INL/MIS-20-59622-Revision-0

Activity Estimations for HSA Co-60 targets for Cycles 168A, 168B, and 169A Memo

Joshua L Peterson-Droogh

September 2020

The INL is a U.S. Department of Energy National Laboratory
operated by Battelle Energy Alliance

INL/MIS-20-59622-Revision-0

Activity Estimations for HSA Co-60 targets for Cycles 168A, 168B, and 169A Memo

Joshua L Peterson-Droogh

September 2020

Idaho National Laboratory
Idaho Falls, Idaho 83415

http://www.inl.gov

Prepared for the
U.S. Department of Energy

Under DOE Idaho Operations Office
Contract DE-AC07-05ID14517

INTEROFFICE MEMORANDUM

Idaho National Laboratory INL

Date: September 2, 2020

To: Andrew J. Zillmer MS 6122 533-E

From: Joshua Peterson-Droogh MS 3830 526-1732

Subject: Activity Estimations for High Specific Activity (HSA) Co-60 targets for Cycles 168A, 168B, and 169A

The purpose of this email is to provide estimated specific activities for High Specific Activity (HSA) Co-60 targets for Cycle 168A, 168B, and 169A for informational purposes only.

67 High Specific Activity (HSA) cobalt targets have been irradiated in the ATR, with initial irradiation starting 2/10/2015. Individual HSA cobalt targets have been irradiated in different positions within ATR for different durations of time and at different power levels. A planning tool called the Isotope Production and Activation tool (IPA tool) [1] was developed to capture the effects different irradiation conditions may have on HSA cobalt targets. The IPA tool uses cross section and flux data, historical ATR operating cycle data, and HSA cobalt target location data to estimate a range of specific activities for each of the HSA cobalt targets to generate SCALE/ORIGENS inputs for each target. The cross section and flux data were extracted from MCNP[2] modeled HSA cobalt experiments, including the MCNP input files from ECAR-3872 [3]. The MCNP HSA cobalt models included different ATR fuel loadings, fuel burnup, OSCC shim rotations, neck shim movements, and experiments. The ATR operating cycle data came from the experiment irradiation plan on the Irradiation Testing home page [4].

The IPA tool also post-processes the results for use in tables and figures. These results should be independently verified using an acceptable alternative method since the IPA tool was not developed, documented or tested per INL lab-wide procedure LWP-13620 [5] for Software Quality Assurance (SQA). Given that the IPA tool does not meet SQA requirements, the results should only be used for informational purposes.

The expected cycle history for cycle 168A, 168B, and 169A can be seen in

Table 1.

Table 1 ATR cycle history for Cycles 168A, 168B, and 169A [4].

cycle	NW lobe (MW)	NE lobe (MW)	C lobe (MW)	SW lobe (MW)	SE lobe (MW)	EFPD	BOC Date	Last Shutdown Date
168A	20	19	21.8	25	23	60.0	4/15/20	7/22/20
168B	20	19	21.3	23	23	60.0	8/26/20	10/25/20
169A	20	20	21.6	23	23	60.0	2/11/21	4/12/21

The assumed target locations and irradiation history by ATR operating cycle is tabulated in Table 2. The cycle-specific location for the HSA cobalt targets can be obtained from different revisions of the 410.22-IP [6]. The history of the HSA targets before cycle 165A-1 can be obtained from different revisions of DP-001 [7]. The "n/a" in Table 2 represents that the HSA cobalt target is not irradiated in the ATR during that cycle. The vertical positioning of the HSA cobalt target are specified in Table 2 as the top (T), bottom (B), and middle (M) and the experiment positions are identified as H[#], A[#], B[#] for H-position, A-position, and B-position respectively.

Table 2 HSA Cobalt Target history (Cycle 168A-1 based on 410.22-IP Rev. 10, Cycle 168B based on 410.22-IP Rev.14) (T for top, B for bottom, and M for Middle) (H[#], A[#], B[#] represent experiment positions within the ATR).

Target	168A	168B	169A
C001	H5-T	H5-T	H5-T
C002	H4-M	H4-M	H4-M
C003	**H5-M**	H5-M	H5-M
C004	n/a	n/a	n/a
C005	**H5-B**	H5-B	H5-B
C006	H6-B	H6-B	H6-B
C007	H6-M	H6-M	H6-M
C008	H4-B	H4-B	H4-B
C009	H7-B	H7-B	H7-B
C010	H7-M	H7-M	H7-M
C011	H1-M	n/a	n/a
C012	n/a	n/a	n/a
C013	n/a	n/a	n/a
C014	n/a	n/a	n/a
C015	H1-B	n/a	n/a
C016	H4-T	H4-T	H4-T
C017	H7-T	H7-T	H7-T
C018	H6-T	H6-T	H6-T
C019	H2-T	n/a	n/a
C020	H9-B	H9-B	H9-B
C021	H9-M	H9-M	H9-M
C022	H9-T	H9-T	H9-T
C023	H12-T	H12-T	H12-T
C024	H12-M	H12-M	H12-M
C025	H12-B	H12-B	H12-B
C026	H13-T	H13-T	H13-T
C027	H13-M	H13-M	H13-M

Target	168A	168B	169A
C028	H2-M	n/a	n/a
C029	H10-T	B2-T	B2-T
C030	H10-M	B2-M	B2-M
C031	H2-B	n/a	n/a
C032	H14-T	H14-T	H14-T
C033	H14-M	H14-M	H14-M
C034	H10-B	B2-B	B2-B
C035	H15-T	n/a	n/a
C036	H15-M	n/a	n/a
C037	H13-B	H13-B	H13-B
C038	H14-B	H14-B	H14-B
C039	H15-B	n/a	n/a
C040	H16-T	n/a	n/a
C041	H16-M	n/a	n/a
C042	H16-B	n/a	n/a
C043	H1-T	n/a	n/a
C044	A1-T	n/a	n/a
C045	A1-M	n/a	n/a
C046	A1-B	n/a	n/a
C047	A2-T	n/a	n/a
C048	A2-M	n/a	n/a
C049	A2-B	n/a	n/a
C050	A3-T	n/a	n/a
C051	A3-M	n/a	n/a
C052	A3-B	n/a	n/a
C053	A4-T	n/a	n/a
C054	A4-M	n/a	n/a
C055	A4-B	n/a	n/a
C056	A5-T	n/a	n/a
C057	A5-M	n/a	n/a
C058	A5-B	n/a	n/a
C059	A6-T	A6-T	A6-T
C060	A6-M	A6-M	A6-M
C061	A6-B	A6-B	A6-B
C062	B2-T	A7-T	A7-T

Target	168A	168B	169A
C063	B2-M	A7-M	A7-M
C064	B2-B	A7-B	A7-B
C065	B3-T	B8-T	B8-T
C066	B3-M	B8-M	B8-M

The average specific activity for all of the targets for cycle 168A, 168B, and 169A is summarized in Table 3. Over one-hundred-thousand cross sections and fluxes were extracted from the hundreds of MCNP models. These cross sections and fluxes were specific to different experiment positions and axial heights (top, middle, bottom) in the ATR. There was a wide range of values for the experiment specific fluxes and cross sections from the MCNP model. The variances in the fluxes and cross sections were from using hundreds of MCNP models that captured the changes in fluxes and cross sections due to variations in the fuel composition, burnup time steps, shim positions, and the impact of other experiments on the HSA cobalt. The percent uncertainty associated with each value is the uncertainty of the results using a range of cross sections (5% to 95%) and fluxes (5% to 95%) obtained from the MCNP HSA cobalt results The percent uncertainty does not take into account other uncertainties, such as fabrication tolerances, material composition, and measurement uncertainty.

Table 3 Specific activity and percent uncertainty for HSA cobalt targets at the EOC for cycle 168A, 168B, and 169A.

Target ID	EOC 168A (Ci/g)	EOC 168A percent uncertainty	EOC 168B (Ci/g)	EOC 168B percent uncertainty	EOC 169A (Ci/g)	EOC 169A percent uncertainty
C001	45	9%	59	10%	71	11%
C002	214	13%	226	12%	234	12%
C003	143	13%	152	12%	158	12%
C004	177	13%	169	13%	159	13%
C005	132	12%	140	12%	146	12%
C006	141	14%	149	13%	155	13%
C007	214	14%	226	14%	234	14%
C008	144	13%	153	12%	159	12%
C009	139	14%	148	14%	154	14%
C010	211	15%	222	15%	231	14%
C011	178	12%	158	12%	149	12%
C012	117	13%	112	13%	105	13%
C013	174	14%	166	14%	156	14%
C014	106	14%	102	14%	96	14%
C015	121	14%	110	14%	104	14%
C016	133	12%	142	12%	148	12%
C017	127	13%	135	13%	141	13%

Key
45
142
242

Target ID	EOC 168A (Ci/g)	EOC 168A percent uncertainty	EOC 168B (Ci/g)	EOC 168B percent uncertainty	EOC 169A (Ci/g)	EOC 169A percent uncertainty
C018	128	14%	136	14%	142	13%
C019	115	14%	105	13%	99	13%
C020	145	12%	154	12%	160	12%
C021	218	13%	230	13%	238	12%
C022	132	12%	141	12%	147	12%
C023	133	12%	141	12%	147	12%
C024	217	13%	229	12%	238	12%
C025	144	12%	153	12%	159	11%
C026	131	12%	139	12%	145	12%
C027	212	11%	224	11%	232	11%
C028	181	11%	161	11%	152	11%
C029	134	12%	140	12%	146	12%
C030	220	13%	229	13%	239	12%
C031	123	13%	112	13%	105	13%
C032	114	12%	122	12%	128	11%
C033	187	11%	199	11%	208	11%
C034	147	12%	156	11%	164	11%
C035	108	14%	98	13%	92	13%
C036	172	12%	153	11%	144	11%
C037	142	12%	150	12%	157	12%
C038	123	13%	131	13%	138	12%
C039	115	14%	105	14%	99	14%
C040	109	14%	100	14%	94	14%
C041	173	13%	154	13%	144	13%
C042	118	14%	107	14%	101	14%
C043	112	14%	102	14%	96	14%
C044	93	15%	85	15%	80	15%
C045	155	17%	139	17%	131	17%
C046	101	16%	92	16%	87	16%
C047	96	16%	88	16%	83	16%
C048	164	17%	146	17%	137	17%
C049	104	17%	95	17%	90	17%
C050	100	16%	91	16%	86	16%
C051	173	19%	153	19%	144	19%
C052	110	17%	100	17%	94	17%
C053	99	17%	90	17%	85	17%

Target ID	EOC 168A (Ci/g)	EOC 168A percent uncertainty	EOC 168B (Ci/g)	EOC 168B percent uncertainty	EOC 169A (Ci/g)	EOC 169A percent uncertainty
C054	172	20%	152	20%	143	20%
C055	110	17%	100	17%	94	17%
C056	102	17%	92	17%	87	17%
C057	173	19%	153	19%	144	19%
C058	110	16%	100	16%	94	16%
C059	106	14%	114	13%	121	13%
C060	182	13%	196	13%	208	13%
C061	122	14%	131	13%	138	13%
C062	106	14%	117	14%	126	14%
C063	157	13%	178	13%	195	13%
C064	128	13%	141	13%	152	12%
C065	117	12%	128	11%	137	10%
C066	210	11%	227	9%	242	9%
C067	141	11%	154	10%	165	10%

Eighteen cobalt targets were assayed on July 28-29, 2020, following irradiation in ATR cycle 168A. The assay results were reported in an internal memo sent on August 6, 2020, from M. A. Reichenberger and J. M. Urban-Klaehn to A. J. Zillmer [8]. The assay results included the measurement uncertainty (at one sigma). The results from the assay measurements were compared with the IPA tool results to validate that the IPA tool produces results within reason (see Table 4). Table 4 shows the lower and upper range from the assay results assuming a 95% confidence interval (2 sigma). Table 4 also shows the lower and upper calculated value produced by the IPA tool. The final column in Table 4 is labeled "Within Range" and it specifies TRUE when the IPA tool results overlap the assay measurement results. As seen in Table 4, the range of the IPA results overlapped the range of the assay measured results for all assay results except for C001, where the IPA result was greater than the assay result. The table shows that overall the IPA results are within range, but they may overpredict in some cases. A graphical representation of Table 4 is provided in Figure 1, where the assay data (red) and IPA calculated values (blue) overlap each other (purple). Figure 1 shows that overall the results are good, with the IPA calculated results slightly overpredicting the assay results.

Table 4 Table showing when the calculated results were within the assay result uncertainty

Target ID	Lower Assay value (2 sigma) (Ci/g)	Upper Assay value (2 sigma) (Ci/g)	Lower Calculated Value (Ci/g)	Upper Calculated Value (Ci/g)	Within Range
C001	26	35	41	48.74	FALSE
C003	124	168	125	161.2	TRUE
C005	103	139	116	148.2	TRUE

Target ID	Lower Assay value (2 sigma) (Ci/g)	Upper Assay value (2 sigma) (Ci/g)	Lower Calculated Value (Ci/g)	Upper Calculated Value (Ci/g)	Within Range
C020	112	151	127	162.3	TRUE
C021	177	238	190	246.3	TRUE
C022	105	142	116	148.7	TRUE
C032	90	122	101	127.5	TRUE
C033	142	191	166	208.6	TRUE
C035	78	104	93	122.5	TRUE
C036	122	164	152	191.5	TRUE
C038	103	138	107	138.1	TRUE
C039	87	117	99	131.7	TRUE
C053	71	95	82	116.4	TRUE
C054	133	180	138	206	TRUE
C055	85	115	91	128.9	TRUE
C065	96	129	103	130.6	TRUE
C066	173	233	187	231.9	TRUE
C067	115	155	125	156.5	TRUE

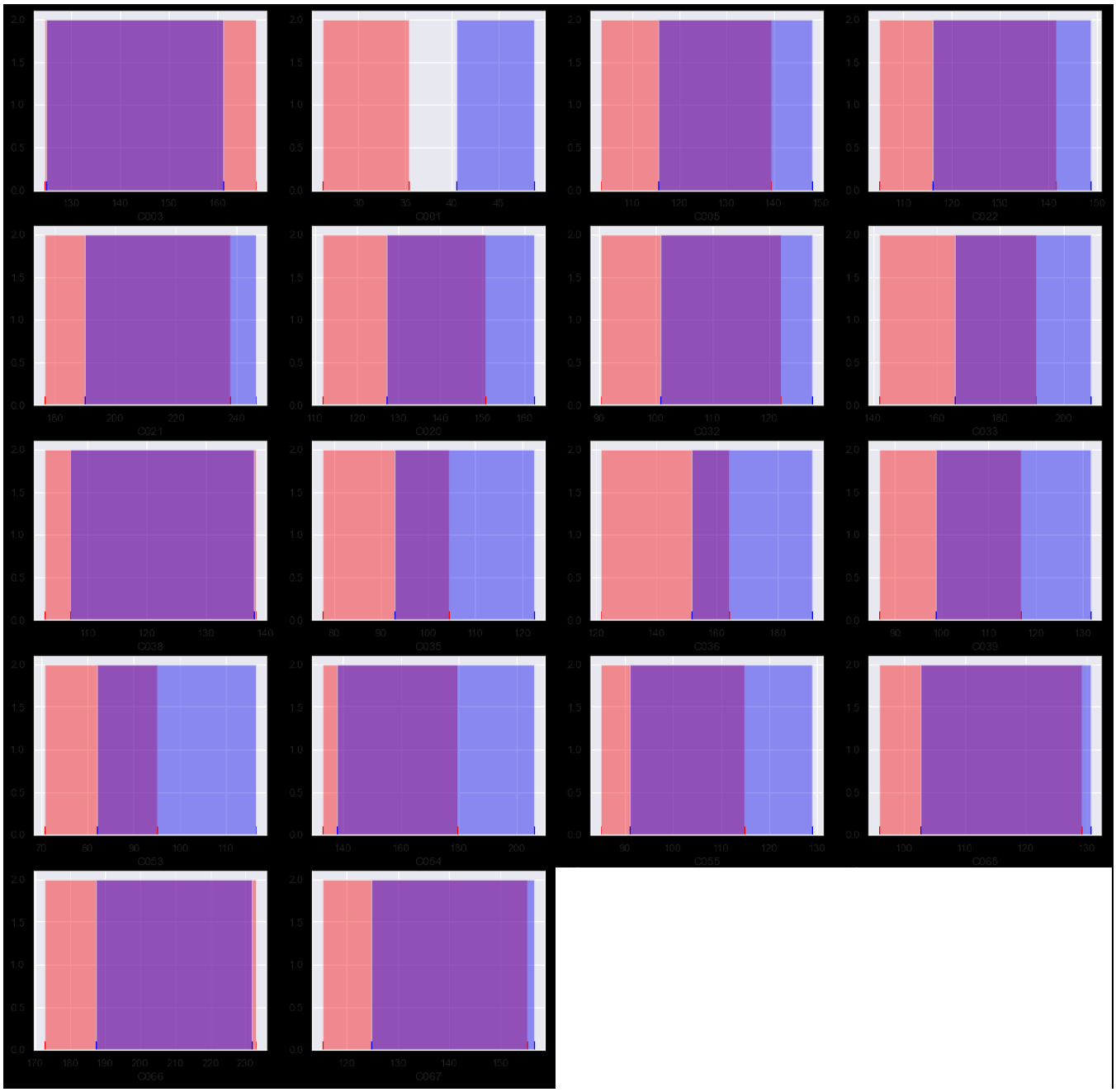

Figure 1 Visualization of where the assay data (red) and the IPA data (blue) overlap each other (purple).

References

1. Peterson-Droogh, Joshua. *IPA-Tool*. 8/27/2020 [cited bfd49e0276cba822b55967b32b2ce8b3254bdfd2; Available from: git@hpcgitlab.hpc.inl.gov:jpg_ecars/ecar-5111-ipa.git.
2. F. Brown, B. Kiedrowsky, et. al. MCNP5-1.60 Release Notes. LA-UR-10-06235
3. Gross, Brian. As-Run Physics Analysis of the HSA Cobalt Targets in the ATR H and Inner A-Positions for Cycles 157C through 166B. Idaho National Laboratory. ECAR-3872, Rev. 1
4. Idaho National Laboratory Irradiation Testing. *Experiment Irradiation Plan*. August 27, 2020 August 27, 2020]; Available from: https://nst.inl.gov/irradiationtesting/_layouts/15/WopiFrame2.aspx?sourcedoc=%7BC4A1F1B6-EA63-40BF-A13F-F110901165B6%7D&file=Experiment%20Irradiation%20Schedule%20Master.xlsx&action=default.
5. Managing Information Technology Assets. Idaho National Laboratory. LWP-13620 Rev. 18
6. ATR Irradiation cycle-Specific Requirements for MFC Space Nuclear Power and Isotope Technologies Division (SNIPT), U300 Isotope production programs (IPP). Idaho National Laboratory. 410.22-IP
7. HSA Co-60 Production Data Package. Idaho National Laboratory. DP-001
8. Reichenberger, Michael A. and Jagoda M. Urban-Klaehn. Measurement results for 60Co Assay baskets H5, H9, H14, H15, A4, and B3 (C003, C001, C005, C022, C021, C020, C032, C033, C038, C035, C036, C039, C053, C054, C055, C065, C066, & C067). Idaho National Laboratory. INL/EXT-20-59409

cc:
B. J. Gross
M. A. Reichenberger
J. M. Urban-Klahn
W. S. Green
M. A. Lillo