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Scientific Notebook No. 315: Hydrogen Generation in Hanford Tanks (03/18/1999 through 03/21/2000)

LABORATORY NOTEBOOK

CNWRA/SwRI

NOTEBOOK NO. _____

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tanks.

Milestone # 1403-201-940

Objectives:

Calculations conducted in this notebook provides the CNWRA assessment of the BNFL, Inc. proposed safety features for hydrogen control in the HLW storage vessels. The HLW storage vessels represent a potential explosive hazard because hydrogen is evolved by radiolysis in the aqueous radioactive wastes. The mixture of hydrogen and air can explode violently if an ignition source is present. NFPA 69 limits the accumulation of hydrogen in air to less than 1/4 concentration of the lower flammability limit (LFL) of 4 % hydrogen by volume.

BNFL Inc. plasn to transfer the contents of the tnals AZ-101 and AZ-102 into at least four different vessels, each containing approximately 1/4 concentration of the insoluble radionuclides. These solids will be stored for 1-2 years before HLW vitrification facility will be ready to accept solids for vitrification.

To evaluate whether the BNFL, Inc. conclusions are conservative, the CNWRA

- Reviewed the BNFL. Inc. calculations and proposed design safety features
- Reviewed the source document that provides radionuclide inventory and uncertainty estimates for Tanks AZ-101 and AZ-102
- Independently verified the BNFL, Inc. hydrogen generation calculationsand assumptions in estimating hydrogen generation rates.
- Evaluated the conservativeness associated with G-factors.
- Evaluated the influence of organics on the hydrogen generation rate.

References

Edwards, D. W., 1999. Design Safety Features and January Topical Deliverable TWRS_P Contarct No. DE-AC06-96RL13308-W375. Letter (January 20) to D. C. Gibbs, Regulatory Unit, Richland. WA: British Nuclear Fuels Limited, Inc.

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[illegible]	3/18/99	Recorded by	

Project No. 1403-201
Book No. 315 TITLE Hydrogen generation

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Table 1: Tank AZ-101 Inventory

Tank Name	Analyte	Value in Standard Units	Standard	Basis	Uncertainty Analyte	Mean	Median	Std Dev	90%
		Best Basis Inventory	Units						Percentile
241-AZ-101	Zr	8240	kg	S	Zr	260.0828	119.6759	314.7417	742.1607
241-AZ-101	3H	4	Ci	S	Tritium	4.141263	4	1.760578	6.670725
241-AZ-101	14C	0.43	Ci	S	C14	0.445781	0.43	0.275509	0.813385
241-AZ-101	59Ni	19.9	Ci	E	Ni59	31.38713	19.9	39.21166	78.2434
241-AZ-101	60Co	4610	Ci	E	Co60	34176.13	4622.579	143875.2	41281.38
241-AZ-101	63Ni	2300	Ci	E	Ni63	3627.658	2300	4532.001	9043.207
241-AZ-101	79Se	41.3	Ci	E	Se79	43.26018	41.3	17.41875	61.19695
241-AZ-101	90Sr	6360000	Ci	E	Sr90	2744026	623761.4	10016653	6095192
241-AZ-101	90Y	6360000	Ci	E	Y90	28025432	6360000	1.02E+08	62268555
241-AZ-101	93Zr	199	Ci	E	Zr93	471.2147	199	585.1954	1369.577
241-AZ-101	93mNb	87.4	Ci	E	Nb93	206.9556	87.4	257.0155	601.5128
241-AZ-101	99Tc	1100	Ci	E	Tc99	2097.945	1100	2491.907	5712.971
241-AZ-101	106Ru	48500	Ci	S/E	Ru106	143785.7	106000	189575.6	304826.3
241-AZ-101	113mCd	2120	Ci	E	Cd113	6165.416	2120	8071.718	18226.27
241-AZ-101	125Sb	131000	Ci	E	Sb125	252883.3	131000	304352.1	697804.2
241-AZ-101	126Sn	65.7	Ci	E	Tin126	191.0697	65.7	250.1471	564.8424
241-AZ-101	129I	7.1	Ci	S	I129	24.0404	7.1	30.48481	69.91606
241-AZ-101	134Cs	43400	Ci	E	Cs134	46641.99	43400	18316.26	64738.91
241-AZ-101	137Cs	7430000	Ci	E	Cs137	6091304	5894232	1113397	7191367
241-AZ-101	137mBa	7030000	Ci	E	Ba137	7447673	6930000	2924694	10337342
241-AZ-101	151Sm	142000	Ci	E	Sm151	218724.3	142000	248389.4	580410.6
241-AZ-101	152Eu	273	Ci	E	Eu152	420.5051	273	477.5373	1115.86
241-AZ-101	154Eu	57600	Ci	E	Eu154	88721.95	57600	100755.1	235434.2
241-AZ-101	155Eu	71500	Ci	E	Eu155	110132.3	71500	125069.3	292249
241-AZ-101	226Ra	0.00018	Ci	E	Ra226	0.000302	0.00018	0.000346	0.000806
241-AZ-101	227Ac	0.001	Ci	E	Ac227	0.00154	0.001	0.001749	0.004087
241-AZ-101	228Ra	1.10E-08	Ci	E	Ra228	2.18E-08	1.30E-08	2.50E-08	5.82E-08
241-AZ-101	229Th	1.20E-06	Ci	E	Th229	2.60E-06	1.20E-06	3.67E-06	7.40E-06
241-AZ-101	231Pa	0.0031	Ci	E	Pa231	0.006726	0.0031	0.009477	0.019121
241-AZ-101	232Th	1.60E-08	Ci	E	Th232	3.47E-08	1.60E-08	4.89E-08	9.87E-08
241-AZ-101	232U	0.0446	Ci	S/M	U232	0.000998	0.00046	0.001406	0.002837
241-AZ-101	233U	0.17	Ci	S/M	U233	0.000586	0.00027	0.000825	0.001665
241-AZ-101	234U	1.18	Ci	S/M	U234	2.603802	1.2	3.668664	7.401539
241-AZ-101	235U	0.0451	Ci	S/M	U235	0.095473	0.044	0.134518	0.27139
241-AZ-101	236U	0.0959	Ci	S/M	U236	0.214814	0.099	0.302665	0.610627
241-AZ-101	237Np	19.6	Ci	E	Np237	148.1072	19.6	745.1699	243.0472
241-AZ-101	238Pu	165	Ci	S	Pu238	1246.821	165	6273.114	2046.061
241-AZ-101	238U	0.819	Ci	S/M	U238	1.779264	0.82	2.506921	5.057718
241-AZ-101	239Pu	958	Ci	S	Pu239	7239.117	958	36422.08	11879.55
241-AZ-101	240Pu	272	Ci	S	Pu240	2055.365	272	10341.13	3372.9
241-AZ-101	241Am	22600	Ci	E	Am241	22516.7	216.8755	160270.9	19906.51
241-AZ-101	241Pu	9990	Ci	S	Pu241	75489.33	9990	379808.6	123879.7
241-AZ-101	242Cm	25.4	Ci	E	Cm242	191.9348	25.4	965.6794	314.9693
241-AZ-101	242Pu	0.074	Ci	E	Pu242	0.55918	0.074	2.813397	0.917627
241-AZ-101	243Am	9.98	Ci	E	Am243	75.41377	9.98	379.4284	123.7557
241-AZ-101	243Cm	4.36	Ci	E	Cm243	32.94629	4.36	165.7623	54.0656
241-AZ-101	244Cm	109	Ci	E	Cm244	770.7619	102	3877.925	1264.837

* See TWINS User's Guide - Uncertainty Description - for more information
** or go to http://twins.pnl.gov:8001/htdocs/TWINS2user_refs/rev20_2.html

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TITLE Hydrogen Generation
Project No. 1403-201
Book No. 315

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Table 1: Tank AZ-101 Inventory

Tank Name	Analyte	Value in Standard Units	Standard	Basis	Uncertainty Analyte	Mean	Median	Std Dev	90%
		Best Basis Inventory	Units						Percentile
241-AZ-101	Al	49000	kg	E	Al	33416	32601	14360	51319.86
241-AZ-101	Bi	0	kg	E	Bi	284.3741	155.3468	332.6323	769.9189
241-AZ-101	Ca	570	kg	S	Ca	4757.304	1809.447	8159.567	12971.35
241-AZ-101	Cl	640	kg	S	Cl	2398.894	710.8837	3037.631	6970.131
241-AZ-101	TIC as CO3	107000	kg	S	CO3	107218.2	106582.9	21804.2	135406.2
241-AZ-101	Cr	2640	kg	S	Cr	3884.288	1781.236	4823.524	11005.92
241-AZ-101	F	6060	kg	S	F	5003.52	5005.367	2434.336	8169.325
241-AZ-101	Fe	23400	kg	S	Fe	6429.903	4818.146	8111.762	13322.2
241-AZ-101	Hg	0	kg	E	Hg	0.756136	0.26	0.989928	2.235297
241-AZ-101	K	15700	kg	S	K	29404	19895.17	32539.23	77443.69
241-AZ-101	La	890	kg	S	La	41.475	37.04388	35.26112	90.57875
241-AZ-101	Mn	5220	kg	S	Mn	427.6119	232.3706	495.7787	1146.265
241-AZ-101	Na	351500	kg	S	Na	325336.3	324659.5	73460.58	419841.3
241-AZ-101	Ni	1360	kg	S	Ni	1195.869	790.3245	1395.599	2863.609
241-AZ-101	NO2	208900	kg	S	NO2	173478.6	173523.4	75429.74	269671.6
241-AZ-101	NO3	241500	kg	S	NO3	190400.1	188966.8	110694	335619.4
241-AZ-101	Pb	455	kg	E	Pb	698.2089	244.0755	908.9887	2056.28
241-AZ-101	PO4	4720	kg	S	PO4	3935.242	3845.427	2505.135	7325.955
241-AZ-101	Si	1380	kg	S	Si	2499.675	1676.271	4923.563	4646.192
241-AZ-101	SO4	57500	kg	S	SO4	58429.43	57810.75	5497.763	64090.69
241-AZ-101	Sr	117	kg	S	Sr	68.29149	43.22128	75.18479	177.4607
241-AZ-101	TOC	6060	kg	S	TOC	4762.871	4532.843	3456.14	9458.49
241-AZ-101	UTOTAL	2460	kg	S	U	11652.6	5544.705	15990.99	32565.53

Source: Internet http://twins.pnl.gov.8001/

Ferryman, T.A., B.G. Amiden, G. Chen, S.A. Hartly C.A. Lopresiti, J.G. Hill, T.J. Defrost, F. Gao, K.M. Remund, and B.J. Simpson. 1998. "Summary of Uncertainty Estimation Results of Hanford Tank Chemical and Radionuclide Inventories. PNNL-12003, Richland WA: Pacific Northwest Laboratory.

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Table 2: Tank AZ-102 Inventory

Tank Name	Analyte	Value in St	Standard	Basis	Uncertainty	Mean	Median	Std Dev	90%
		Best Basis	Units						Percentile
241-AZ-102	Zr	6720	kg	S/E	Zr	250.9117	133.6886	300.3872	701.2838
241-AZ-102	3H	1870	Ci	E	Tritium	15221.53	14700	5256.734	22253.19
241-AZ-102	14C	0.83	Ci	S	C14	0.848517	0.83	0.531758	1.550391
241-AZ-102	59Ni	10.8	Ci	E	Ni59	17.02089	10.8	20.02994	44.28913
241-AZ-102	60Co	3420	Ci	E	Co60	17823.91	2421.853	74610.96	20884.65
241-AZ-102	63Ni	1250	Ci	E	Ni63	1970.011	1250	2318.281	5126.057
241-AZ-102	79Se	22.8	Ci	E	Se79	24.28153	22.8	9.586254	35.32583
241-AZ-102	90Sr	3700000	Ci	E	Sr90	3215360	962342.7	10275878	7339686
241-AZ-102	90Y	3700000	Ci	E	Y90	12404702	3700000	39701625	28339346
241-AZ-102	93Zr	111	Ci	E	Zr93	231.8274	111	287.9681	665.0441
241-AZ-102	93mNb	43.3	Ci	E	Nb93	90.43357	43.3	112.3335	259.4271
241-AZ-102	99Tc	599	Ci	S/E	Tc99	1116.98	599	1280.732	2995.467
241-AZ-102	106Ru	76200	Ci	E	Ru106	92480.14	76200	112577.6	159988.9
241-AZ-102	113mCd	1220	Ci	E	Cd113	3459.043	1220	4509.427	10115.18
241-AZ-102	125Sb	92700	Ci	E	Sb125	174107.7	92700	209438.7	484470.5
241-AZ-102	126Sn	35.4	Ci	E	Tin126	100.3689	35.4	130.8473	293.5062
241-AZ-102	129I	1.52	Ci	E	I129	3.997283	1.52	4.748032	11.11395
241-AZ-102	134Cs	41200	Ci	E	Cs134	42818.7	41200	17184.51	62144.46
241-AZ-102	137Cs	4320000	Ci	E	Cs137	4007147	3941208	700974	4795329
241-AZ-102	137mBa	4090000	Ci	E	Ba137	4136370	3980000	1660057	6003276
241-AZ-102	151Sm	80200	Ci	E	Sm151	125481.2	80200	141797	335682.9
241-AZ-102	152Eu	142	Ci	E	Eu152	222.1737	142	251.0621	594.3513
241-AZ-102	154Eu	23100	Ci	E	Eu154	36142.34	23100	40841.79	96686.72
241-AZ-102	155Eu	26600	Ci	M	Eu155	104672	66900	118282.1	280014.8
241-AZ-102	226Ra	8.50E-05	Ci	E	Ra226	0.000137	8.50E-05	0.000156	0.000361
241-AZ-102	227Ac	0.00048	Ci	E	Ac227	0.000751	0.00048	0.000849	0.002009
241-AZ-102	228Ra	6.00E-09	Ci	E	Ra228	1.12E-08	7.00E-09	1.28E-08	2.98E-08
241-AZ-102	229Th	6.80E-07	Ci	E	Th229	1.21E-06	6.80E-07	1.54E-06	3.06E-06
241-AZ-102	231Pa	0.0018	Ci	E	Pa231	0.003203	0.0018	0.004072	0.008098
241-AZ-102	232Th	9.39E-09	Ci	E	Th232	1.67E-08	9.39E-09	2.12E-08	4.22E-08
241-AZ-102	232U	0.0185	Ci	S/M	U232	0.001299	0.00073	0.001651	0.003284
241-AZ-102	233U	0.0671	Ci	S/M	U233	0.000641	0.00036	0.000814	0.00162
241-AZ-102	234U	4.64	Ci	S/M	U234	3.98544	2.24	5.067215	10.07724
241-AZ-102	235U	0.177	Ci	S/M	U235	0.157105	0.0883	0.199748	0.397241
241-AZ-102	236U	0.382	Ci	S/M	U236	0.327375	0.184	0.416236	0.827774
241-AZ-102	237Np	11.7	Ci	E	Np237	53.06469	11.7	206.9469	99.81
241-AZ-102	238Pu	181	Ci	S/E	Pu238	820.9153	181	3201.486	1544.069
241-AZ-102	238U	3.19	Ci	S/M	U238	2.722198	1.53	3.461089	6.883117
241-AZ-102	239Pu	1250	Ci	S/E	Pu239	5669.305	1250	22109.71	10663.46
241-AZ-102	240Pu	372	Ci	S/E	Pu240	1687.185	372	6579.85	3173.446
241-AZ-102	241Am	14800	Ci	E	Am241	12881.72	810.7104	78945.28	13251.1
241-AZ-102	241Pu	17100	Ci	S/E	Pu241	77556.09	17100	302460.8	145876.2
241-AZ-102	242Cm	11.2	Ci	E	Cm242	50.79697	11.2	198.103	95.54462
241-AZ-102	242Pu	0.034	Ci	E	Pu242	0.154205	0.034	0.601384	0.290046
241-AZ-102	243Am	4.42	Ci	E	Am243	20.04666	4.42	78.17994	37.706
241-AZ-102	243Cm	1.77	Ci	E	Cm243	8.027736	1.77	31.30735	15.09946
241-AZ-102	244Cm	42.1	Ci	E	Cm244	178.2429	39.3	695.1293	335.2592
241-AZ-101	243Am	9.98	Ci	E	Am243	75.41377	9.98	379.4284	123.7557
241-AZ-101	243Cm	4.36	Ci	E	Cm243	32.94629	4.36	165.7623	54.0656
241-AZ-101	244Cm	109	Ci	E	Cm244	770.7619	102	3877.925	1264.837

* See TWINS User's Guide - Uncertainty Description - for more information
** or go to http://twins.pnl.gov:8001/htdocs/TWINS2user_refs/rev20_2.html

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Table 2: Tank AZ-102 Inventory

Tank Name	Analyte	Value in St	Standard	Basis	Uncertainty	Mean	Median	Std Dev	90%
		Best Basis	Units						Percentile
241-AZ-102	Cl	32	kg	S/E	Cl	2476.637	947.094	2931.566	6870.665
241-AZ-102	TIC as CO3	128000	kg	S/E	CO3	106928.7	106779.6	21850.87	134897.5
241-AZ-102	Cr	3950	kg	S/E	Cr	3724.104	1752.912	4593.678	10587.51
241-AZ-102	F	3690	kg	S/E	F	4460.987	4456.122	2369.118	7534.431
241-AZ-102	Fe	48400	kg	S/E	Fe	7501.706	6279.676	8464.097	12578.2
241-AZ-102	Hg	0	kg	E	Hg	0.034023	0.012	0.044355	0.099494
241-AZ-102	K	11100	kg	S/E	K	28298.49	18796.32	31244.61	74396.51
241-AZ-102	La	1670	kg	S/E	La	40.19931	35.30423	34.03698	88.47333
241-AZ-102	Mn	1060	kg	S/E	Mn	430.0708	239.652	478.5264	1131.265
241-AZ-102	Na	199000	kg	S/E	Na	232803.1	232629.2	70680.94	323754.3
241-AZ-102	Ni	3280	kg	S/E	Ni	1032.368	687.2596	1125.451	2563.897
241-AZ-102	NO2	104000	kg	S/E	NO2	130273.1	128618.8	70269.84	223275.3
241-AZ-102	NO3	79500	kg	S/E	NO3	135729.5	127859.1	98995.29	271224.9
241-AZ-102	Pb	400	kg	S/E	Pb	671.2868	240.7915	869.1455	1954.085
241-AZ-102	PO4	457	kg	S/E	PO4	2656.227	2258.374	2176.168	5687.768
241-AZ-102	Si	3430	kg	S/E	Si	3163.335	2207.505	5024.641	5309.079
241-AZ-102	SO4	62100	kg	S/E	SO4	60716.5	59891.76	5336.471	66864.63
241-AZ-102	Sr	121	kg	S/E	Sr	66.12289	43.9044	72.14909	169.936
241-AZ-102	TOC	6220	kg	S/E	TOC	11145.6	8919.246	12633.3	19608.76
241-AZ-102	UTOTAL	9580	kg	S/E	U	6962.863	4110.412	8312.082	16955.93

Same source as on page 3.

Heat generation rate was calculated for same radionuclides that ~~was~~ were selected by BN BNFL, Inc. for calculating hydrogen generation rate.

- Selected radionuclides from Tank AZ-101 and AZ-102 were combined.
- Combined inventory was assumed to be completely transferred to BNFL, Inc. Tanks.
- Total inventory for each radionuclide ~~was~~ listed in Curies was converted to Bq. by multiplying factor of 3.7×10^{10}.
- Heat generation rate factors were obtained from BNFL report.

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For example.

^{90}Sr inventory

AZ 101 = 6.36×10^6 · Ci
AZ 102 = 3.70×10^6 · Ci

Total ^{90}Sr = 1.01×10^7 Ci

1 Ci = 3.7×10^{10} Bq.

^{90}Sr = $1.01 \times 10^7 \times 3.7 \times 10^{10}$

= 3.72×10^{17} Bq.

Heat generation rate for ^{90}Sr = 3.14×10^{-14} W/Bq.
(β, γ - radiation)

Heat generation = $3.72 \times 10^{17} \times 3.14 \times 10^{-14}$

= 1.17×10^4 W.

Table 2 Page 7, shows the total heat generation rate using Best Basis inventory for Tanks AZ 101 and AZ 102.

Hydrogen generation rate (molecules/sec) is given by

= $G(H_2)_{\beta\gamma} \times$ (total heat generation)$_{\beta\gamma}$
+ $G(H_2)_{\alpha} \times$ (total heat generation)$_{\alpha}$

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Table 2-2. Calculated heat generation rate from Tanks AZ–101 and AZ–102 using Best-Basis inventory

Radionuclide	AZ–101 Inventory (Ci)	AZ–102 Inventory (Ci)	Total Inventory (Ci)	Total Inventory (Bq)	Heat Generation Rate (W/Bq)	Heat Generation (W)	BNFL, Inc. Estimated Heat Generation (W)
^{60}Co	4.61E+3	3.42E+3	8.03E-3	2.97E+14	4.16E-13 (βγ)	1.24E+2	1.24E+2
^{90}Sr	6.36E+06	3.70E+6	1.01E+7	3.72E+17	3.14E-14 (βγ)	1.17E+4	6.73E+4 (^{90}Sr and ^{90}Y)
^{90}Y	6.36E+06	3.70E+6	1.01E+7	3.72E+17	1.49E-13 (βγ)	5.55E+4	
^{152}Eu	2.73E+2	1.42E+02	4.15E+2	1.54E+13	1.22E-13 (βγ)	1.87E+0	1.53E+1
^{154}Eu	5.76E+4	2.31E+4	8.07E+4	2.99E+15	2.43E-13 (βγ)	7.26E2	1.45E+3
^{155}Eu	7.15E+4	2.66E+4	9.81E+4	3.63E+15	1.95E-14 (βγ)	7.08E+1	7.10E+1
^{233}U	1.70E-1	6.71E-2	2.37E-1	8.77E+9	7.68E-13 (α)	6.74E-3	6.73E-3
^{235}U	4.51E-2	1.77E-1	2.22E-1	8.22E+9	7.32E-13 (α)	6.02E-3	3.01E-2
^{237}Np	1.96E+1	1.17E+1	3.13E+1	1.16E+12	7.78E-13 (α)	9.01E-1	2.70E+0
^{238}Pu	1.65E+2	1.81E+2	3.46E+2	1.28E+13	8.81E-13 (α)	1.13E+1	1.13E+1
^{239}Pu	9.58E+2	1.25E+3	2.21E+3	8.17E+13	8.24E-13 (α)	1.23E+3	1.35E+2
^{241}Pu	9.99E+3	1.71E+4	2.71E+4	1.00E+15	8.38E-16 (α)	8.40E-1	8.4E-1
^{241}Am	2.26E+4	1.48E+4	3.74E+4	1.38E+15	8.86E-13 (βγ)	1.23E+3	1.23E+3
^{244}Cm	1.09E+2	4.21E+1	1.51E+2	5.59E+12	9.30E-13 (α)	5.20E+0	2.75E+1
					Total (βγ)	**6.81E+4**	**6.89E+4**
					Total (α)	**1.31E+3**	**1.40E+3**

Table also indicates (last column), BNFL, INC. calculations from their report (Edwards, 1999)

BNFL's calculations are acceptable.

Total Heat generation = $6.81 \times 10^4 + 1.31 \times 10^3$

= 6.94×10^4 W.

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where

$G(H_2)_{\beta\gamma}$ = molecules of H_2 per 100 eV $\beta\gamma$ radiation absorbed
= 0.45 molecules/100 eV
= 2.81E + 16 molecules/joule

(total heat generation)$_{\beta\gamma}$ = 6.81E + 4 W for 4 tanks
= 1.70E + 4 W per tank

$G(H_2)_{\alpha}$ = molecules of H_2 per 100 eV α radiation absorbed
= 1.57 molecules/100 eV
= 9.81E + 16 molecules/eV

(total heat generation)$_{\alpha}$ = 1.31E + 3 W for 4 tanks
= 3.28E + 2 W per tank

Using these values, the hydrogen generation rate is given by

Hydrogen generation rate (molecules/s) = 2.81E+16 × 1.7E+4 + 9.81E + 16 × 3.28E + 2
= 5.11E+20 molecules/s

Assuming the hydrogen generation rate at standard pressure and temperature, the volume of hydrogen generated is given by

$$\text{Hydrogen generation rate (L / hr)} = \frac{5.11\text{E}+20\,\text{molecules / s} \times 22.4\,\text{L / mole} \times 60\,\text{s / hr}}{6.023\text{E}+23\,\text{molecules / mole}} = 68.4\,\text{L / hr}$$

Assuming a well mixed tank, the time required to reach 1 percent hydrogen in free space of 85,000 L in the tank is given by

$$\text{Time to reach 1 percent LFL} = \frac{85{,}000\ \text{L}}{68.4\ \text{L/hr} \times 100} = 12.4\ \text{hrs}$$

Similar calculations were done using excel spreadsheet for mean, median and 90% percentile values for combined AZ101 and AZ102 inventory. In addition, 90% percentile with 25% inventory was also used in calculations. Radionuclides, as shown in Page 7, for Best Basis inventory were used. To allow comparsion between datasets.

Page 9 – 12 show data using different sets of radionuclide inventory.

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Mean

Radionuclides	AZ-101	AZ-102	Total Ci	Total Bq	Iventory In Tank beta-gam Bq	Iventory In Tank alpha	Decay Heat beta-gam W/bq	Decay Heat alpha	Heat Generation beta-gam	Heat Generation alpha
Total waste	4.04E+06	3.88E+06	7.92E+06			3.70E+10				
H-3	4.14E+00	1.52E+04	1.52E+04	5.63E+14						
C-14	4.46E-01	8.49E-01	1.29E+00	4.79E+10						
Ni-59	3.14E+01	1.70E+01	4.84E+01	1.79E+12						
Co-60	3.42E+04	1.78E+04	5.20E+04	1.92E+15	1.92E+15		4.16E-13		8.00E+02	
Ni-63	3.63E+03	1.97E+03	5.60E+03	2.07E+14						
Se-79	4.33E+01	2.43E+01	6.75E+01	2.50E+12						
Sr-90	2.74E+06	3.22E+06	5.96E+06	2.20E+17	2.20E+17		3.14E-14		6.92E+03	
Y-90	2.80E+07	1.24E+07	4.04E+07	1.50E+18	1.50E+18		1.49E-13		2.23E+05	
Zr-93	4.71E+02	2.32E+02	7.03E+02	2.60E+13						
Nb-93m	2.07E+02	9.04E+01	2.97E+02	1.10E+13						
Tc-99	2.10E+03	1.12E+03	3.21E+03	1.19E+14						
Ru-106	1.44E+05	9.25E+04	2.36E+05	8.74E+15						
Cd-113m	6.17E+03	3.46E+03	9.62E+03	3.56E+14						
Sb-125	2.53E+05	1.74E+05	4.27E+05	1.58E+16						
Sn-126	1.91E+02	1.00E+02	2.91E+02	1.08E+13						
I-129	2.40E+01	4.00E+00	2.80E+01	1.04E+12						
Cs-134	4.66E+04	4.28E+04	8.95E+04	3.31E+15						
Cs-137	6.09E+06	4.01E+06	1.01E+07	3.74E+17						
Ba-137m	7.45E+06	4.14E+06	1.16E+07	4.29E+17						
Sm-151	2.19E+05	1.25E+05	3.44E+05	1.27E+16						
Eu-152	4.21E+02	2.22E+02	6.43E+02	2.38E+13	2.38E+13		1.22E-13		2.90E+00	
Eu-154	8.87E+04	3.61E+04	1.25E+05	4.62E+15	4.62E+15		2.43E-13		1.12E+03	
Eu-155	1.10E+05	1.05E+05	2.15E+05	7.95E+15	7.95E+15		1.95E-14		1.55E+02	
Ra-226	3.02E-04	1.37E-04	4.39E-04	1.62E+07						
Ac-227	1.54E-03	7.51E-04	2.29E-03	8.48E+07						
Ra-228	2.18E-08	1.12E-08	3.31E-08	1.22E+03						
Th-229	2.60E-06	1.21E-06	3.81E-06	1.41E+05						
Pa-231	6.73E-03	3.20E-03	9.93E-03	3.67E+08						
Th-232	3.47E-08	1.67E-08	5.14E-08	1.90E+03						
U-232	9.98E-04	1.30E-03	2.30E-03	8.50E+07						
U-233	5.86E-04	6.41E-04	1.23E-03	4.54E+07		4.54E+07		7.68E-13		3.48E-05
U-234	2.60E+00	3.99E+00	6.59E+00	2.44E+11						
U-235	9.55E-02	1.57E-01	2.53E-01	9.35E+09		9.35E+09		7.32E-13		6.84E-03
U-236	2.15E-01	3.27E-01	5.42E-01	2.01E+10						
Np-237	1.48E+02	5.31E+01	2.01E+02	7.44E+12		7.44E+12		7.78E-13		5.79E+00
Pu-238	1.25E+03	8.21E+02	2.07E+03	7.65E+13		7.65E+13		8.81E-13		6.74E+01
U-238	1.78E+00	2.72E+00	4.50E+00	1.67E+11						
Pu-239	7.24E+03	5.67E+03	1.29E+04	4.78E+14		4.78E+14		8.24E-13		3.94E+02
Pu-240	2.06E+03	1.69E+03	3.74E+03	1.38E+14						
Am-241	2.25E+04	1.29E+04	3.54E+04	1.31E+15		1.31E+15		8.86E-13		1.16E+03
Pu-241	7.55E+04	7.76E+04	1.53E+05	5.66E+15	5.66E+15		8.38E-16		4.75E+00	
Cm-242	1.92E+02	5.08E+01	2.43E+02	8.98E+12				9.78E-13		
Pu-242	5.59E-01	1.54E-01	7.13E-01	2.64E+10						
Am-243	7.54E+01	2.00E+01	9.55E+01	3.53E+12						
Cm-243	3.29E+01	8.03E+00	4.10E+01	1.52E+12						
Cm-244	7.71E+02	1.78E+02	9.49E+02	3.51E+13		3.51E+13		9.30E-13		3.27E+01
			6.98E+07		1.74E+18	1.91E+15			2.32E+05	1.66E+03 Joules/sec
										2.59E+21 J/s pertank

Total dose	1.74E+18	
Dose per tank	4.35E+17	bq
Volume	197000	L
Dose per tank	2.21E+12	bq/L
G(h2) beta gam	0.45	per 100 ev 2.81E+16 joules
G(h2) alpha	1.57	per 100 ev 9.81E+16 joules
1ev	1.60E-19	joules
Energy/tank (b-g)	57975.15	Watts
H2 gen	1.63E+21	mol./sec
Energy/tank (al)	414.9595	
H2 gen	4.07E+19	mol./sec
Total	1.67E+21	mol./sec
Avagadros #	6.02E+23	mol./mole
	2.77E-03	moles/sec
at stp	22.4	l/mole
H2 gen	0.062156	L/sec
	223.7608	L/hr
1 ft3/hr	28.3	L/hr
H2 gen	**7.906743**	ft3/hr
Volume	8.50E+04	
Time	3.80E+00	hours

Time to reach 1% H_2

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Median Inventory

1 Ci 3.70E+10 bq

Radionuclid	AZ-101	AZ-102	Total Ci	Total Bq	Iventory In Tank beta-gam	Iventory In Tank alpha	Decay Heat beta-gam	Decay Heat alpha	Heat Generation beta-gam	Heat Generation alpha
					Bq		W/bq			
H-3	4.00E+00	1.47E+04	1.47E+04	5.44E+14						
C-14	4.30E-01	8.30E-01	1.26E+00	4.66E+10						
Ni-59	1.99E+01	1.08E+01	3.07E+01	1.14E+12						
Co-60	4.62E+03	2.42E+03	7.04E+03	2.61E+14	2.61E+14		4.16E-13		1.08E+02	
Ni-63	2.30E+03	1.25E+03	3.55E+03	1.31E+14						
Se-79	4.13E+01	2.28E+01	6.41E+01	2.37E+12						
Sr-90	6.24E+05	9.62E+05	1.59E+06	5.87E+16	5.87E+16		3.14E-14		1.84E+03	
Y-90	6.36E+06	3.70E+06	1.01E+07	3.72E+17	3.72E+17		1.49E-13		5.55E+04	
Zr-93	1.99E+02	1.11E+02	3.10E+02	1.15E+13						
Nb-93m	8.74E+01	4.33E+01	1.31E+02	4.84E+12						
Tc-99	1.10E+03	5.99E+02	1.70E+03	6.29E+13						
Ru-106	1.06E+05	7.62E+04	1.82E+05	6.74E+15						
Cd-113m	2.12E+03	1.22E+03	3.34E+03	1.24E+14						
Sb-125	1.31E+05	9.27E+04	2.24E+05	8.28E+15						
Sn-126	6.57E+01	3.54E+01	1.01E+02	3.74E+12						
I-129	7.10E+00	1.52E+00	8.62E+00	3.19E+11						
Cs-134	4.34E+04	4.12E+04	8.46E+04	3.13E+15						
Cs-137	5.89E+06	3.94E+06	9.84E+06	3.64E+17						
Ba-137m	6.93E+06	3.98E+06	1.09E+07	4.04E+17						
Sm-151	1.42E+05	8.02E+04	2.22E+05	8.22E+15						
Eu-152	2.73E+02	1.42E+02	4.15E+02	1.54E+13	1.54E+13		1.22E-13		1.87E+00	
Eu-154	5.76E+04	2.31E+04	8.07E+04	2.99E+15	2.99E+15		2.43E-13		7.26E+02	
Eu-155	7.15E+04	6.69E+04	1.38E+05	5.12E+15	5.12E+15		1.95E-14		9.99E+01	
Ra-226	1.80E-04	8.50E-05	2.65E-04	9.81E+06						
Ac-227	1.00E-03	4.80E-04	1.48E-03	5.48E+07						
Ra-228	1.30E-08	7.00E-09	2.00E-08	7.40E+02						
Th-229	1.20E-06	6.80E-07	1.88E-06	6.96E+04						
Pa-231	3.10E-03	1.80E-03	4.90E-03	1.81E+08						
Th-232	1.60E-08	9.39E-09	2.54E-08	9.39E+02						
U-232	4.60E-04	7.30E-04	1.19E-03	4.40E+07						
U-233	2.70E-04	3.60E-04	6.30E-04	2.33E+07		2.33E+07		7.68E-13		1.79E-05
U-234	1.20E+00	2.24E+00	3.44E+00	1.27E+11						
U-235	4.40E-02	8.83E-02	1.32E-01	4.90E+09		4.90E+09		7.32E-13		3.58E-03
U-236	9.90E-02	1.84E-01	2.83E-01	1.05E+10						
Np-237	1.96E+01	1.17E+01	3.13E+01	1.16E+12		1.16E+12		7.78E-13		9.01E-01
Pu-238	1.65E+02	1.81E+02	3.46E+02	1.28E+13		1.28E+13		8.81E-13		1.13E+01
U-238	8.20E-01	1.53E+00	2.35E+00	8.70E+10						
Pu-239	9.58E+02	1.25E+03	2.21E+03	8.17E+13		8.17E+13		8.24E-13		6.73E+01
Pu-240	2.72E+02	3.72E+02	6.44E+02	2.38E+13						
Am-241	2.17E+02	8.11E+02	1.03E+03	3.80E+13		3.80E+13		8.86E-13		3.37E+01
Pu-241	9.99E+03	1.71E+04	2.71E+04	1.00E+15	1.00E+15		8.38E-16		8.40E-01	
Cm-242	2.54E+01	1.12E+01	3.66E+01	1.35E+12				9.78E-13		
Pu-242	7.40E-02	3.40E-02	1.08E-01	4.00E+09						
Am-243	9.98E+00	4.42E+00	1.44E+01	5.33E+11						
Cm-243	4.36E+00	1.77E+00	6.13E+00	2.27E+11						
Cm-244	1.02E+02	3.93E+01	1.41E+02	5.23E+12		5.23E+12		9.30E-13		4.86E+00
			3.34E+07	1.24E+18	4.40E+17	1.39E+14			5.82E+04	1.18E+02 Joules/sec

Total dose 4.40E+17
Dose per ta 1.10E+17 bq

Supernaten 7.95E+17
Cs/Ba 7.68E+17

Volume 1.97E+05 L
Dose per ta 5.59E+11

G(h2) beta 4.50E-01 per 100 ev 2.81E+16 joules
G(h2) alpha 1.57E+00 per 100 ev 9.81E+16 joules
1ev 1.60E-19 joules
Energy/tan 1.46E+04 Watts
H2 gen 4.10E+20 mol./sec
Energy/tan 2.95E+01
H2 gen 2.90E+18 mol./sec

Beta/alp 4.93E+02

Total 4.12E+20 mol./sec
Avagadros 6.02E+23 mol./mole
6.85E-04 moles/sec

at stp 2.24E+01 l/mole
H2 gen 1.53E-02 L/sec
5.52E+01 L/hr
1 ft3/hr 2.83E+01 L/hr
H2 gen **1.95E+00** ft3/hr
Volume 8.50E+04 L
Time 1.54E+01 hrs

Time to reach 1% H_2

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90 percentile

Total waste 4.04E+06 3.88E+06 7.92E+06 3.70E+10

Radionuclid	AZ-101	AZ-102	Total Ci	Total Bq	Iventory In Tank beta-gam	Iventory In Tank alpha	Decay Heat beta-gam	Decay Heat alpha	Heat Generation beta-gam	Heat Generation alpha
					Bq		W/bq			
H-3	6.67E+00	2.23E+04	2.23E+04	8.24E+14						
C-14	8.13E-01	1.55E+00	2.36E+00	8.75E+10						
Ni-59	7.82E+01	4.43E+01	1.23E+02	4.53E+12						
Co-60	4.13E+04	2.09E+04	6.22E+04	2.30E+15	2.30E+15		4.16E-13		9.57E+02	
Ni-63	9.04E+03	5.13E+03	1.42E+04	5.24E+14						
Se-79	6.12E+01	3.53E+01	9.65E+01	3.57E+12						
Sr-90	6.10E+06	7.34E+06	1.34E+07	4.97E+17	4.97E+17		3.14E-14		1.56E+04	
Y-90	6.23E+07	2.83E+07	9.06E+07	3.35E+18	3.35E+18		1.49E-13		5.00E+05	
Zr-93	1.37E+03	6.65E+02	2.03E+03	7.53E+13						
Nb-93m	6.02E+02	2.59E+02	8.61E+02	3.19E+13						
Tc-99	5.71E+03	3.00E+03	8.71E+03	3.22E+14						
Ru-106	3.05E+05	1.60E+05	4.65E+05	1.72E+16						
Cd-113m	1.82E+04	1.01E+04	2.83E+04	1.05E+15						
Sb-125	6.98E+05	4.84E+05	1.18E+06	4.37E+16						
Sn-126	5.65E+02	2.94E+02	8.58E+02	3.18E+13						
I-129	6.99E+01	1.11E+01	8.10E+01	3.00E+12						
Cs-134	6.47E+04	6.21E+04	1.27E+05	4.69E+15						
Cs-137	7.19E+06	4.80E+06	1.20E+07	4.44E+17						
Ba-137m	1.03E+07	6.00E+06	1.63E+07	6.05E+17						
Sm-151	5.80E+05	3.36E+05	9.16E+05	3.39E+16						
Eu-152	1.12E+03	5.94E+02	1.71E+03	6.33E+13	6.33E+13		1.22E-13		7.72E+00	
Eu-154	2.35E+05	9.67E+04	3.32E+05	1.23E+16	1.23E+16		2.43E-13		2.99E+03	
Eu-155	2.92E+05	2.80E+05	5.72E+05	2.12E+16	2.12E+16		1.95E-14		4.13E+02	
Ra-226	8.06E-04	3.61E-04	1.17E-03	4.32E+07						
Ac-227	4.09E-03	2.01E-03	6.10E-03	2.26E+08						
Ra-228	5.82E-08	2.98E-08	8.79E-08	3.25E+03						
Th-229	7.40E-06	3.06E-06	1.05E-05	3.87E+05						
Pa-231	1.91E-02	8.10E-03	2.72E-02	1.01E+09						
Th-232	9.87E-08	4.22E-08	1.41E-07	5.21E+03						
U-232	2.84E-03	3.28E-03	6.12E-03	2.26E+08						
U-233	1.67E-03	1.62E-03	3.28E-03	1.22E+08		1.22E+08		7.68E-13		9.33E-05
U-234	7.40E+00	1.01E+01	1.75E+01	6.47E+11						
U-235	2.71E-01	3.97E-01	6.69E-01	2.47E+10		2.47E+10		7.32E-13		1.81E-02
U-236	6.11E-01	8.28E-01	1.44E+00	5.32E+10						
Np-237	2.43E+02	9.98E+01	3.43E+02	1.27E+13		1.27E+13		7.78E-13		9.87E+00
Pu-238	2.05E+03	1.54E+03	3.59E+03	1.33E+14		1.33E+14		8.81E-13		1.17E+02
U-238	5.06E+00	6.88E+00	1.19E+01	4.42E+11						
Pu-239	1.19E+04	1.07E+04	2.25E+04	8.34E+14		8.34E+14		8.24E-13		6.87E+02
Pu-240	3.37E+03	3.17E+03	6.55E+03	2.42E+14						
Am-241	1.99E+04	1.33E+04	3.32E+04	1.23E+15		1.23E+15		8.86E-13		1.09E+03
Pu-241	1.24E+05	1.46E+05	2.70E+05	9.98E+15	9.98E+15		8.38E-16		8.36E+00	
Cm-242	3.15E+02	9.55E+01	4.11E+02	1.52E+13				9.78E-13		
Pu-242	9.18E-01	2.90E-01	1.21E+00	4.47E+10						
Am-243	1.24E+02	3.77E+01	1.61E+02	5.97E+12						
Cm-243	5.41E+01	1.51E+01	6.92E+01	2.56E+12						
Cm-244	1.26E+03	3.35E+02	1.60E+03	5.92E+13		5.92E+13		9.30E-13		5.51E+01
			1.36E+08		3.90E+18	2.27E+15			5.20E+05	1.96E+03 Joules/sec
										3.06E+21 J/s pertank

Total dose 3.90E+18
Dose per ta 9.74E+17 bq

Volume 197000 L
Dose per ta 4.95E+12

G(h2) beta 0.45 per 100 ev 2.81E+16 joules
G(h2) alpha 1.57 per 100 ev 9.81E+16 joules
1ev 1.60E-19 joules
Energy/tan 129875.5 Watts
H2 gen 3.65E+21 mol./sec
Energy/tan 489.0597
H2 gen 4.80E+19 mol./sec

Total 3.70E+21 mol./sec
Avagadros 6.02E+23 mol./mole
6.14E-03 moles/sec

at stp 22.4 l/mole
H2 gen 0.137633 L/sec
495.4797 L/hr
1 ft3/hr 28.3 L/hr
H2 gen **17.50812** ft3/hr
Volume 8.50E+04 L
Time 1.72E+00 hrs

Time to reach 1% H_2

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90 percentile with25% extra inventory

Total waste 4.04E+06 3.88E+06 7.92E+06 3.70E+10

Radionuclid	AZ-101	AZ-102	Total Ci	Bq	Iventory In Tank beta-gam Bq	alpha	Decay Heat beta-gam W/bq	alpha	Heat Generation beta-gam	alpha
H-3	6.67E+00	2.23E+04	2.23E+04	8.24E+14						
C-14	8.13E-01	1.55E+00	2.36E+00	8.75E+10						
Ni-59	7.82E+01	4.43E+01	1.23E+02	4.53E+12						
Co-60	4.13E+04	2.09E+04	6.22E+04	2.30E+15	2.30E+15		4.16E-13		9.57E+02	
Ni-63	9.04E+03	5.13E+03	1.42E+04	5.24E+14						
Se-79	6.12E+01	3.53E+01	9.65E+01	3.57E+12						
Sr-90	6.10E+06	7.34E+06	1.34E+07	4.97E+17	4.97E+17		3.14E-14		1.56E+04	
Y-90	6.23E+07	2.83E+07	9.06E+07	3.35E+18	3.35E+18		1.49E-13		5.00E+05	
Zr-93	1.37E+03	6.65E+02	2.03E+03	7.53E+13						
Nb-93m	6.02E+02	2.59E+02	8.61E+02	3.19E+13						
Tc-99	5.71E+03	3.00E+03	8.71E+03	3.22E+14						
Ru-106	3.05E+05	1.60E+05	4.65E+05	1.72E+16						
Cd-113m	1.82E+04	1.01E+04	2.83E+04	1.05E+15						
Sb-125	6.98E+05	4.84E+05	1.18E+06	4.37E+16						
Sn-126	5.65E+02	2.94E+02	8.58E+02	3.18E+13						
I-129	6.99E+01	1.11E+01	8.10E+01	3.00E+12						
Cs-134	6.47E+04	6.21E+04	1.27E+05	4.69E+15						
Cs-137	7.19E+06	4.80E+06	1.20E+07	4.44E+17						
Ba-137m	1.03E+07	6.00E+06	1.63E+07	6.05E+17						
Sm-151	5.80E+05	3.36E+05	9.16E+05	3.39E+16						
Eu-152	1.12E+03	5.94E+02	1.71E+03	6.33E+13	6.33E+13		1.22E-13		7.72E+00	
Eu-154	2.35E+05	9.67E+04	3.32E+05	1.23E+16	1.23E+16		2.43E-13		2.99E+03	
Eu-155	2.92E+05	2.80E+05	5.72E+05	2.12E+16	2.12E+16		1.95E-14		4.13E+02	
Ra-226	8.06E-04	3.61E-04	1.17E-03	4.32E+07						
Ac-227	4.09E-03	2.01E-03	6.10E-03	2.26E+08						
Ra-228	5.82E-08	2.98E-08	8.79E-08	3.25E+03						
Th-229	7.40E-06	3.06E-06	1.05E-05	3.87E+05						
Pa-231	1.91E-02	8.10E-03	2.72E-02	1.01E+09						
Th-232	9.87E-08	4.22E-08	1.41E-07	5.21E+03						
U-232	2.84E-03	3.28E-03	6.12E-03	2.26E+08						
U-233	1.67E-03	1.62E-03	3.28E-03	1.22E+08		1.22E+08		7.68E-13		9.33E-05
U-234	7.40E+00	1.01E+01	1.75E+01	6.47E+11						
U-235	2.71E-01	3.97E-01	6.69E-01	2.47E+10		2.47E+10		7.32E-13		1.81E-02
U-236	6.11E-01	8.28E-01	1.44E+00	5.32E+10						
Np-237	2.43E+02	9.98E+01	3.43E+02	1.27E+13		1.27E+13		7.78E-13		9.87E+00
Pu-238	2.05E+03	1.54E+03	3.59E+03	1.33E+14		1.33E+14		8.81E-13		1.17E+02
U-238	5.06E+00	6.88E+00	1.19E+01	4.42E+11						
Pu-239	1.19E+04	1.07E+04	2.25E+04	8.34E+14		8.34E+14		8.24E-13		6.87E+02
Pu-240	3.37E+03	3.17E+03	6.55E+03	2.42E+14						
Am-241	1.99E+04	1.33E+04	3.32E+04	1.23E+15		1.23E+15		8.86E-13		1.09E+03
Pu-241	1.24E+05	1.46E+05	2.70E+05	9.98E+15	9.98E+15		8.38E-16		8.36E+00	
Cm-242	3.15E+02	9.55E+01	4.11E+02	1.52E+13				9.78E-13		
Pu-242	9.18E-01	2.90E-01	1.21E+00	4.47E+10						
Am-243	1.24E+02	3.77E+01	1.61E+02	5.97E+12						
Cm-243	5.41E+01	1.51E+01	6.92E+01	2.56E+12						
Cm-244	1.26E+03	3.35E+02	1.60E+03	5.92E+13		5.92E+13		9.30E-13		5.51E+01
			1.36E+08		3.90E+18	2.27E+15			5.20E+05	1.96E+03 Joules/sec
										3.06E+21 J/s pertank

Total dose 3.90E+18
Dose per ta 9.74E+17 bq

Volume 197000 L
Dose per ta 4.95E+12

G(h2) beta 0.45 per 100 ev 2.81E+16 joules
G(h2) alpha 1.57 per 100 ev 9.81E+16 joules
1ev 1.60E-19 joules
Energy/tan 129875.5 Watts
H2 gen 3.65E+21 mol./sec
Energy/tan 489.0597
H2 gen 4.80E+19 mol./sec

Total 3.70E+21 mol./sec
Avagadros 6.02E+23 mol./mole
6.14E-03 moles/sec

at stp 22.4 l/mole
H2 gen 0.137633 L/sec
495.4797 L/hr **619.3496**
1 ft3/hr 28.3 L/hr
H2 gen 17.50812 ft3/hr **21.88515**
Volume 8.50E+04
Time 1.37E+00

Time to reach 1% LFL

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Data Collected from various inventories discussed on pages 7 through 12 is summarized below.

Table 2-3. Hydrogen generation rates

Inventory	Hydrogen generation rate L/hr (ft³/hr)	Time to reach 25% LFL (hr)
Best-Basis inventory	68.4 (2.42)	12.4
Mean (Uncertainty Method)	224 (7.90)	3.80
Median (Uncertainty Method)	55.2 (1.95)	15.4
90th percentile (Uncertainty Method)	495 (17.5)	1.72
90th percentile with 25% extra radionuclide in one of the four storage tanks	619 (21.9)	1.37

~~As shown~~ VJ 8/15/00
From the above table, it is evident that hydrogen generation rates estimated by the BNFL, Inc. appears to be non-conservative, based on their use of "Best-Basis" inventory values (without the consideration of uncertainty estimates).

~~To show~~ VJ 8/15/00 the difference between ~~various~~ "Best-Basis" and mean VJ 8/15/00 and median, it is shown VJ 8/15/00 in a table on page 14.

Tal Data is tabulated for a combined AZ 101 and AZ-102 radionuclides.

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For example

		Best Basis	Mean
^{90}Sr	AZ101 =	6.36×10^6 Ci	2.74×10^6 Ci
	AZ102 =	3.70×10^6 Ci	3.22×10^6 Ci
	Total ^{90}Sr =	1.01×10^7 Ci	5.96×10^6

$$\% \text{ difference} = \frac{1.01\times10^7 - 5.96\times10^6}{1.01\times10^7}$$

$$= 41\%$$

^{90}Sr is 41% higher in "Best-Basis" inventory compared to mean inventory. Similarly, % differences were calculated for remaining radionuclides shown in Table below

Table 2-4. Percent difference between the Best-Basis, mean and median inventories for the combined Tanks AZ-101 and AZ-102

Radionuclide	Percent Difference between Best-Basis and Mean Inventory	Percent Difference between Best-Basis and Median Inventory
^{60}Co	-548%	12%
^{90}Sr	41%	84%
^{90}Y	-302%	0%
^{152}Eu	-55%	0%
^{154}Eu	-55%	0%
^{155}Eu	-119%	-41%
^{233}U	99%	100%
^{235}U	-14%	-40%
^{237}Np	-543%	0%
^{238}Pu	-498%	0%
^{239}Pu	-485%	0%
^{241}Pu	-465%	0%
^{241}Am	5%	97%
^{244}Cm	-528%	6%

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"Best-Basis" inventory is closer to the "median" inventory than to the "mean" inventory.

The mean values of the actinides are 400-500% higher compared "Best-Basis" value.

^{90}Y is has over 300% higher mean radionuclide inventory compared to Best-Basis inventory.

Higher H_2 generation rate is mostly attributed to high ^{90}Y.

224 l/hr for mean inventory
64 l/hr for "Best-Basis" inventory.

Note that ^{90}Sr and ^{90}Y are closely related. If ^{90}Sr is removed, its daughter ^{90}Y decays quickly. The two ^{90}Sr and ^{90}Y coexist together in similar concentrations.

According to Ferryman (Page 3, reference) (attached email correspondence) the current version of the database doesn't relate ^{90}Sr and ^{90}Y! In the next update to the methodology, such relationships will be included.

To Page No. 16

Witnessed & Understood by me, | Date 3/18/99 | Invented by | Recorded by | Date

Date: 3/4/99
Sender: "Ferryman Thomas A" <tom.ferryman@pnl.gov>
To: "'vjain@swri.edu'" <vjain@swri.edu>
bcc: Vijay Jain
Priority: Normal
Subject: RE: RE: Best Basis Inventory

<<...>>

4

We generated a rigid, repeatable, tractable methodology to calculate the numbers. The median values for 90Sr and 90Y are
623761 and 6360000. The median 90Sr number comes from the results of chemical analysis of waste of similar type(s) as what is believed to be in tank AZ-101. The median 90Y number comes from the values used by the best basis estimate.

Our FY98 version of the methodology did not directly relate 90Sr to 90Y. It is
our plan that the next update to the methodology will show that relationship.

Is your concern that the 90Sr and 90Y numbers differ or is it that the median 90Sr and the Best Basis 90Sr differ?

Tom

al Message-----
From: vjain@swri.edu [SMTP:vjain@swri.edu]
Sent: Thursday, March 04, 1999 2:40 PM
To: Ferryman, Thomas A
Subject: Re:RE: Best Basis Inventory

3

Tom:

I had earlier send you an email, requesting explantion as to why certain nuclides like Sr-90 and Y-90 differ by more than an order of magnitude. In the attached excel file downloaded from TWINS database shows this difference in cell
G35 and G36, H35 and H36. I35, and I36 for Sr-90 and Y-90. This continues through rows 35 and 36 in the attached table. Do you think this could be a typographical error (extra zero). SR-90 and Y-90 coexist together in same concentration. The numbers for Cs-137 and Ba-137 are ok. They both also coexist
together. I am process of verifing some calculations conducted by the BNFL and would very much like to have your input.

Look forward to hearing from you.

Thanks

Vijay

Vijay Jain
Center for Nuclear Waste Regulatory Analysis
Southwest Research Institute
San Antonio, TX 78238

To Page No. 17

210 522 5439

2

_____Reply Separator_____
Subject: RE: Best Basis Inventory
Author: "Ferryman Thomas A" <tom.ferryman@pnl.gov>
Date: 2/3/99 1:18 PM

The two methods, the point estimate and the uncertainty methods, are similar but differ in details in the implementation. This is address to some extent in
one of the sections in the user guide. A more detailed explanation is possible
but not trivial.

May I ask, what brings you to ask? What aspect of your work does this relate to?

Thanks, Tom

-----Original Message-----
From: vjain@swri.edu [SMTP:vjain@swri.edu]
Sent: Wednesday, February 03, 1999 1:07 PM
To: Ferryman, Thomas A
Subject: Best Basis Inventory

1

Tom:

I would really appreciate if you could provide an explanation as to why the best
basis inventory numbers are different than the mean inventory numbers in the
excel file Best Basis Inventory Uncertainity Estimation Results in TWINS/TCD.

Your name was listed as a contact person in the userguide.

Thanks

Vijay

Vijay Jain
Center for Nuclear Waste Regulatory Analyses
Southwest Research Institute
San Antonio, TX
210 522 5439

<< File: RFC822.TXT >> << File: hcde.xls >>

RFC822.TXT

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Organics in tanks.

G-factor

According to Meisel (1991)

$$G(H_2) = G(H_2)_{RH=0} + R_x \times [RH]$$

R_x - G value /mole is a conversion efficiency for organic 'X'.

[RH] = molar concentration (M/L) of organic X.

R_x = 0.167 for EDTA

Assuming all organics in tank AZ101 and AZ102 are EDTA type.

$G(H_2)_{RH=0}$ = 0.45 ~~w~~ same as assumed by BNFL, Inc. assuming for pure water (no nitrates).

R_x = 0.167 has to be multiplied by ~~0.15~~ 1.55 to account for under prediction of hydrogen generation in Tank SY-101.

Therefore

$$G(H_2)_{(B,r)} = 0.45 + (0.167 \times 1.55) \times [RH]$$

Meisel, D. H., et al. 1991. Radiolytic generation of gases from synthetic waste Annual Report - FY1991.

ANL-91/41. ~~Argonne~~ Argonne National Laboratory.

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From tables on page 3 and 5

TOC	Best Basis (kg)	90th percentile (kg)
Tank AZ-101	~~6220~~ kg 6060	~~19609~~ 9458
Tank AZ 102	6220	19609
Total	12,280 kg	29,067 kg

Best Basis

$$RH[moles/L] = \frac{12{,}280 \text{ kg TOC}}{4 \text{ tanks}} \times \frac{1000 \text{ g}}{1 \text{ kg}} \times \frac{1 \text{ mole C}}{12 \text{ g C}} \times \frac{1 \text{ mole EDTA}}{10 \text{ mole C}} \times \frac{1}{197{,}000 \text{ L}}$$

= 0.13 moles/L EDTA

~~$G[H_2]_{Br} = 0.45 + 0.13 = 0.48$~~

~~% Change = $\frac{0.13}{0.45}$ =~~

VJ 8/15/00

$$G[H_2]_{Br} = 0.45 + 0.167 \times 1.55 \times 0.13$$

$$= 0.45 + 0.033$$

$$= 0.48$$

$$\% \text{ Change} = \frac{0.033}{0.45} \times 100 = 7.5\%$$

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90 Percentile

$$[RH](moles/L) = \frac{29{,}067\ kg}{4\ tanks} \times \frac{1{,}000g}{1\ kg} \times \frac{1\ mole\ C}{12g\ C} \times \frac{1\ mole\ EDTA}{10\ mole\ C} \times \frac{1}{197000\ L}$$

$$= 0.307$$

$$G(H_2)_{BY} = 0.45 + 0.167 \times 1.55 \times 0.307$$

$$= 0.45 + 0.0796$$

$$= 0.5295 \sim 0.53$$

$$\%\ difference = \frac{0.0796}{0.45} \times 100$$

$$= 17.7\%.$$

$G(H_2)_\alpha$ – no data available in literature to estimate H_2 due to α-radiation in organics.

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Organics can contribute 7 to 17% to the total hydrogen generation. BNFL, Inc. has neglected organics in their calculations.

Heat generation by other insoluble radionuclide not considered by the BNFL, Inc.

^{125}Sb is the only radionuclide that contributes more than 100 W to the tank heat generation that has been neglected.

	^{125}Sb
AZ 101	1.31×10^5 Ci
AZ 102	9.27×10^4 Ci
	2.24×10^5 Ci

$$^{125}Sb = 2.24 \times 10^5\ Ci \times \frac{3.7 \times 10^{10}\ Bq}{1\ Ci}$$

$$= 8.28 \times 10^{15}\ Bq.$$

$$^{125}Sb\ (heat\ generation\ rate)_{BY} = 1.048 \times 10^{-13}\ W/Bq.$$

$$Heat\ generation\ rate\ (W) = 8.28 \times 10^{15} \times 1.048 \times 10^{-13}$$

$$= 867.4\ W \approx 870\ W$$

$$Heat\ generation\ rate/tank = \frac{867.4}{4} = 216.9\ W.$$

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Project No. 1403-201
Book No. 315 TITLE Hydrogen Generation

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Graves (1994) Calculations -

Tank AZ 101
TOC = 0.12 g/L

Volume of tank = 952 kgal. f
= 952 × 3.78 × 1000 L.

$$TOC = \frac{0.12 \times 952 \times 3.78 \times 1000}{1000} \text{ kg}$$

= 431.8 kg
~ 430 kg

Tank AZ 102
TOC = 1.59 g/L

Volume of tank AZ 102 = 953 kgal/
= 953 × 10^3 × 3.78 l.

$$TOC = \frac{1.59 \times 10^3 \times 3.78 \times 953}{10^3}$$

= 5727.7 kg
~ 5700 kg

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Witnessed & Understood by me,	Date	Invented by	Date
[signature]	3/19/99	Recorded by	

TITLE
Project No.
Book No.

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Project completed.
No more work anticipated in this project.

[signature]
3/21/2000

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		Recorded by	

Project No._____
Book No._____ TITLE_____

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Element Managers are requested to put the following statement at the conclusion of "manual" Scientific Notebooks:

"I have reviewed this scientific notebook and find it in compliance with QAP-001. There is sufficient information regarding procedures used for conducting tests, acquiring and analyzing data so that another qualified individual could repeat the activity.

N. Friedkab 3/24/00

(Element Manager signature and date above line,
Name of Element beneath line)"

Witnessed & Understood by me, Date

Invented by Date

Recorded by

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