PRODUCTION OF ^{4}HE AND TRITIUM FROM BE IN THE COBRA-1A2 IRRADIATION -

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OBJECTIVE

The purpose of this work was to predict ^{4}He and tritium production from Be irradiated in the COBRA-1A2 experiment.

SUMMARY

The production of ^{4}He and tritium has been calculated for beryllium irradiated in the COBRA-1A2 experiment in the Experimental Breeder Reactor II. Reaction rates were based on adjusted neutron spectra determined from reactor dosimetry measurements at three different elevations in the region of the beryllium capsules. Equations are given so that gas production can be calculated for any specific capsule elevation.

PROGRESS AND STATUS

Introduction

The irradiation conditions for the COBRA-1A2 experiment are described in a preliminary report by A. M. Ermi [1]. The COBRA subassembly X516 was irradiated in core position 2B1 from November 26, 1992 to September 26, 1994 for a total of 337.26 effective full power days at 62.5 Mwt. Beryllium specimens were irradiated in two different locations including subcapsule C03, spanning -2.29" to -6.10" in capsule B390, and subcapsule D03, spanning -2.46" to -6.27" in capsule B391.

Reactor dosimetry capsules were located above and below both the C03 and the D03 subcapsules. A full report of the neutron dosimetry results has been submitted for publication [2]. For the present calculations, there were three measurements of the neutron fluence spectrum, which cover the elevations of the beryllium capsules. Neutron flux gradient measurements were conducted in the various subcapsules that were located at the same elevations in the reactor. These gradient data indicate that the neutron fluences were virtually identical for the two beryllium assemblies C03 and D03. Hence, the gas production calculations as a function of reactor elevation are the same for both assemblies.

The reactor dosimetry measurements were used to adjust neutron flux spectra at six different heights in the COBRA assembly. Three of these spectral adjustments bound the roughly 9" long beryllium capsules at elevations of -1.2", -6.3", and -11.3". Beryllium reaction rates were thus calculated at these three heights using the dosimetry-adjusted neutron spectra. Table 1 lists the neutron fluences and reaction rates for these three locations.

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Table 1. Neutron fluences and dpa for COBRA-1A2

Neutron Energy, MeV	Neutron Fluence, E+22 n/cm^2		
	-1.2"	-6.3"	-11.3"
Total	7.50	6.66	4.19
> 0.1 MeV	5.94	4.95	2.62
> 1 MeV	1.68	1.31	0.330
dpa,Fe	29.3	23.5	10.1
dpa,Be	33.5	28.5	16.4

Gas Production Calculations

The production of tritium and ^{4}He from beryllium is dependent on the following nuclear reaction products:

^{9}Be(n,α)^{6}Li; ^{9}Be(n,2n)2α; ^{9}Be(n,d)2α; Li(n,α)t; ^{9}Be(n,t)^{7}Li

At short irradiation times, only the direct Be reactions are important. However, as ^{6}Li grows in, this reaction can become an increasingly important source of both helium and tritium due to the very high thermal neutron cross section. Two other nuclear processes must also be considered, mainly the decay of tritium to ^{3}He and the ^{3}He(n,p)t reaction which has a very high thermal neutron cross section for converting ^{3}He back into tritium.

Neutron cross sections for these reactions were taken from the ENDF/B-V Gas Production File 533 [3]. This file was specially constructed to sum all sources of a particular gaseous species such as helium. The file thus lists neutron cross section data for the ^{9}Be(n,helium) reaction. This reaction was thus used to determine the direct production of helium from beryllium. Reaction rates calculated from the dosimetry-adjusted neutron spectra at the three elevations spanning the beryllium materials are listed in Table 2.

Table 2. Reaction rates in beryllium for COBRA-1A@ (62.5 MWt)

	Reaction Rate (at/at-day)		
Reaction	-1.2"	-6.3"	-11.3"
^{9}Be(n,helium)	1.22E-5	7.74E-6	1.39E-6
^{9}Be(n,)^{6}Li	2.16E-6	1.51E-6	3.11E-7
^{9}Be(n,t)^{7}Li	1.37E-10	8.85E-11	1.34E-11
^{6}Li(n,)t	1.80E-4	1.79E-4	2.06E-4
^{3}He(n,p)t	1.02E-3	1.02E-3	1.17E-3

The reaction rates listed in Table 2 are given at the full reactor power of 62.5 Mwt. Since tritium decays during irradiation and the resultant ^{3}He can burn back to tritium, it is important to consider the reactor power history for the COBRA-1A2 irradiation. For these calculations, the reaction rates were time-averaged over the entire 669-day irradiation history.

Results and Discussion

The calculations were performed using a Fortran program to numerically integrate the production and burnup of each nuclear species on a daily basis over the 669-day irradiation period. The results are listed in Table 3. The net ^{4}He and tritium values are shown as a function of elevation in the reactor in Figure 1. It is important to note that the net production of both ^{4}He and tritium vary strongly with the elevation in the reactor. The fast neutron fluences and dpa in Be are shown as a function of elevation in the reactor in Figure 2. The trendlines for the calculated values for each reaction as well as neutron fluence and Be dpa are described by polynomials, as shown on Figures 1 and 2. These equations can thus be used to determine the gas production at any height within the C03 and D03 assembly. However, the equations should not be used at higher or lower elevations.

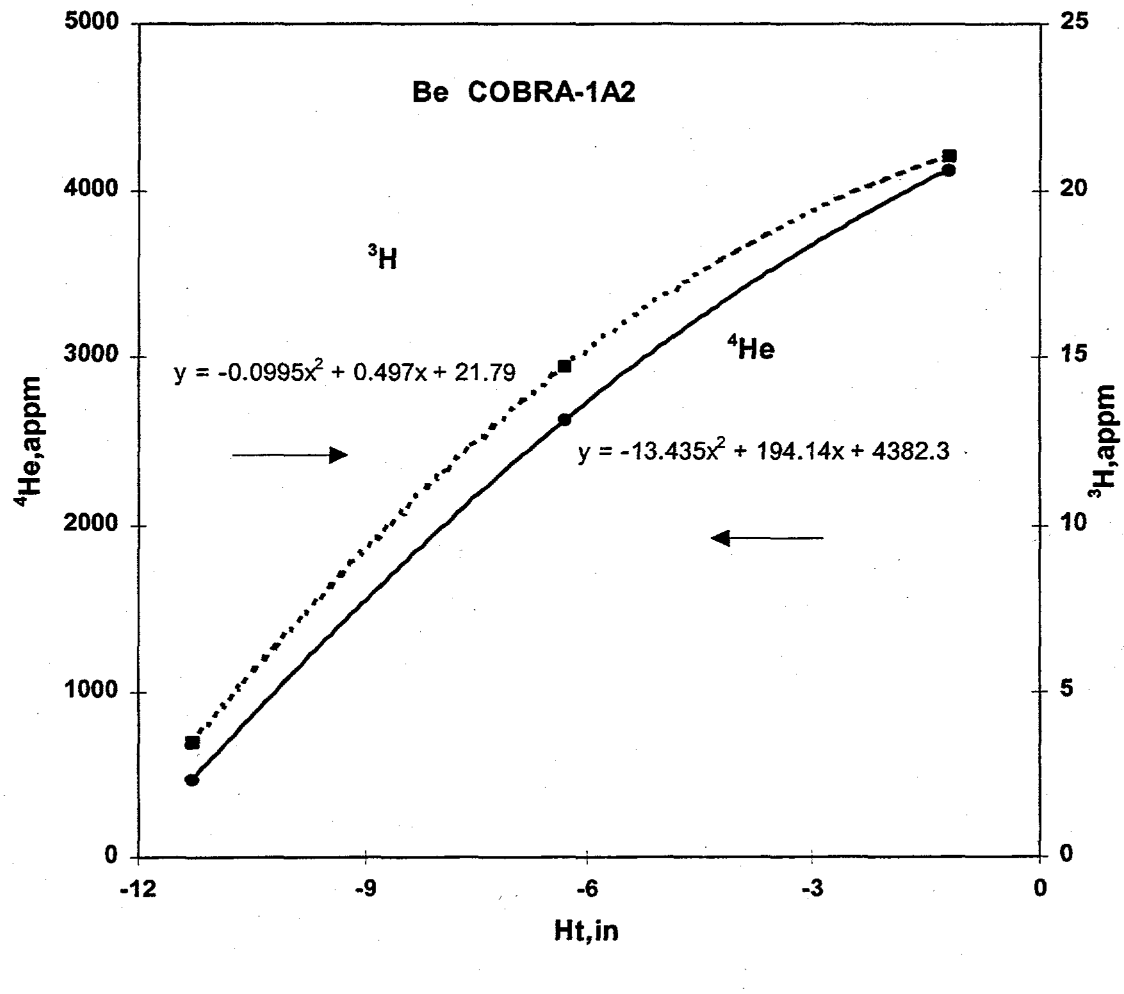

Figure 1. Production of ^{4}He and ^{3}H as a function of reactor elevation

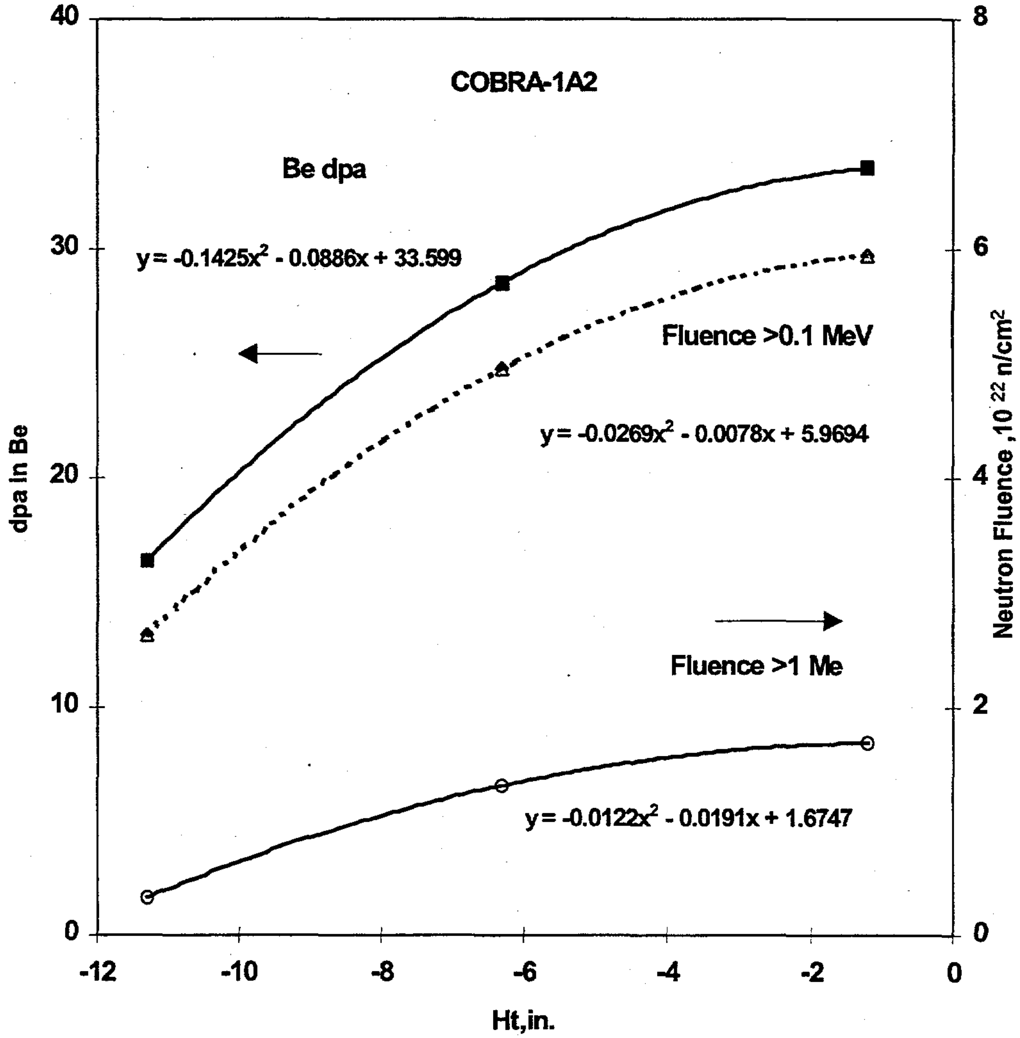

Figure 2. Fast neutron fluence and Be dpa as a function of reactor elevation

The present calculations for the production of ^4He and tritium assume that both species remain trapped in the beryllium close to the point of generation. Although this is a good assumption for helium, the tritium may be subject to significant diffusion and possible loss from the beryllium at the irradiation temperatures of 388°C and 395°C for the C03 and D03 subcapsules, respectively. Consequently, comparisons of these calculations with measured tritium evolution from the beryllium must consider the possible diffusion and loss from the subcapsules.

It is also important to note that the calculated values in Table 3 are given at the end of irradiation time, September 26, 1994. Tritium decays with a half-life of 12.32 years, which amounts to 5.5% per year. Table 4 corrects the tritium and ^3He values for decay to May 1997.

Table 3. Calculate ^{4}He. ^{3}H, ^{3}He, and ^{6}Li results for COBRA-1A2 (EOI = 9/26/94)

	Production in Be, appm		
	-1.2"	-6.3"	-11.3"
^{4}He	4130	2626	473
^{3}H	21.1	14.7	3.47
^{3}He	0.68	0.47	0.11
^{6}Li	706	495	101

Table 4. Calculated ^{3}H and ^{3}He results for COBRA-1A2 at 5/1/97

	Production in Be, appm		
	-1.2"	-6.3"	-11.3"
^{3}H	18.2	12.7	3.00
^{3}He	3.58	2.47	0.58

The elevations of the 1, 3, and 5 mm beryllium balls were determined using the radiographs shown in Figure 3. The resultant elevation ranges were then used to calculate the ^{4}He and ^{3}H expected for each type of ball in each capsule. There were no 3 mm balls in D03. For the 1 mm balls, the calculated values are given at the estimated center of the ball. For the 3 and 5 mm balls, values are given at the top and bottom of the elevation ranges. It is not possible to determine the exact elevation of each 3 and 5 mm ball; hence, the best we can do is give a range of values. Tables 5 and 6 summarize our best estimates of the ^{4}He and ^{3}H concentrations in each type of Be ball decayed to May 1, 1997.

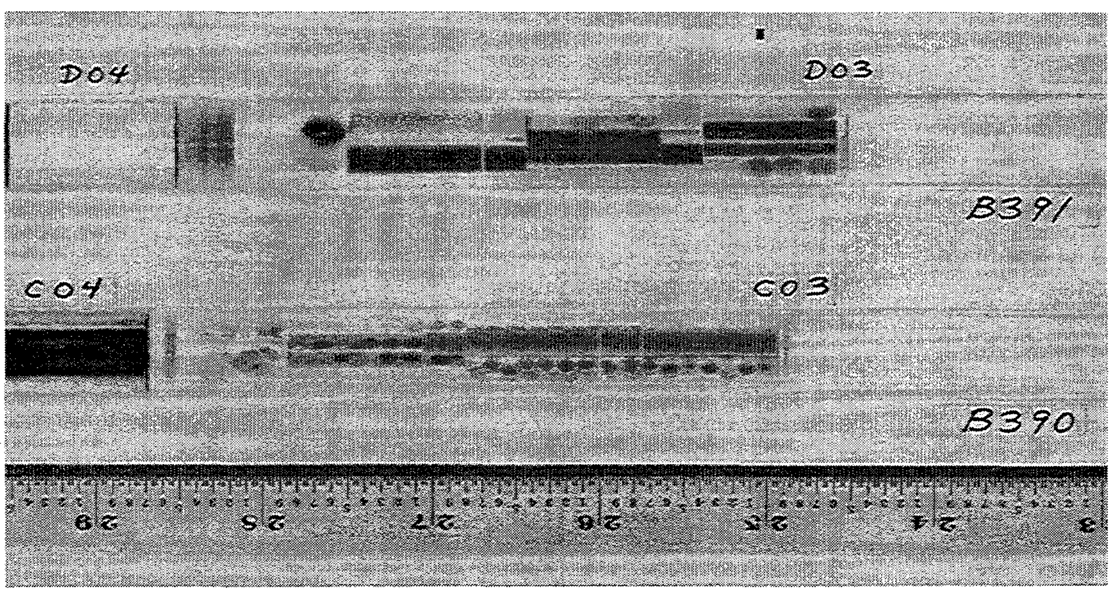

Figure 3. Radiograph of Be capsules in COBRA-1A2

Table 5. Calculations for Be balls in position C03 of COBRA-1A2 at 5/1/97

Be Ball	Ht,in.	^{4}He,appm	^{3}H,appm	Fast Fluence > 1 MeV xE+22 n/cm^2	Fast Fluence >0.1 MeV xE+22 n/cm^2	Be dpa
1 mm	-6.03	2723	13.1	1.35	5.04	29.0
3 mm	-6.0	2734	13.2	1.35	5.05	29.0
3 mm	-3.3	3595	16.5	1.60	5.70	32.3
5 mm	-3.3	3595	16.5	1.60	5.70	32.3
5 mm	-2.8	3733	17.0	1.63	5.78	32.7

Table 6. Calculations for Be balls in position D03 of COBRA-1A2 at 5/1/97

Be Ball	Ht,in.	^{4}He,appm	^{3}H,appm	Fast Fluence > 1 MeV xE+22 n/cm^2	Fast Fluence >0.1 MeV xE+22 n/cm^2	Be dpa
1 mm	-6.20	2662	12.9	1.32	4.98	28.7
5 mm	-6.2	2662	12.9	1.32	4.98	28.7
5 mm	-4.6	3205	15.0	1.50	5.44	31.0

FUTURE WORK

This work is completed.

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