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CONVERSION RATIO TABLES

By

R. A. Chitwood
Reactor Physics
Research and Engineering

July 30, 1965

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CONVERSION RATIO TABLES

INTRODUCTION

This manual provides a listing of the quantities of plutonium and plutonium isotope formation. Other isotopes whose concentrations are important and included in this report are U-236 buildup, U-235 burnout, U burnout, Np-237 buildup, GVR (the Gas Volume Ratio) in coproduct target elements and equivalent grams of plutonium. These conversion tables have been calculated on the IBM 7090 digital computer using a program entitled "FLEX-3."⁽¹⁾ The results of the computer solutions have not been normalized to conversion observed by Chemical Processing Department measurement since none are yet available. Such a correction may be required after fuel from N-Reactor is processed.

Conversion ratios for four types of N-Reactor fuel have been evaluated, they are:

- .947 percent U-235 normal fuel loading
- 1.25 percent U-235 "spike" enrichment
- 1.25 percent U-235 outer, Li-Al inner - coproduct fuel
- 1.96 percent U-235 outer, Li-Al inner - coproduct fuel

DISCUSSION

These studies represent the current best estimates of plutonium yield. The results for various fuel loadings are of some importance in the plant accountability operation and in the determination of unit cost.

An effort to obtain some measure of the accuracy of the FLEX-3 program was made by using a K-Reactor loaded with the KV fuel in zirconium tubes. For reference, the input to that computer run is included in this report in Table 1. The results were compared with⁽²⁾ the accepted conversion ratio tables for IPD, and the agreement was quite good. The test case is in Table 2.

EXPLANATION OF CONVERSION TABLES

These conversion tables are tabulated by fuel type. The parameters reported are as follows:

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- (1) RL-NRD-226, "FLEX 3 - A Fuel Element Design Analysis Code," R. J. Shields, February 8, 1965.
 - (2) RL-REA-576, "Irradiation Processing Fuel and Product Conversion Tables," E. R. Perl and A. D. Vaughn, June 1, 1965, SECRET.

percent Pu-239

The fraction of the plutonium formed that is the Pu-239 isotope.

percent Pu-240

The fraction of the plutonium formed that is the Pu-240 isotope.

percent Pu-241

The fraction of the plutonium formed that is the Pu-241 isotope.

grams Pu/ton

The grams of total plutonium per ton of fuel.

grams Np-237/ton

Grams of the isotope Np-237 per ton of fuel.

grams U-235/ton

Grams of the isotope U-236 per ton of fuel.

lbs. B.O. U-235

Pounds of U-235 burned per ton of fuel.

lbs. B.O. U

Pounds of U burned per ton of fuel.

grams Pu/MWD

Grams of plutonium formed per megawatt day of production.

GVR

The volume that the gas formed in a target element (both tritium and helium) would occupy under standard temperature and pressure divided by the volume of the bare target element.

Equivalent grams of Pu/MWD

This number assumes that every neutron that was used in the formation of tritium could have been used to produce plutonium.

A great many of the tubes in N-Reactor contain fuel elements of different lengths but no effort will be made to segment them in this report. One charge, however, the 1.25 percent U-235 "spike" contains two types of fuel, and it was necessary to evaluate the spike conversion ratio parameters from two separate conversion tables.

CONVERSION RATIO AND RELATIVE PLUTONIUM ISOTOPE GRAPHS

The graphs were generated from the information in the conversion ratio tables. They were made to complement the tables, since the exposure steps are rather large.

R.A. Chitwood

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Reactor Physics
Research and Engineering

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TABLE 1

K REACTOR TEST CASE
(550°C Graphite)

INPUT

1	2.000000000	8.462799907	1.609999999	550.000000000	-0.	1.000000000
2	1.000000000	1.970399991	1.000000000	400.000000000	-0.	-0.
3	14.000000000	1.806999996	1.000000000	200.000000000	-0.	-0.
4	3.000000000	1.723999992	1.000000000	100.000000000	-0.	-0.
5	13.000000000	1.527999997	1.289999992	120.000000000	-0.	-0.
6	11.000000000	1.430999994	17.750000000	600.000000000	-0.	-0.
7	13.000000000	0.533000000	1.289999992	120.000000000	-0.	-0.
8	3.000000000	0.419999994	1.000000000	100.000000000	-0.	-0.
19	-0.000000000	-0.	800.000000000	8.000000000	1.059999987	0.949999996
20	38.000000000	0.730399996	1.399999991	38.349999905	38.349999905	0.219999999
21	1700.000000000	460.000000000	85.000000000	10.000000000	80.000000000	30000.000000000
22	-0.000000000	5.469999969	5.469999969	8.000000000	0.	-0.
26	0.029999994	-0.	-0.	-0.	-0.	-0.
27	0.250000000	-0.	-0.	-0.	-0.	-0.
30	4.000000000	-0.	-0.	-0.	-0.	-0.
31	4.000000000	-0.	-0.	-0.	-0.	-0.
32	1.000000000	0.711499996	-0.	99.288499832	-0.	-0.
34	1.000000000	18.859999895	-0.	-0.	-0.	-0.
36	0.750000000	1.199999988	-0.	0.799999997	-0.	0.849999994

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TABLE 2
K-REACTOR CONVERSION RATIOS
(Test Case)

	<u>RL-REA-576</u>	<u>500°C Graphite FLEX-3</u>	<u>550°C Graphite FLEX-3</u>
Pu-239	92.139	92.339	91.986
Pu-240	7.126	7.120	7.460
Pu-241	.719	.513	.532
Pu gms/ton	699.610	713.600	709.600
B.O. U-235 lbs	1.813	1.775	1.769
B.O. U lbs	3.650	3.662	3.653
gms Pu/MWD	.875	.892	.887

These points are for an exposure of 800 MWD/Ton.

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TABLE 3
.947 PERCENT U-235
(Normal Load)

<u>Region</u>	<u>Material</u>	<u>Diameter (in.)</u>	<u>Temperature°C</u>
1	H ₂ O	9.575	65
2	Zircaloy-2	9.552	95
3	Graphite	9.549	430
4	Void	6.050	430
5	Graphite	4.226	370
6	Void	3.340	370
7	Zircaloy-2	3.258	242
8	H ₂ O	2.708	215
9	Zircaloy-2	2.406	236
10	Metal Fuel	2.351	353
11	Zircaloy-2	1.815	243
12	H ₂ O	1.763	218
13	Zircaloy-2	1.250	237
14	Metal Fuel	1.164	379
15	Zircaloy-2	0.493	245
16	H ₂ O	0.438	222

Fuel Element Length: 1.9333 feet
Fuel Element No.: 18
Effective Pile Width: 27.726 feet
Effective Pile Height: 29.597 feet
Augmentation Distance (front to rear): 1.45 feet

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TABLE 4
1.25 PERCENT U-235
(Spike Load)

<u>Region</u>	<u>Material</u>	<u>Diameter (in.)</u>	<u>Temperature°C</u>
1	H ₂ O	9.575	65
2	Zircaloy-2	9.552	95
3	Graphite	9.549	430
4	Void	6.050	430
5	Graphite	4.226	370
6	Void	3.340	370
7	Zircaloy-2	3.258	232
8	H ₂ O	2.708	205
9	Zircaloy-2	2.406	225
10	Metal Fuel	2.351	345
11	Zircaloy-2	1.815	229
12	H ₂ O	1.763	205
13	Zircaloy-2	1.250	220
14	Metal Fuel	1.164	344
15	Zircaloy-2	0.493	224
16	H ₂ O	0.438	206

Charge Makeup from Rear to Front:

2 (1.933 feet .947 percent U-235) elements + 12 (2.175 feet 1.25 percent U-235) elements.

+2 (1.9333 feet .947 percent U-235) elements + 1 (1.0 feet .947 percent U-235) elements.

Effective Pile Width: 27.726 feet

Effective Pile Height: 29.597 feet

Augmentation Distance (front to rear): 1.45 feet

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TABLE 5

1.25 PERCENT U-235
(Coproduct Load)

<u>Region</u>	<u>Material</u>	<u>Diameter (in.)</u>	<u>Temperature°C</u>
1	H ₂ O	9.575	65
2	Zircaloy-2	9.552	95
3	Graphite	9.549	430
4	Void	6.050	430
5	Graphite	4.226	370
6	Void	3.340	370
7	Zircaloy-2	3.258	236
8	H ₂ O	2.708	209
9	Zircaloy-2	2.292	239
10	Metal Fuel	2.222	457
11	Zircaloy-2	1.491	260
12	H ₂ O	1.441	210
13	Zircaloy-2	0.565	210
14	Li-Al	0.402	210

Percent Lithium in Target Alloy: 166 percent
Percent Lithium that is Li⁶: 22.0 percent
Fuel Element Length: 26 inches
Elements per Column: 16
Augmentation Distance: 1.52 feet
Effective Pile Width: 27.726 feet
Effective Pile Height: 29.597 feet

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TABLE 6
1.96 PERCENT U-235
(Coproduct Load)

<u>Region</u>	<u>Material</u>	<u>Diameter (in.)</u>	<u>Temperature°C</u>
1	H ₂ O	9.575	65
2	Zircaloy	9.552	95
3	Graphite	9.549	430
4	Void	6.050	430
5	Graphite	4.226	370
6	Void	3.340	370
7	Zircaloy-2	3.258	244
8	H ₂ O	2.708	218
9	Zircaloy-2	2.345	248
10	Metal Fuel	2.275	480
11	Zircaloy-2	1.414	263
12	H ₂ O	1.364	218
13	Zircaloy	0.739	218
14	Li-Al	0.622	218

Percent Lithium in Target Alloy: 13.05 percent
Percent Li⁶ in Lithium: 62.27
Fuel Element Length: 27.8 inches
Elements Per Column: 15
Augmentation Distance: 1.60 feet
Effective Pile Width: 27.726 feet
Effective Pile Height: 29.597 feet

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TABLE 7
.947 STANDARD FUEL

<u>Exposure</u>	<u>Pu-239</u>	<u>Pu-240</u>	<u>Pu-241</u>	<u>Pu/Ton</u>	<u>gms</u> <u>Np-237/Ton</u>	<u>gms</u> <u>U-236/Ton</u>	<u>lbs</u> <u>B.O. U-235</u>	<u>lbs</u> <u>B.O. U</u>	<u>gms</u> <u>Pu/MWD</u>
0									
100	99.509	.484	.007	95.8	.26	19.99	.251	.477	.958
200	98.726	1.245	.028	188.8	.57	39.44	.496	.948	.944
400	97.074	2.794	.128	365.2	1.30	76.65	.965	1.865	.913
600	95.447	4.261	.281	530.4	2.16	111.81	1.409	2.753	.884
800	93.869	5.641	.470	685.6	3.14	145.27	1.832	3.617	.857
1000	92.343	6.944	.680	833.0	4.23	177.10	2.236	4.460	.833
1200	90.863	8.183	.904	973.2	5.40	207.57	2.623	5.284	.811
1400	89.428	9.365	1.136	1107.4	6.65	236.77	2.994	6.091	.791
1600	88.041	10.494	1.370	1235.2	7.98	264.80	3.351	6.882	.772
1800	86.693	11.579	1.606	1357.2	9.37	291.67	3.696	7.661	.754
2000	85.386	12.618	1.842	1474.0	10.83	317.63	4.029	8.428	.737
2200	84.115	13.621	2.076	1588.4	12.34	342.63	4.351	9.183	.722
2400	82.882	14.583	2.308	1699.2	13.92	366.80	4.663	9.929	.708
2600	81.682	15.512	2.538	1804.4	15.53	390.13	4.964	10.663	.694

See Figures 1, 2, 3

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TABLE 8
1.25 PERCENT SPIKE FUEL
COLUMN

<u>Exposure</u>	<u>Pu-239</u>	<u>Pu-240</u>	<u>Pu-241</u>	<u>Pu/Ton</u>	<u>gms</u> <u>Np-237/Ton</u>	<u>gms</u> <u>U-236/Ton</u>	<u>lbs</u> <u>B.O. U-235</u>	<u>lbs</u> <u>B.O. U</u>	<u>gms</u> <u>Pu/MWD</u>
0									
100	99.60	.42	.004	86	.24	20.6	.26	.47	.867
200	98.86	1.15	.018	170	.55	40.6	.51	.92	.855
400	97.40	2.50	.100	329	1.25	77.7	.98	1.81	.833
600	96.02	3.74	.227	482	2.12	113.5	1.45	2.65	.812
800	94.68	4.92	.388	625	3.10	149.4	1.89	3.48	.793
1000	93.34	6.08	.569	762	4.19	184.0	2.32	4.30	.775
1200	92.02	7.18	.764	892	5.36	217.0	2.73	5.11	.757
1400	90.70	8.22	.970	1018	6.62	248.2	3.12	5.92	.741
1600	89.45	9.24	1.180	1139	7.95	279.0	3.50	6.73	.725
1800	88.22	10.23	1.395	1258	9.35	308.0	3.88	7.50	.710
2000	87.03	11.21	1.610	1374	10.82	336.0	4.23	8.25	.696
2200	85.88	12.18	1.822	1485	12.34	364.0	4.59	9.00	.684

See Figures 4, 5, 6

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TABLE 9
1.25 COPRODUCT FUEL

<u>Exposure</u>	<u>%</u> <u>Pu-239</u>	<u>%</u> <u>Pu-240</u>	<u>%</u> <u>Pu-241</u>	<u>gms</u> <u>Pu/Ton</u>	<u>gms</u> <u>Np-237/Ton</u>	<u>gms</u> <u>U-236/Ton</u>	<u>lbs</u> <u>B.O. U-235</u>	<u>lbs</u> <u>B.O. U.</u>	<u>G.V.R.</u>	<u>Equivalent</u> <u>gms</u> <u>Pu/MWD</u>	<u>gms</u> <u>Pu/MWD</u>	<u>Total</u> <u>Effective</u> <u>gms</u> <u>Pu/MWD</u>
0												
100	99.67	.33	-	74.7	.23	20.3	.244	.421	1.1	.152	.747	.899
200	99.09	.89	.016	148.0	.49	40.2	.506	.861	2.1	.151	.740	.891
400	97.84	2.09	.072	292.8	1.12	79.1	.995	1.704	4.1	.150	.723	.882
600	96.56	3.27	.166	424.2	1.87	116.6	1.468	2.530	6.1	.148	.707	.855
800	95.30	4.40	.289	552.8	2.72	152.8	1.927	3.342	8.1	.146	.691	.837
1000	94.06	5.49	.433	677.0	3.66	187.9	2.372	4.139	10.0	.144	.677	.821
1200	92.84	6.53	.592	795.6	4.69	222.0	2.804	4.923	11.8	.142	.663	.805
1400	91.65	7.55	.760	908.6	5.79	255.0	3.225	5.694	13.6	.141	.649	.790
1600	90.47	8.54	.936	1019.2	6.97	287.2	3.635	6.457	15.4	.139	.637	.776
1800	89.32	9.49	1.117	1125.0	8.21	318.4	4.037	7.209	17.1	.137	.625	.762
2000	88.18	10.42	1.301	1228.0	9.51	348.9	4.427	7.954	18.8	.136	.614	.750
2200	87.07	11.33	1.487	1328.8	10.87	378.6	4.808	8.688	20.4	.134	.604	.738
2400	85.98	12.21	1.674	1425.6	12.29	407.5	5.181	9.416	22.0	.133	.594	.727
2600	84.90	13.07	1.861	1518.4	13.76	435.7	5.544	10.132	23.6	.131	.584	.715

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TABLE 10
1.96 COPRODUCT FUEL

<u>Exposure</u>	<u>Pu-239</u>	<u>Pu-240</u>	<u>Pu-241</u>	<u>Pu/Ton</u>	<u>Np-237/Ton</u>	<u>gms</u> <u>U-236/Ton</u>	<u>lbs</u> <u>B.O. U-235</u>	<u>lbs</u> <u>B.O. U</u>	<u>G.V.R.</u>	<u>Equivalent</u> <u>gms</u> <u>Pu/MWD</u>	<u>gms</u> <u>Pu/MWD</u>	<u>Total</u> <u>Effective</u> <u>gms</u> <u>Pu/MWD</u>
0												
100	99.75	.25	--	64.7	.26	21.7	.256	.412	1.0	.302	.647	.949
200	99.33	.66	.050	128.4	.57	43.2	.511	.824	2.1	.303	.642	.945
400	98.21	1.51	.102	253.6	1.32	85.3	1.010	1.636	4.1	.302	.634	.936
600	97.55	2.34	.163	374.4	2.23	126.7	1.502	2.444	6.2	.303	.624	.927
800	96.65	3.14	.240	492.8	3.27	167.1	1.984	3.241	8.2	.303	.616	.919
1000	95.75	3.91	.323	608.0	4.44	206.7	2.456	4.029	10.2	.302	.608	.910
1200	94.88	4.65	.437	720.0	5.72	245.5	2.919	4.809	12.3	.302	.600	.902
1400	94.02	5.38	.567	828.8	7.10	283.5	3.375	5.584	14.3	.302	.592	.894
1600	93.17	6.09	.705	936.0	8.58	320.8	3.823	6.349	16.4	.302	.585	.887
1800	92.33	6.78	.843	1040.4	10.14	357.3	4.264	7.110	18.4	.302	.578	.880
2000	91.50	7.45	.987	1142.0	11.79	393.2	4.696	7.862	20.4	.302	.571	.873
2200	90.68	8.11	1.133	1240.8	13.51	428.5	5.121	8.607	22.5	.302	.564	.866
2400	89.87	8.76	1.281	1339.2	15.33	463.1	5.540	9.350	24.5	.302	.558	.860
2600	89.07	9.39	1.429	1435.2	17.19	497.2	5.955	10.086	26.6	.302	.552	.854

See Figures 10, 11, 12

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FIGURE 2
LOS ANGELES FUEL

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