.4.1.5
7.27	Standard Person (Operator)—Water Cuboid Size Height Width Depth	 183 38 15	 cm cm cm	Sect. 6.4.1.6
7.28	Bounding atmospheric water density from sprinkler activation	0.00 – 0.10	g/cm^3	Sect. 6.5.1
7.29	Sprinkler Water Film Thickness Non-Horizontal Surfaces Horizontal Surfaces	 0.35 0.70	 cm cm	Sect. 6.5.2
7.30	Construction of Gloveboxes, Airlocks, Hoods Floor – 304 Stainless Steel minimum design thickness, from design criterion	7 0.1875	ga in.	Sect. 6.4.1.3 or design criteria
7.31	Gloveboxes, Airlocks, Hoods: Lexan MR-10 window nominal thickness, from design criterion	3/8	in.	Sect. 6.4.1.3 or design criteria
7.32	Reflection from Enclosures (gloveboxes, airlocks, hoods) - 304 stainless steel Floor thickness for light-duty enclosures Floor thickness for heavy-duty enclosures (minimum)	 0.25 0.5	 in. in.	 Sect. 6.4.1.3 Sect. 6.4.1.3
7.33	Reflection from Enclosures (gloveboxes, airlocks, hoods) thickness of water for walls, windows, roof	1.0	in.	Sect. 6.4.1.3

Table 7.1-1 Summary Table of Results

Result Number	Description	Value	Units	Result Section
7.34	Glovebox Spacing from Walls, minimum Glovebox and other equipment spacing from floor, minimum	35 6	in. in.	Sect. 6.4.1.4 or design criteria
7.35	Room Reflection: Typical concrete process room/bay size	120 × 100 × 20	ft × ft × ft	Sect. 6.4.1.4
7.36	Concrete structure thickness, typical Lower level foundation Upper level floors Walls	>3 1 3	ft ft ft	Sect. 6.4.1.4 Ref. 4.73 – 4.84
7.37	Default Model for Non-Structural Walls — water	2	in.	Sect. 6.4.1.4
7.38	Spacing From Floors Equipment, storage racks, tanks array Glovebox systems	6 6 to 3-5	in. in.	Sect.6.4.1.4 Sect. 6.4.1.4 From design criteria
7.39	Number of Operator Reflectors Number per workstation Number by storage rack Number per 10 tanks	2 2 1	Operators	Sect. 6.4.1.4
7.40	Pipe Outer Dimension	As specified	As specified	Sect. 6.6.1,Table 6.6-1
7.41	Tube Outer Dimension	As specified	As specified	Sect. 6.6.1,Table 6.6-2
7.42	Pipe System Specifications	As specified	As specified	Sect. 6.6.2,Table 6.6-4
7.43	Avogadro's Constant	6.0221×10^{23}	Entities/Mole	Sect. 6.7,Table 6.7-1
7.44	Glass Tubing Outer Dimension	As specified	As specified	Sect. 6.6.1,Table 6.6-3
7.45	Weight Fractions of selected Compounds and Mixtures	As specified	g/cm^3	Section 6.3.7, Table 6.3-13
7.46	Isotopic Atom Densities of selected Compounds and Mixtures	As specified	at /b-cm	Section 6.3.7, Table 6.3-14
7.47	Fissile liquid spill on room floor depth and concentration	As specified	As specified	Sect. 6.5.3,Table 6.5-1
7.48	#3 Inner Can Outer Radius Outer Height with lid Volume	7.6962 12.5730 2.340	cm cm L	Sect. 6.8.1, Table 6.8-1
7.49	#4 Inner Can Outer Radius Outer Height with lid Volume	6.2992 26.8986 3.353	cm cm L	Sect. 6.8.1, Table 6.8-1
7.50	#5 Inner Can Outer Radius Outer Height with lid Volume	7.6962 22.3012 4.150	cm cm L	Sect. 6.8.1, Table 6.8-1

Table 7.1-1 Summary Table of Results

Result Number	Description	Value	Units	Result Section
7.51	Tube Vault Can (TVC) Radius Height Volume	 7.8105 22.4561 4.304	 cm cm L	Sect. 6.8.1, Table 6.8-1
7.52	#5 Inner Can /TVC Combined Model Radius Height Volume	 7.8105 22.4561 4.304	 cm cm L	Sect. 6.8.1, Table 6.8-1
7.53	#3 Outer Container Outer Radius Outer Height with lid Volume	 8.3947 15.3924 3.408	 cm cm L	Sect. 6.8.2, Table 6.8-2
7.54	#4 Outer Container Outer Radius Outer Height with lid Volume	 6.9850 29.8704 4.579	 cm cm L	Sect. 6.8.2, Table 6.8-2
7.55	#5 Outer Container Outer Radius Outer Height with lid Volume	 8.3947 26.0604 5.770	 cm cm L	Sect. 6.8.2, Table 6.8-2

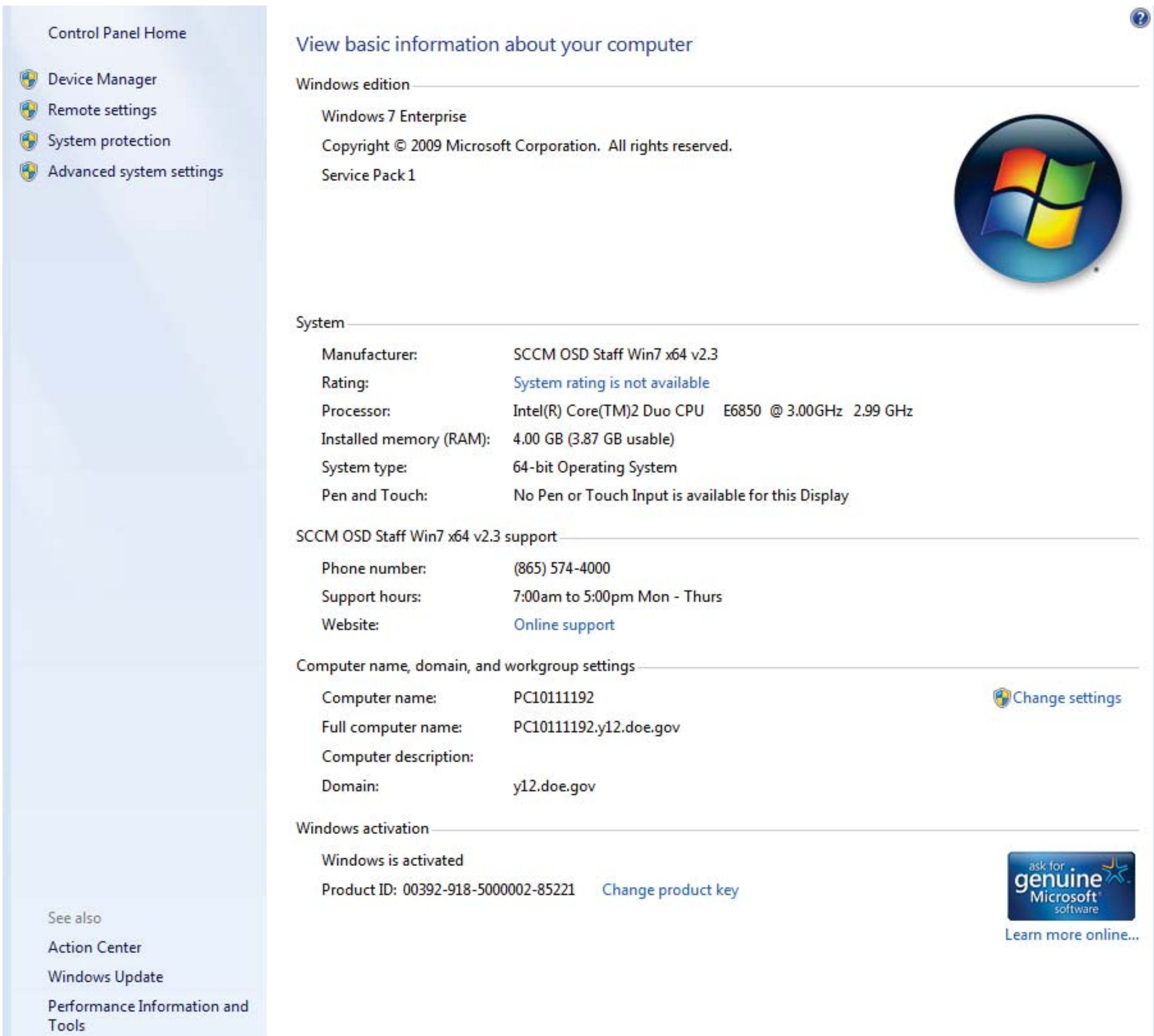
8. CONCLUSIONS

Data were collected and evaluated to provide inputs into calculations performed to support CSPSs done for UPF. All data come from sources contained in UPF acceptable archives that are readily accessible. All calculations performed as part of the data development have been determined by the analysts and reviewers to be accurate and appropriate for use in other DACs. This DAC does not contain any assumptions requiring confirmation. It therefore meets the criteria of a “CONFIRMED” DAC.

APPENDIX A. COMPUTING PLATFORMS

(Page 1 of 3)

Type: PC Using Local Software



DAC-EN-801768-A100 REV1

NUCLEAR ANALYSIS COMPUTER CALCULATION QUALITY ASSURANCE SHEET

COMPUTER SYSTEM	CLASSIFICATION	APPLICATION	VERSION	SEQUENCE	SQA STATUS
ENGHPC01	UNCLASSIFIED	SCALE	6.1.1	CSAS5	PRODUCTION

VALIDATION DOCUMENT(s): Edit to ensure only applicable validations are listed.
RP-EN-801768-A014.doc, Y/DD-1221, YAREA-F-0221, YAREA-F-0455, YDD_1220_1_0.pdf,Y/DD-1220

DOCUMENT STORED IN UPF/InfoWorks

Directory for Archive: ~ dhf /archive/ DAC-EN-801768-A100-REV1
(uid) *(document number)*

Calculation file dates: Earliest 12/07/2015 **Latest** 12/07/2015

DOCUMENT REVIEW	ANALYST YES	ANALYST N/A	REVIEWER CONCUR
INFORMATION AND CALCULATIONAL MODELS			
Drawings and field measurements used are current. Exceptions are explained.	☒		☒
Appropriate field measurements or observations are used in checking the calculational models.		☒	☒
Computer input and program options deemed appropriate.	☒		☒
Calculational models judged to be neither too conservative nor non-conservative.	☒		☒
Consideration/treatment of normal/abnormal conditions deemed appropriate.	☒		☒
CALCULATIONAL DOCUMENTATION			
Contains statement of purpose, descriptions of calculational methods and results.	☒		☒
Ensure that the software application and version are correctly referenced in the document, code output and QA check sheet.	☒		☒
Lists assumptions, simplifications,and major differences between calculation models and actual process, system or component being modeled.	☒		☒
Includes in the presentation of results for each case: file name, title description, appropriate independent variables, computational results. NOTE: Average energy group or average energy of neutron causing fission is optional.	☒		☒
Discusses results including comparison with validation document.	☒		☒
Presents conclusions of the calculation study to include a discussion of conditions that must be met to ensure their validity.	☒		☒
Does not attempt to establish safety on the basis of a single computer calculation.		☒	
COMPUTATIONS AND INTERPRETATION OF RESULTS			
Output does not contain any unacceptable warning/error messages.	☒		☒
Representative Monte Carlo sampling is evident in calculational results. Calculations are converged and the answers are not misread.	☒		☒
Ensure the calculations are within the range and area of applicability of the validation.	☒		☒
E-mail(s) with Reviewer comments are included as attachments		☒	

FILE ARCHIVAL	ANALYST YES	REVIEWER CONCUR
All relevant project calculation files (including spreadsheets) are ready for archive. Superfluous files have been removed.	☒	☒
Using the preserve script, a folder has been created under the user's archive directory (uid/ archive). The folder name is consistent with the Directory for Archive shown on this form. Execute: **preserve project document_number**	☒	☒
The System Administrator/Software Configuration Manager is provided an electronic copy of this QA sheet. (Only the SA/SCM will remove or change the archive directory.)	☒	

Ref. Y70-68-005 UCN-21633 (10-15)

SA/SCM USE ONLY ____________________

APPENDIX B. SPREADSHEET

(Page 1 of 3)

	A	B	C	D	E	F	G	H	I	J	K
1	**DAC-EN-801768-A100, Rev. 0**						N_A	0.60221			
2	Volume fractions for U_3O_8 / Water mixtures						H	1.0079			
3	Maxiumum Theroretical U_3O_8 Density =				8.29	g/cm^3	O	15.9994			
4	Maximum Theoretical Water Density =				0.9982	g/cm^3	^{235}U	235.0439			
5	U_3O_8 Density (g/cm3) (Specified)	Uranium Density (g/cm^3) (Eq. 3.8.1)	U_3O_8 Volume Fraction (Eq. 3.8.2)	Water Volume Fraction (Eq. 3.8.3)	Water Density (g/cm^3) (Eq. 3.8.4)	Mixture Density (g/cm^3) (Eq. 3.8.5)	Hydrogen (atoms/bn-cm) (Eq. 3.8.6)	Oxygen (atoms/bn-cm) (Eq. 3.8.6)	^{235}U (atoms/bn-cm) (Eq. 3.8.6)	Total (atoms/bn-cm) (Eq. 3.8.7)	H/U ratio (Eq. 3.8.8)
6	0.00	0.0000	0.0000	1.0000	0.9982	0.9982	6.6735E-02	3.3368E-02	0.0000E+00	1.0010E-01	
7	0.01	0.0085	0.0012	0.9988	0.9970	1.0070	6.6655E-02	3.3385E-02	2.1685E-05	1.0006E-01	3073.79
8	0.02	0.0169	0.0024	0.9976	0.9958	1.0158	6.6574E-02	3.3403E-02	4.3370E-05	1.0002E-01	1535.04
9	0.03	0.0254	0.0036	0.9964	0.9946	1.0246	6.6494E-02	3.3420E-02	6.5055E-05	9.9979E-02	1022.12
10	0.04	0.0339	0.0048	0.9952	0.9934	1.0334	6.6413E-02	3.3438E-02	8.6740E-05	9.9938E-02	765.66
11	0.05	0.0423	0.0060	0.9940	0.9922	1.0422	6.6333E-02	3.3456E-02	1.0842E-04	9.9897E-02	611.79
12	0.06	0.0508	0.0072	0.9928	0.9910	1.0510	6.6252E-02	3.3473E-02	1.3011E-04	9.9856E-02	509.20
13	0.07	0.0592	0.0084	0.9916	0.9898	1.0598	6.6172E-02	3.3491E-02	1.5179E-04	9.9814E-02	435.93
14	0.08	0.0677	0.0097	0.9903	0.9886	1.0686	6.6091E-02	3.3508E-02	1.7348E-04	9.9773E-02	380.98
15	0.09	0.0762	0.0109	0.9891	0.9874	1.0774	6.6011E-02	3.3526E-02	1.9516E-04	9.9732E-02	338.23
16	0.10	0.0846	0.0121	0.9879	0.9862	1.0862	6.5930E-02	3.3543E-02	2.1685E-04	9.9691E-02	304.04
17	0.20	0.1693	0.0241	0.9759	0.9741	1.1741	6.5125E-02	3.3719E-02	4.3370E-04	9.9278E-02	150.16
18	0.30	0.2539	0.0362	0.9638	0.9621	1.2621	6.4320E-02	3.3895E-02	6.5055E-04	9.8866E-02	98.87
19	0.40	0.3385	0.0483	0.9517	0.9500	1.3500	6.3515E-02	3.4071E-02	8.6740E-04	9.8454E-02	73.23
20	0.50	0.4232	0.0603	0.9397	0.9380	1.4380	6.2710E-02	3.4247E-02	1.0842E-03	9.8041E-02	57.84
21	0.60	0.5078	0.0724	0.9276	0.9260	1.5260	6.1905E-02	3.4422E-02	1.3011E-03	9.7629E-02	47.58
22	0.70	0.5925	0.0844	0.9156	0.9139	1.6139	6.1100E-02	3.4598E-02	1.5179E-03	9.7216E-02	40.25
23	0.80	0.6771	0.0965	0.9035	0.9019	1.7019	6.0295E-02	3.4774E-02	1.7348E-03	9.6804E-02	34.76
24	0.90	0.7617	0.1086	0.8914	0.8898	1.7898	5.9490E-02	3.4950E-02	1.9516E-03	9.6392E-02	30.48
25	1.00	0.8464	0.1206	0.8794	0.8778	1.8778	5.8685E-02	3.5125E-02	2.1685E-03	9.5979E-02	27.06
26	2.00	1.6927	0.2413	0.7587	0.7574	2.7574	5.0635E-02	3.6883E-02	4.3370E-03	9.1855E-02	11.68
27	3.00	2.5391	0.3619	0.6381	0.6370	3.6370	4.2585E-02	3.8640E-02	6.5055E-03	8.7731E-02	6.55
28	4.00	3.3855	0.4825	0.5175	0.5166	4.5166	3.4535E-02	4.0398E-02	8.6740E-03	8.3607E-02	3.98
29	5.00	4.2318	0.6031	0.3969	0.3961	5.3961	2.6485E-02	4.2156E-02	1.0842E-02	7.9483E-02	2.44
30	6.00	5.0782	0.7238	0.2762	0.2757	6.2757	1.8435E-02	4.3913E-02	1.3011E-02	7.5359E-02	1.42
31	7.00	5.9246	0.8444	0.1556	0.1553	7.1553	1.0385E-02	4.5671E-02	1.5179E-02	7.1235E-02	0.68
32	8.00	6.7709	0.9650	0.0350	0.0349	8.0349	2.3345E-03	4.7428E-02	1.7348E-02	6.7111E-02	0.13
33	8.29	7.0164	1.0000	0.0000	0.0000	8.2900	0.0000E+00	4.7938E-02	1.7977E-02	6.5915E-02	0.00

	A	B	C	D	E	F	G
1	DAC-EN-801768-A100, Rev. 0						N_A
2	Volume fractions for U_3O_8 / Water mixtures						H
3	Maxiumum Theroretical U_3O_8 Density =				8.29	g/cm^3	O
4	Maximum Theoretical Water Density =				0.9982	g/cm^3	^{235}U
5	U_3O_8 Density (g/cm3) (Specified)	Uranium Density (g/cm^3) (Eq. 5.3.3)	U_3O_8 Volume Fraction (Eq. 5.3.4)	Water Volume Fraction (Eq. 5.3.5)	Water Density (g/cm^3) (Eq. 5.3.6)	Mixture Density (g/cm^3) (Eq. 5.3.7)	Hydrogen Density (atoms/bn-cm) (Eq. 5.3.8)
6	0	=A6*3*$H$4/(3*$H$4+8*$H$3)	=A6/$E$3	=1 -C6	=D6*$E$4	=A6 + E6	=E6*($H$1/$H$2)*(2*$H$2)/(2*$H$2+$H$3)
7	0.01	=A7*3*$H$4/(3*$H$4+8*$H$3)	=A7/$E$3	=1 -C7	=D7*$E$4	=A7 + E7	=E7*($H$1/$H$2)*(2*$H$2)/(2*$H$2+$H$3)
8	0.02	=A8*3*$H$4/(3*$H$4+8*$H$3)	=A8/$E$3	=1 -C8	=D8*$E$4	=A8 + E8	=E8*($H$1/$H$2)*(2*$H$2)/(2*$H$2+$H$3)
9	0.03	=A9*3*$H$4/(3*$H$4+8*$H$3)	=A9/$E$3	=1 -C9	=D9*$E$4	=A9 + E9	=E9*($H$1/$H$2)*(2*$H$2)/(2*$H$2+$H$3)
10	0.04	=A10*3*$H$4/(3*$H$4+8*$H$3)	=A10/$E$3	=1 -C10	=D10*$E$4	=A10 + E10	=E10*($H$1/$H$2)*(2*$H$2)/(2*$H$2+$H$3)
11	0.05	=A11*3*$H$4/(3*$H$4+8*$H$3)	=A11/$E$3	=1 -C11	=D11*$E$4	=A11 + E11	=E11*($H$1/$H$2)*(2*$H$2)/(2*$H$2+$H$3)
12	0.06	=A12*3*$H$4/(3*$H$4+8*$H$3)	=A12/$E$3	=1 -C12	=D12*$E$4	=A12 + E12	=E12*($H$1/$H$2)*(2*$H$2)/(2*$H$2+$H$3)
13	0.07	=A13*3*$H$4/(3*$H$4+8*$H$3)	=A13/$E$3	=1 -C13	=D13*$E$4	=A13 + E13	=E13*($H$1/$H$2)*(2*$H$2)/(2*$H$2+$H$3)
14	0.08	=A14*3*$H$4/(3*$H$4+8*$H$3)	=A14/$E$3	=1 -C14	=D14*$E$4	=A14 + E14	=E14*($H$1/$H$2)*(2*$H$2)/(2*$H$2+$H$3)
15	0.09	=A15*3*$H$4/(3*$H$4+8*$H$3)	=A15/$E$3	=1 -C15	=D15*$E$4	=A15 + E15	=E15*($H$1/$H$2)*(2*$H$2)/(2*$H$2+$H$3)
16	0.1	=A16*3*$H$4/(3*$H$4+8*$H$3)	=A16/$E$3	=1 -C16	=D16*$E$4	=A16 + E16	=E16*($H$1/$H$2)*(2*$H$2)/(2*$H$2+$H$3)
17	0.2	=A17*3*$H$4/(3*$H$4+8*$H$3)	=A17/$E$3	=1 -C17	=D17*$E$4	=A17 + E17	=E17*($H$1/$H$2)*(2*$H$2)/(2*$H$2+$H$3)

	H	I	J	K
1	0.60221			
2	1.0079			
3	15.9994			
4	235.0439			
5	Oxygen Density (atoms/bn-cm) (Eq. 5.3.8)	^{235}U Density (atoms/bn-cm) (Eq. 5.3.8)	Total Density (atoms/bn-cm) (Eq. 5.3.9)	H/U ratio (Eq. 5.3.10)
6	=E6*($H$1/$H$3)*($H$3)/(2*$H$2+$H$3) + A6*($H$1/$H$3)*(8*$H$3)/(3*$H$4+8*$H$3)	=A6*($H$1/$H$4)*3*$H$4/(3*$H$4+8*$H$3)	=G6 + H6 + I6	
7	=E7*($H$1/$H$3)*($H$3)/(2*$H$2+$H$3) + A7*($H$1/$H$3)*(8*$H$3)/(3*$H$4+8*$H$3)	=A7*($H$1/$H$4)*3*$H$4/(3*$H$4+8*$H$3)	=G7 + H7 + I7	=G7/I7
8	=E8*($H$1/$H$3)*($H$3)/(2*$H$2+$H$3) + A8*($H$1/$H$3)*(8*$H$3)/(3*$H$4+8*$H$3)	=A8*($H$1/$H$4)*3*$H$4/(3*$H$4+8*$H$3)	=G8 + H8 + I8	=G8/I8
9	=E9*($H$1/$H$3)*($H$3)/(2*$H$2+$H$3) + A9*($H$1/$H$3)*(8*$H$3)/(3*$H$4+8*$H$3)	=A9*($H$1/$H$4)*3*$H$4/(3*$H$4+8*$H$3)	=G9 + H9 + I9	=G9/I9
10	=E10*($H$1/$H$3)*($H$3)/(2*$H$2+$H$3) + A10*($H$1/$H$3)*(8*$H$3)/(3*$H$4+8*$H$3)	=A10*($H$1/$H$4)*3*$H$4/(3*$H$4+8*$H$3)	=G10 + H10 + I10	=G10/I10
11	=E11*($H$1/$H$3)*($H$3)/(2*$H$2+$H$3) + A11*($H$1/$H$3)*(8*$H$3)/(3*$H$4+8*$H$3)	=A11*($H$1/$H$4)*3*$H$4/(3*$H$4+8*$H$3)	=G11 + H11 + I11	=G11/I11
12	=E12*($H$1/$H$3)*($H$3)/(2*$H$2+$H$3) + A12*($H$1/$H$3)*(8*$H$3)/(3*$H$4+8*$H$3)	=A12*($H$1/$H$4)*3*$H$4/(3*$H$4+8*$H$3)	=G12 + H12 + I12	=G12/I12
13	=E13*($H$1/$H$3)*($H$3)/(2*$H$2+$H$3) + A13*($H$1/$H$3)*(8*$H$3)/(3*$H$4+8*$H$3)	=A13*($H$1/$H$4)*3*$H$4/(3*$H$4+8*$H$3)	=G13 + H13 + I13	=G13/I13
14	=E14*($H$1/$H$3)*($H$3)/(2*$H$2+$H$3) + A14*($H$1/$H$3)*(8*$H$3)/(3*$H$4+8*$H$3)	=A14*($H$1/$H$4)*3*$H$4/(3*$H$4+8*$H$3)	=G14 + H14 + I14	=G14/I14
15	=E15*($H$1/$H$3)*($H$3)/(2*$H$2+$H$3) + A15*($H$1/$H$3)*(8*$H$3)/(3*$H$4+8*$H$3)	=A15*($H$1/$H$4)*3*$H$4/(3*$H$4+8*$H$3)	=G15 + H15 + I15	=G15/I15
16	=E16*($H$1/$H$3)*($H$3)/(2*$H$2+$H$3) + A16*($H$1/$H$3)*(8*$H$3)/(3*$H$4+8*$H$3)	=A16*($H$1/$H$4)*3*$H$4/(3*$H$4+8*$H$3)	=G16 + H16 + I16	=G16/I16
17	=E17*($H$1/$H$3)*($H$3)/(2*$H$2+$H$3) + A17*($H$1/$H$3)*(8*$H$3)/(3*$H$4+8*$H$3)	=A17*($H$1/$H$4)*3*$H$4/(3*$H$4+8*$H$3)	=G17 + H17 + I17	=G17/I17