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CONVERSION EFFICIENCY AND U²³⁵ DEPLETION IN B-10

by

R. E. Peterson

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Summary

Preliminary observations on tritium production from extracted Z slugs in the H-10 load indicated yields which were lower than those calculated by approximately twenty percent. The calculated conversion efficiency $\left(\frac{\text{H}^3 \text{ atoms produced}}{\text{U}^{235} \text{ atoms destroyed}} \right)$ for this

loading is 0.835. Results of a measurement of the conversion efficiency for three separate tubes are reported and found to be lower than 0.835 by approximately twenty percent, or very nearly the same as the discrepancy in tritium production. The values measured are 0.67, 0.61, and 0.60 for the three tubes respectively. Details of 25 burnup calculations are also presented with a measured depletion factor of 0.584 grams of 25 destroyed. Reasons for the large discrepancy in conversion

tube MWD

efficiency are not known at the present time. However, some possibilities are discussed.

I. Introduction

H-10 was the designation given to the loading in H-pile designed for large scale production of tritium. This design consists of nine J(25-Al alloy 7% 25 by wt.) slugs and nine Z (LiAl alloy 3.5% Li by wt.) slugs placed alternately in the central portion of process tubes with natural uranium slugs completing the tube loading on each end. The J and Z slugs contained on the average 37.87 g. of U and 8 g. of Li respectively. The nuclear reactions of interest here are:

For the Li-Al slugs

and for the 25-Al slugs,

Design calculations for this loading yield a conversion efficiency

$\frac{\text{neutrons absorbed in Li}}{\text{neutrons absorbed in } 25}$ or $\frac{H^3 \text{ atoms produced}}{25 \text{ atoms destroyed}}$ of $0.835 \frac{1}{2}$. However,

preliminary observations at Hanford on tritium production from extracted Li-Al slugs indicated yields which were lower than the calculated values by approximately twenty percent.² These yields were calculated on the basis of the power production in the loading. This indicated either of two things were taking place. (1) Either tritium was being lost in the extraction process or (2) the conversion efficiency was actually lower than that calculated due to uncertainties in the data used. Therefore, it appeared that a direct measurement of the conversion efficiency would serve to clarify the existing discrepancy. This was undertaken in February 1952, just prior to the closing down of P-10 activities.

2. Method of Measurement

Measurement of the conversion efficiency involves obtaining the ratio of the number of tritium atoms produced to the number of U^{235} atoms destroyed in a particular tube in the H-10 load. This may also be extended to include all the tritium produced and all the 25 destroyed in the H-10 load.

Tritium yields may be obtained from product log books kept during P-10 operations.² Burn-up of 25 can be secured from data furnished by the American Cyanamid Co. at the Arco Reactor Testing Station, where 25 is currently being recovered from the H-10 J slugs.⁴ Determination of the conversion efficiency is complicated by the fact that measurements of this type were not anticipated and useable data are scarce. This may be seen more clearly below.

3. Tritium Yield

Upon examination of each of the tubes in the H-10 load, only three tubes were found for which the tritium yield per tube was available. This was due to the fact that when extracted, 2 slugs from different tubes were mixed together. Since the tubes in general ran at different power levels, yields from mixed slugs could not be used. 2 slugs from several tubes could not be traced to their extraction because of incomplete records. Yields from the three tubes of interest are shown in Table I:

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TABLE I.

Calculated and Observed Tritium Production From Three
Tubes in H-10

Tube No.	Tube Energy (MWD)	P-10 Run No. (Glass line)	No. of Z Slugs Per Run	H ³ per Run (Cm ³ @ NTP)	He ⁴ *	Observed Total H ³ Per Tube (Cm ³ @ NTP)	Observed Avg. H ³ Per Z Slug (Cm ³)	Calcu- lated Avg. H ³ Per Slug (Cm ³)	** Percent Less
					$\frac{H^3 + \frac{1}{2} He^3}{H^3 + \frac{1}{2} He^3}$				
2476	73.976	967	5	738	1.74	1297	144.1	192.8	25.3
1483	72.603	971	4	559	2.18	1354	150.4	189.4	20.6
		963	5	737	2.11				
1478	72.366	965	4	617	2.13	1236	137.3	188.7	27.2
		956	1	149	2.12				
		955	1	135	2.15				
		958	1	148	2.12				
		962	1	141	2.14				
		964	1	74	3.59				
		968	1	144	2.11				
		972	1	148	2.20				
		974	1	158	2.13				
		976	1	139	2.12				

* The ratio $\frac{He^4}{H^3 + \frac{1}{2} He^3}$ is included here as a measure of the recovery of

tritium. If one reviews the reactions given in the introduction, it can be seen that this ratio should ideally have a value of 2 (using volumes of gas @ NTP) if none of the evolved tritium is lost, and, indeed, it is shown not to exceed this value by more than seven percent in most runs here. An average value of 2.08 ± 0.05 is reported for most of the P-10 runs. Uncertainties in He³ and He⁴ are believed to be the major reason for deviations in the ratio rather than loss of gas.

** Calculated yields are made using the tube energy, a value of 203 Mev. for the fission energy, a value of 0.48 for the fraction of the energy contributed

to the tube by the 9 J slugs, and the calculated conversion efficiency 0.835. The percent discrepancies agree quite well with those reported by W. J. Ozeroff 2

4. U235 Burn-Up

Upon discharge, the J-slugs were placed in casks and shipped to the American Cyanamid recovery plant at Arco for separation of uranium from the fission products. The plant was completed early this year and after initial cold runs, processing of the J-slugs began in March. It was agreed to process the three tubes of interest (#1478, 1483, and 2476) separately so that the 25 burn-up per tube could be obtained. 6 However, due to an oversight, the slugs were mixed with slugs from other tubes in 15 slug batches, with one exception. In this case, nine slugs from tube 1483 were mixed with six from tube 1478. These two tubes had very nearly the same exposure so it is possible to utilize this data with reasonable confidence. The data received from American Cyanamid for batches before, during, and after those containing the 27 slugs of interest are presented in Table 2.

Percent burn-up of 25 is determined from the mass assay by use of the following formula:

$$\% \text{ burn-up} = \frac{\frac{\sigma_{\text{total } 25}}{\sigma_{\text{act } 25}} \times \%26 \times 100}{\%25 + \frac{\sigma_{\text{total } 25}}{\sigma_{\text{act } 25}} \times \%26}$$

where

$\frac{\sigma_{\text{total } 25}}{\sigma_{\text{act } 25}}$ is the ratio of the total to the activation cross-section for 25. This is taken from ENL-170 (2200 M/S values) and is 6.434 ± 0.128 . %25 and %26 are obtained from mass assay at Arco after irradiation.

It is, at present, difficult to assign a probable error to the burn-up since the errors in mass assay have not yet been determined completely at Arco. However, it may be said with some certainty that the error in burn-up is small

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Table 2

Burn-up, Mass Assay, and Heel Data for
Batches Processed Before, During, and After Introduction of Slugs of Interest

Batch No.	Tubes in Batch	Weighted Avg. Tube (MWD)	No. of Slugs	U Dissolved (g)	U Conco. (g/l)	Heel (gU)	Mass Assay				U 235 Burn-up (%)
							U 234	U 235	U 236	U 238	
1016J	--	--	15	532	1.62	388	--	--	--	--	--
1018J	--	53.724	15	486	1.63	474	1.13	91.40	1.57	5.91	9.95
1020J	--	61.818	15	480	1.63	553	1.12	90.22	1.67	7.00	10.65
1022J	--	68.386	15	522	1.75	567	1.12	90.11	1.85	6.92	11.67
1024J*	1478	69.202	15	565	2.00	548	1.13	90.04	1.90	6.94	12.00
1026J*	3070	72.508	15	579	2.03	514	1.15	89.75	2.00	7.10	12.54
1028J	1478	73.509	15	470	1.69	592	1.15	89.96	2.07	6.83	12.90
1030J*	3275	73.868	15	485	1.62	658	1.15	89.74	2.09	7.02	13.03
1030J*	879	--	--	440	1.59	218	1.15	90.56	2.04	6.26	12.66
1032J	--	74.564	15	388	1.10	337	1.15	90.36	2.14	6.37	13.22
1034J	--	74.213	15	471	1.31	416	1.16	90.20	2.15	6.58	13.30
1036J	--	74.522	12	462	1.75	395	1.16	90.46	2.18	6.22	13.43
1036J (Heel 1)	--	--	--	397	0.82	-2	1.15	90.40	2.06	6.39	12.79
1036J (Heel 2)	--	--	--	370	1.28(?)	-372	1.18	90.76	2.02	6.04	12.53

* Batches containing slugs of interest.

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compared to the discrepancy in conversion efficiency. Measurement of burn-up by use of this formula is discussed in some detail by G. J. Alkire.

A bar graph is included in Figure 1, showing percent burn-up and weighted average tube energy for each batch. A weighted average is used because, as pointed out before, slugs from different tubes are present in each batch. Now, if one assumes the measured burn-up of 25 in batch 1026-J to be the same percentage as that in tube 1483, one can then calculate the number of grams of 25 destroyed in this tube, and dividing by the tube energy, one obtains:

$$\frac{0.1254 \times 338.143 \text{ gm. U}^{235} \text{ originally in tube}}{72.603 \text{ MWD}} = \frac{0.584 \text{ gm. of 25 destroyed}}{\text{Tube MWD}}$$

This compares quite well with the calculated value 0.557 reported by P. F. Gast.⁸ This assumption should be quite good because the two tubes in this batch received nearly identical exposures. (72.603 MWD as compared with 72.366 MWD).

It should be pointed out here that the uranium in each batch is not completely dissolved so that a certain amount of heel is passed on to the following batch. The error in the estimated amount of heel accumulated over a series of runs is shown in batch 1036-J (heel 2) in Table 2. The metal heels are calculated from the difference between the average uranium content of the slugs as stated on the S. F. accountability forms and the amount of uranium going into solution based on coulometric analysis of the dissolver solutions.⁴ Referring to Figure 1, it can be seen that burn-up in the heels is smaller as expected, since the burn-up is known to be highest in the surface metal. It is not known exactly to what extent the presence of these heels perturbs the mass assay and hence the burn-up for each batch. If we assume that the heel left from a preceding batch is nearly the same as that left by the batch under consideration, then certainly the effect will be small. Because of uncertainties it is of interest to compare the calculated and measured burn-up using the same constants used previously to calculate tritium production. The results are presented in Table 3.

Table 3

Comparison of Calculated and Measured U^{235} Burn-up
in the Three Tubes of Interest

Tube No.	Batch No.	Canned Wt. 25 Orig. Present (Grams)	Measured Burn-up (Grams)	Calculated Burn-up (Grams)	Percent Difference
1478	1024J & 1026J	341.293	42.83	42.74	0.2
1483	1026J	338.143	42.40	42.86	1.0
2476	1030J	348.743	45.44	43.67	4.0

Agreement appears to be quite favorable in these tubes, so it is believed that measured burn-up values may be used to calculate the conversion efficiency with considerable confidence.

5. Conversion Efficiency

The conversion efficiency is calculated from the following:

$$C = \frac{(\text{Cm}^3 \text{ of H}^3 \text{ produced}) \left(5.38 \times 10^{19} \frac{\text{atoms}}{\text{Cm}^3} \right)}{(\text{grams of 25 burnt-up}) \left(2.56 \times 10^{21} \frac{\text{atoms}}{\text{gram}} \right)}$$

Inserting the measured values, the conversion efficiencies for the three tubes are then:

1. Tube 1483	$0.67 \pm 5\%$
2. Tube 1478	$0.61 \pm 15\%$
3. Tube 2476	$0.60 \pm 15\%$

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Upon comparing these with the calculated conversion efficiency of 0.835, it is seen that the difference is approximately 20% in agreement with the discrepancy between the observed and calculated H^3 production shown in earlier calculations. Of the three, most confidence can be placed in the conversion efficiency of Table 1483 for reasons previously mentioned.

The reason for a large discrepancy in conversion efficiency are not apparent. It is thought at present to be attributed to several factors. The conversion efficiency is calculated also from:

$$\begin{aligned} C &= \frac{1+S_{25}}{1+S_L} \left(\frac{\bar{\nu} f}{1+S_{25}} - 1 \right) \\ &= \frac{\bar{\nu} f}{1+S_L} - \frac{1+S_{25}}{1+S_L} \\ &= \frac{\bar{\nu} f - 1 - S_{25}}{1+S_L} \end{aligned}$$

where

$$S_{25} = \frac{\text{Parasitic Absorption in J Slug}}{\text{Absorption in 25}}$$

$$S_L = \frac{\text{Parasitic Absorption in Z Slug}}{\text{Absorption in Li}}$$

$$\bar{\nu} = \frac{\text{No. of Neutrons Released}}{\text{Thermal Neutron Capture in U}} = 2.12 \pm 0.02$$

$$f = \text{equivalent thermal utilisation for the lattice}$$

$$= \frac{f_{25} + \beta f_L}{1 + \beta} \quad \text{where } \beta \text{ is the ratio of Li to 25 slug length}$$

From this one can see that a decrease in f as well as an increase in S_L and S_{25} would tend to lower the conversion efficiency. Changes in this manner may be expected during irradiation due to build-up of poison and depletion of Li and

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25, ^{2,10} however, the effect is believed to be small. More important are uncertainties in cross-sections used to calculate these factors. Specifically, a hardening of the neutron flux occurs from the surface in to the center of the metal pieces due to preferential absorption by $1/v$ capture. Calculation shows this effect to be about 7% greater in the Li slug than in 25. There seem to be no better values for the cross-sections available at this time than those used in the original calculations.

6. Conclusion

It is unfortunate that good data for more tubes are not available so that a statistical evaluation of the conversion efficiency might be made. One more value may be obtained, upon completion of the J slug processing; for the entire H-10 load. However, the total burn-up data will not be available for several months since there are some 7,500 slugs to be dissolved.

As has been pointed out by W. J. Ozeroff, an improvement in conversion efficiency may be had by increasing the 25 concentration in the J slugs. ¹

References

1. HW-17026, "Preliminary Study of Large Scale P-10 Production", W. J. Ozeroff
2. HW-19974, "Calculated and Observed P-10 Production in H-10", W. J. Ozeroff
3. HW-2784-L, "P-10 Project Run Data" (notebook), J. C. Chatten
4. ACCO-3270, "Process and Irradiation Data for Batches Before, During, and After Those Containing the 27 Slugs of Interest to HW", K. K. Kennedy to D. G. Reid
5. Private Communication from W. R. DeHollander and H. F. Zuhr
6. HW-24223, "Conversion Efficiency for H-10", R. E. Peterson to D. G. Reid
7. HW-28118, "Trip Report Re: U²³⁵ Depletion", G. J. Alkire
8. HW-20268, "Depletion Factor for J Slugs", P. F. Gast
9. ANL-4535, "Optimum Irradiation for Tritium Production", W. L. Krisberg
10. NAA-SR-99, "Tritium Production", Arnold Benton

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