Specification for Joint FTI/LLNL/UNED-IFN Contact Dose Comparison Exercise

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FUSION TECHNOLOGY INSTITUTE

UNIVERSITY OF WISCONSIN

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This specification defines the common input parameters to be used in a comparison exercise of the contact dose[1] calculation capabilities of the UW-Madison's Fusion Technology Institute, the Lawrence Livermore National Laboratory, and the Universidad Nacional de Educación a Distancia and Instituto de Fusión Nuclear, Madrid. This comparison is designed to eliminate differences in the inputs and focus on the differences in the output.

In brief, this exercise will compare the calculated specific activity and contact dose for each element from atomic number 1 (H) through 83 (Bi) following a four year steady state irradiation with a neutron spectrum characteristic of that found at the outboard first wall of a tokamak with a liquid breeding blanket.

Inputs:

- Neutron flux: a 175 group (vitamin-j) neutron flux is provided in appendix A. This flux is based on the outboard first wall flux of the ARIES-AT design[2].
- Material: a separate set of results will be provided for each element from hydrogen (1) through bismuth (83) using naturally occurring isotopic abundances provided in appendix B.
- Irradiation schedule: all calculations will be performed with a four year steady-state irradiation with the specified flux.
- Data library: FENDL/A-2.0 and FENDL/D-2.0.

Results for comparison:

- All results will be provided for 9 cooling times, ranging between 1 minute and 90 days, following the four year irradiation provided in appendix C.
- For each element, a complete set of results will include both the specific activity [Bq/kg] and contact dose [Sv/hr] contributed by each product isotope, and the total specific activity and contact dose summed over all the contributing isotopes.

The neutron flux data and elemental abundances are available in electronic form.

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[1] **Contact Dose:** This very approximate measure of dose has become a popular mechanism for comparing different materials, components and systems in the fusion technology community. It is based upon an approximation that calculates the dose from a γ-source uniformly distributed throughout a semi-infinite half-space of homogenous material.

[2] A.R. Raffray, L. El-Guebaly, S. Gordeev, S. Malang, E. Mogahed, F. Najmabadi, I. Sviatoslavsky, D.K. Sze, M.S. Tillack, X. Wang, and the ARIES Team, "High performance blanket for ARIES-AT power plant," *Fusion Engineering and Design*, **58-59** (2001).

Appendix A: 175-Group Neutron Flux

Group Number	Group Energy [MeV]	Upper Bound Neutron Flux [n/cm^2]	Group Number	Group Energy [MeV]	Upper Bound Neutron Flux [n/cm^2]	Group Number	Group Energy [MeV]	Upper Bound Neutron Flux [n/cm^2]
1	1.96E+01	0.00E+00	61	1.17E+00	2.81E+13	121	2.48E-02	5.66E+12
2	1.73E+01	0.00E+00	62	1.11E+00	5.30E+13	122	2.42E-02	5.59E+12
3	1.69E+01	0.00E+00	63	1.00E+00	1.98E+13	123	2.36E-02	1.63E+13
4	1.65E+01	0.00E+00	64	9.62E-01	2.81E+13	124	2.19E-02	2.58E+13
5	1.57E+01	0.00E+00	65	9.07E-01	2.86E+13	125	1.93E-02	4.63E+13
6	1.49E+01	0.00E+00	66	8.63E-01	2.38E+13	126	1.50E-02	4.08E+13
7	1.46E+01	0.00E+00	67	8.21E-01	2.72E+13	127	1.17E-02	1.51E+13
8	1.42E+01	3.45E+14	68	7.81E-01	2.87E+13	128	1.06E-02	2.10E+13
9	1.38E+01	1.79E+13	69	7.43E-01	2.99E+13	129	9.12E-03	3.06E+13
10	1.35E+01	9.95E+12	70	7.07E-01	3.14E+13	130	7.10E-03	2.60E+13
11	1.28E+01	2.13E+12	71	6.72E-01	3.00E+13	131	5.53E-03	2.18E+13
12	1.25E+01	2.11E+12	72	6.39E-01	2.94E+13	132	4.31E-03	1.14E+13
13	1.22E+01	5.09E+12	73	6.08E-01	2.91E+13	133	3.71E-03	6.62E+12
14	1.16E+01	5.43E+12	74	5.78E-01	2.44E+13	134	3.35E-03	6.33E+12
15	1.11E+01	3.53E+12	75	5.50E-01	2.54E+13	135	3.04E-03	5.79E+12
16	1.05E+01	2.65E+12	76	5.23E-01	3.10E+13	136	2.75E-03	2.71E+12
17	1.00E+01	2.03E+12	77	4.98E-01	5.77E+13	137	2.61E-03	2.58E+12
18	9.51E+00	3.11E+12	78	4.51E-01	5.38E+13	138	2.49E-03	4.78E+12
19	9.05E+00	3.31E+12	79	4.08E-01	2.63E+13	139	2.25E-03	4.21E+12
20	8.61E+00	2.63E+12	80	3.88E-01	2.57E+13	140	2.03E-03	8.75E+12
21	8.19E+00	2.03E+12	81	3.69E-01	4.93E+13	141	1.58E-03	6.64E+12
22	7.79E+00	1.93E+12	82	3.34E-01	4.40E+13	142	1.23E-03	4.94E+12
23	7.41E+00	2.29E+12	83	3.02E-01	4.78E+12	143	9.61E-04	3.57E+12
24	7.05E+00	2.85E+12	84	2.99E-01	1.77E+12	144	7.48E-04	2.52E+12
25	6.70E+00	1.08E+12	85	2.97E-01	3.71E+12	145	5.83E-04	1.72E+12
26	6.59E+00	2.34E+12	86	2.95E-01	9.82E+12	146	4.54E-04	1.13E+12
27	6.38E+00	2.74E+12	87	2.87E-01	1.83E+13	147	3.54E-04	7.25E+11
28	6.07E+00	2.38E+12	88	2.73E-01	3.17E+13	148	2.75E-04	4.47E+11
29	5.77E+00	2.33E+12	89	2.47E-01	1.40E+13	149	2.14E-04	2.66E+11
30	5.49E+00	2.55E+12	90	2.35E-01	1.32E+13	150	1.67E-04	1.53E+11
31	5.22E+00	2.66E+12	91	2.24E-01	1.22E+13	151	1.30E-04	8.43E+10
32	4.97E+00	2.86E+12	92	2.13E-01	1.12E+13	152	1.01E-04	4.48E+10
33	4.72E+00	3.21E+12	93	2.02E-01	1.01E+13	153	7.89E-05	2.30E+10
34	4.49E+00	7.36E+12	94	1.93E-01	9.66E+12	154	6.14E-05	1.13E+10
35	4.07E+00	9.48E+12	95	1.83E-01	1.20E+13	155	4.79E-05	5.38E+09
36	3.68E+00	1.13E+13	96	1.74E-01	1.82E+13	156	3.73E-05	2.47E+09
37	3.33E+00	6.81E+12	97	1.66E-01	2.40E+13	157	2.90E-05	1.10E+09
38	3.17E+00	7.65E+12	98	1.58E-01	2.31E+13	158	2.26E-05	4.75E+08
39	3.01E+00	8.29E+12	99	1.50E-01	2.45E+13	159	1.76E-05	2.03E+08
40	2.87E+00	9.65E+12	100	1.43E-01	2.14E+13	160	1.37E-05	8.69E+07
41	2.73E+00	1.13E+13	101	1.36E-01	2.01E+13	161	1.07E-05	3.83E+07
42	2.59E+00	1.24E+13	102	1.29E-01	1.98E+13	162	8.32E-06	1.81E+07
43	2.47E+00	9.42E+12	103	1.23E-01	1.71E+13	163	6.48E-06	9.43E+06
44	2.39E+00	2.39E+12	104	1.17E-01	2.13E+13	164	5.04E-06	5.44E+06
45	2.37E+00	2.43E+12	105	1.11E-01	4.76E+13	165	3.93E-06	3.42E+06
46	2.35E+00	4.80E+12	106	9.80E-02	4.40E+13	166	3.06E-06	2.27E+06
47	2.31E+00	1.03E+13	107	8.65E-02	1.70E+13	167	2.38E-06	1.55E+06
48	2.23E+00	1.58E+13	108	8.25E-02	1.21E+13	168	1.86E-06	1.08E+06
49	2.12E+00	1.66E+13	109	7.95E-02	3.40E+13	169	1.45E-06	7.36E+05
50	2.02E+00	1.65E+13	110	7.20E-02	2.13E+13	170	1.13E-06	5.12E+05
51	1.92E+00	1.68E+13	111	6.74E-02	4.57E+13	171	8.76E-07	3.58E+05
52	1.83E+00	2.05E+13	112	5.66E-02	1.59E+13	172	6.83E-07	2.51E+05
53	1.74E+00	1.98E+13	113	5.25E-02	4.47E+13	173	5.32E-07	1.75E+05
54	1.65E+00	1.94E+13	114	4.63E-02	3.30E+13	174	4.14E-07	2.39E+05
55	1.57E+00	2.18E+13	115	4.09E-02	4.83E+13	175	1.00E-07	4.60E+04
56	1.50E+00	2.41E+13	116	3.43E-02	1.93E+13			
57	1.42E+00	2.53E+13	117	3.18E-02	2.72E+13			
58	1.35E+00	2.47E+13	118	2.85E-02	1.29E+13			
59	1.29E+00	2.50E+13	119	2.70E-02	8.35E+12			
60	1.23E+00	2.65E+13	120	2.61E-02	1.15E+13			

Appendix B: Natural Elemental Abundances [%]

h 1		v 23		nb 41		xe 54		tm 69	
1	0.999850E+02	50	0.250000E+00	93	0.100000E+03	124	0.100000E+00	169	0.100000E+03
2	0.150000E-01	51	0.997500E+02	mo 42		126	0.900000E-01	yb 70	
he 2		cr 24		92	0.148400E+02	128	0.191000E+01	168	0.130000E+00
3	0.100000E-03	50	0.434500E+01	94	0.925000E+01	129	0.264000E+02	170	0.305000E+01
4	0.100000E+03	52	0.837900E+02	95	0.159200E+02	130	0.410000E+01	171	0.143000E+02
li 3		53	0.950000E+01	96	0.166800E+02	131	0.212000E+02	172	0.219000E+02
6	0.752000E+01	54	0.236500E+01	97	0.955000E+01	132	0.269000E+02	173	0.161200E+02
7	0.924800E+02	mn 25		98	0.241300E+02	134	0.104000E+02	174	0.318000E+02
be 4		55	0.100000E+03	100	0.963000E+01	136	0.890000E+01	176	0.127000E+02
9	0.100000E+03	fe 26		ru 44		cs 55		lu 71	
b 5		54	0.590000E+01	96	0.554000E+01	133	0.100000E+03	175	0.974000E+02
10	0.199000E+02	56	0.917200E+02	98	0.186000E+01	ba 56		176	0.260000E+01
11	0.801000E+02	57	0.210000E+01	99	0.127000E+02	130	0.106000E+00	hf 72	
c 6		58	0.280000E+00	100	0.126000E+02	132	0.101000E+00	174	0.162000E+00
12	0.988920E+02	co 27		101	0.171000E+02	134	0.242000E+01	176	0.520600E+01
13	0.110800E+01	59	0.100000E+03	102	0.316000E+02	135	0.659300E+01	177	0.186060E+02
n 7		ni 28		104	0.186000E+02	136	0.785000E+01	178	0.272970E+02
14	0.996340E+02	58	0.682700E+02	rh 45		137	0.112300E+02	179	0.136290E+02
15	0.366000E+00	60	0.261000E+02	103	0.100000E+03	138	0.717000E+02	180	0.351000E+02
o 8		61	0.113000E+01	pd 46		la 57		ta 73	
16	0.997590E+02	62	0.359000E+01	102	0.102000E+01	138	0.900000E-01	181	0.100000E+03
17	0.370000E-01	64	0.910000E+00	104	0.111400E+02	139	0.999100E+02	w 74	
18	0.204000E+00	cu 29		105	0.223300E+02	ce 58		180	0.120000E+00
f 9		63	0.691700E+02	106	0.273300E+02	136	0.190000E+00	182	0.263000E+02
19	0.100000E+03	65	0.308300E+02	108	0.264600E+02	138	0.250000E+00	183	0.142800E+02
ne 10		zn 30		110	0.117200E+02	140	0.884300E+02	184	0.307000E+02
20	0.904800E+02	64	0.486000E+02	ag 47		142	0.111300E+02	186	0.286000E+02
21	0.270000E+00	66	0.279000E+02	107	0.518400E+02	pr 59		re 75	
22	0.929000E+01	67	0.410000E+01	109	0.481600E+02	141	0.100000E+03	185	0.374000E+02
na 11		68	0.188000E+02	cd 48		nd 60		187	0.626000E+02
23	0.100000E+03	70	0.600000E+00	106	0.125000E+01	142	0.271300E+02	os 76	
mg 12		ga 31		108	0.890000E+00	143	0.121800E+02	184	0.200000E-01
24	0.789900E+02	69	0.601100E+02	110	0.124900E+02	144	0.238000E+02	186	0.158000E+01
25	0.100000E+02	71	0.398900E+02	111	0.128000E+02	145	0.830000E+01	187	0.160000E+01
26	0.110100E+02	ge 32		112	0.241300E+02	146	0.171900E+02	188	0.133000E+02
al 13		70	0.205000E+02	113	0.122200E+02	148	0.576000E+01	189	0.161000E+02
27	0.100000E+03	72	0.274000E+02	114	0.287300E+02	150	0.564000E+01	190	0.264000E+02
si 14		73	0.780000E+01	116	0.749000E+01	sm 62		192	0.410000E+02
28	0.922300E+02	74	0.365000E+02	in 49		144	0.310000E+01	ir 77	
29	0.467000E+01	76	0.776000E+01	113	0.428000E+01	147	0.150000E+02	191	0.373000E+02
30	0.310000E+01	as 33		115	0.957200E+02	148	0.113000E+02	193	0.627000E+02
p 15		75	0.100000E+03	sn 50		149	0.138000E+02	pt 78	
31	0.100000E+03	se 34		112	0.970000E+00	150	0.740000E+01	190	0.100000E-01
s 16		74	0.900000E+00	114	0.650000E+00	152	0.267000E+02	192	0.790000E+00
32	0.950200E+02	76	0.910000E+01	115	0.360000E+00	154	0.227000E+02	194	0.329000E+02
33	0.750000E+00	77	0.760000E+01	116	0.145300E+02	eu 63		195	0.338000E+02
34	0.421000E+01	78	0.236000E+02	117	0.768000E+01	151	0.478000E+02	196	0.253000E+02
36	0.200000E-01	80	0.499000E+02	118	0.242200E+02	153	0.522000E+02	198	0.720000E+01
cl 17		82	0.890000E+01	119	0.858000E+01	gd 64		au 79	
35	0.757700E+02	br 35		120	0.325900E+02	152	0.200000E+00	197	0.100000E+03
37	0.242300E+02	79	0.506900E+02	122	0.463000E+01	154	0.218000E+01	hg 80	
ar 18		81	0.493100E+02	124	0.579000E+01	155	0.148000E+02	196	0.150000E+00
36	0.337000E+00	kr 36		sb 51		156	0.204700E+02	198	0.100000E+02
38	0.630000E-01	78	0.350000E+00	121	0.574000E+02	157	0.156500E+02	199	0.169000E+02
40	0.996000E+02	80	0.225000E+01	123	0.426000E+02	158	0.248400E+02	200	0.231000E+02
k 19		82	0.116000E+02	te 52		160	0.218600E+02	201	0.132000E+02
39	0.932580E+02	83	0.115000E+02	120	0.950000E-01	tb 65		202	0.298000E+02
41	0.674000E+01	84	0.570000E+02	122	0.259000E+01	159	0.100000E+03	204	0.685000E+01
ca 20		86	0.173000E+02	123	0.905000E+00	dy 66		tl 81	
40	0.969410E+02	rb 37		124	0.479000E+01	156	0.600000E-01	203	0.295200E+02
42	0.647000E+00	85	0.721600E+02	125	0.712000E+01	158	0.100000E+00	205	0.704800E+02
43	0.135000E+00	87	0.278400E+02	126	0.189300E+02	160	0.234000E+01	pb 82	
44	0.208600E+01	sr 38		128	0.317000E+02	161	0.189000E+02	204	0.140000E+01
46	0.400000E-02	84	0.560000E+00	130	0.338700E+02	162	0.255000E+02	206	0.241000E+02
48	0.187000E+00	86	0.986000E+01	i 53		163	0.249000E+02	207	0.221000E+02
sc 21		87	0.700000E+01	127	0.100000E+03	164	0.282000E+02	208	0.524000E+02
45	0.100000E+03	88	0.825800E+02			ho 67		bi 83	
ti 22		y 39				165	0.100000E+03	209	0.100000E+03
46	0.800000E+01	89	0.100000E+03			er 68			
47	0.730000E+01	zr 40				162	0.140000E+00		
48	0.738000E+02	90	0.514500E+02			164	0.161000E+01		
49	0.550000E+01	91	0.112200E+02			166	0.336000E+02		
50	0.540000E+01	92	0.171500E+02			167	0.229500E+02		
		94	0.173800E+02			168	0.268000E+02		
		96	0.280000E+01			170	0.149000E+02		

Appendix C: Cooling Times

The following nine cooling times will be reported.

1	m	60	s
15	m	900	s
1	h	3600	s
6	h	21600	s
1	d	86400	s
7	d	604800	s
30	d	2592000	s
60	d	5184000	s
90	d	7776000	s