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INDUCED RADIOACTIVITY OF ELEMENTS
IRRADIATED IN FFTF/MOTA AND EBR-II

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INDUCED RADIOACTIVITY OF ELEMENTS IRRADIATED IN FFTF/MOTA AND
EBR-2 - H. L. Heinisch (Pacific Northwest Laboratory), F. M.
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PURPOSE

The purpose of this work is to provide information for evaluating the residual induced radioactivity of materials irradiated in FFTF/MOTA and EBR-2 irradiation facilities.

SUMMARY

Calculations of decay rates of radionuclides in 36 elements irradiated in FFTF/MOTA core center and EBR-2 mid-core and top-core positions have been made using REAC*2. Tables of the results have been made and are being used in compiling test specimen waste disposal documentation.

PROGRESS AND STATUS

Residual induced radioactivity of test materials is an unavoidable consequence of radiation effects experiments performed in nuclear reactors. Knowledge of the activity level of the specimens and the associated irradiation hardware is essential to planning the experiment, performing the tests and disposing of the waste materials. Gamma dose rates are measured directly during storage and handling as part of ALARA procedures, but for aspects such as waste disposal, detailed laboratory analysis is needed to fully characterize the quantity of each radioactive isotope in a test specimen.

Calculations provide a reliable, yet inexpensive method of estimating the concentrations of all the radioactive isotopes in an irradiated material. Characterization of residual radioactivity of test specimens required for handling and waste disposal is routinely done at Hanford using the REAC*2 computer code system¹. To avoid doing calculations on a case by case basis, tables of decay rates have recently been compiled for the radionuclides of 36 elements irradiated in FFTF/MOTA and in EBR-2. Samples of this information are given in Tables 1 and 2 for FFTF/MOTA and EBR-2, respectively.

Decay rates were calculated with REAC*2 for 250 day irradiations in FFTF/MOTA Level 3 (core center) at a total neutron flux of 5.45×10^{15} n/cm² (72% having $E > 0.1$ MeV). This results in a total neutron fluence of 1.2×10^{23} n/cm², about 35 dpa in steel. Decay rates were also calculated for irradiation in EBR-2 Row 2 Midplane for 40 days at a total neutron flux of 2.1×10^{15} n/cm² (93% having $E > 0.1$ MeV) to a total neutron fluence of 7.2×10^{21} n/cm² (about 5 dpa in steel) and for 40 days in EBR-2 Row 2 Top-of-Core at a total neutron flux of 2.80×10^{14} n/cm² (35% having $E > 0.1$ MeV) to a total neutron fluence of 9.6×10^{20} n/cm² (about .25 dpa in steel).

In the tables decay rates are given for the individual radionuclides in each element that together contribute 99% or more of the total activity. Decay rates are given in Ci/g of the pure element. Radionuclides decaying by beta emission are identified. The tables contain decay rates after decay times of 0.5, 1, 2, 3, 4, and 5 years out of reactor.

The tables have been useful in documenting radioisotope levels in activated test specimens and in the waste products of their preparation and testing. When disposing of irradiated test materials, the decay rates of the radionuclides for each element in the specimen are obtained from the table corresponding to the greatest decay time that is less than the real time out of reactor. The results are linearly scaled for specimens exposed in multiple irradiations. The total contribution of each radionuclide present is evaluated, and those contributing at least 1% to the total activity of a specimen are noted in the records.

Uncertainty in the calculations depends on the elements involved and the uncertainties in the irradiation information. Calculations require nuclear reaction cross sections and decay data, the neutron flux spectrum, irradiation time and power history, and the material composition. In principle, the largest uncertainty in such calculations originates from uncertainty in the cross sections, where uncertainties can range from less than a percent to a factor of two or more, depending on the reaction. Cross sections for most of the reactions involving common alloying elements are well known. Irradiation times are well-known, and, because the irradiations are for materials experiments, the compositions are usually well-known. Uncertainties in the neutron fluence and spectrum, including differences in neutron flux spectra of these facilities over the years, are not considered significant within the scope of these calculations. Differences are assumed to be accounted for by the assumption that the dose for a typical run in a "generic" spectrum for each facility is an upper limit for any real, single irradiation.

FUTURE WORK

Calculations for positions above and below the core in FFTF/MOTA will be made and included in a final report. Effective ways of including this information in a computer data base are being considered.

REFERENCES

1. F. M. Mann, REAC*2: Users Manual and Code Description, WHC-EP-0282 (1989)

TABLE 1. Decay Rates of Radionuclides of Selected Elements, in Ci/g of the Pure Element, after Irradiation to 1.2×10^{23} total n/cm² in FFTF/MOTA, Level 3 (core center). Only radionuclides contributing at least 1% to the total activity are listed for each element. The letter B following the isotope name indicates radionuclides that undergo beta decay.

Elem.	Isotope	Decay Rates in Ci/g after Decay Times of					
		0.5 year	1 year	2 years	3 years	4 years	5 years
Ti	Sc 46 B	2.61e-02	5.76e-03	2.81e-04	1.37e-05	6.67e-07	
	Ca 45 B	1.43e-03	6.63e-04	1.43e-04	3.08e-05	6.65e-06	1.43e-06
	H 3 B			4.85e-06	4.58e-06	4.33e-06	4.09e-06
V	V 49	4.12e-05	2.81e-05	1.31e-05	6.09e-06	2.83e-06	1.32e-06
	H 3 B	2.07e-06	2.01e-06	1.90e-06	1.79e-06	1.70e-06	1.60e-06
Cr	Cr 51	1.90e-02	1.96e-04				
	V 49	3.01e-04	2.05e-04	9.54e-05	4.44e-05	2.07e-05	9.62e-06
	H 3 B		7.17e-06	6.78e-06	6.41e-06	6.06e-06	5.73e-06
Mn	Mn 54	8.88e-03	5.92e-03	2.63e-03	1.17e-03	5.20e-04	2.31e-04
Fe	Fe 55	2.48e-01	2.18e-01	1.68e-01	1.30e-01	1.00e-01	7.76e-02
	Mn 54	2.25e-01	1.50e-01	6.67e-02	2.97e-02	1.32e-02	5.86e-03
Co	Co 60 B	1.88e+01	1.76e+01	1.54e+01	1.35e+01	1.19e+01	1.04e+01
Ni	Co 58 B	2.50e+00	4.20e-01	1.18e-02			
	Fe 55	7.74e-02	6.80e-02	5.25e-02	4.05e-02	3.13e-02	2.42e-02
	Co 60 B		2.34e-02	2.06e-02	1.80e-02	1.58e-02	1.39e-02
	Co 57			3.53e-03	1.39e-03	5.47e-04	
	Ni 63 B			6.02e-03	5.97e-03	5.93e-03	5.89e-03

TABLE 2. Decay Rates of Radionuclides of Selected Elements, in Ci/g of the Pure Element, after Irradiation to 7.2×10^{21} total n/cm² in EBR-2, Row 2 Midplane. Only radionuclides contributing at least 1% to the total activity are listed for each element. The letter B following the isotope name indicates radionuclides that undergo beta decay.

Elem.	Isotope	Decay Rates in Ci/g after Decay Times of					
		0.5 year	1 year	2 years	3 years	4 years	5 years
Ti	Sc 46 B	7.24e-03	1.60e-03	7.79e-05	3.80e-06	1.85e-07	
	Ca 45 B	3.27e-04	1.52e-04	3.27e-05	7.06e-06	1.52e-06	3.29e-07
	H 3 B			1.14e-06	1.08e-06	1.02e-06	9.64e-07
V	V 49	1.04e-05	7.10e-06	3.30e-06	1.54e-06	7.16e-07	3.33e-07
	H 3 B	4.78e-07	4.65e-07	4.39e-07	4.15e-07	3.92e-07	3.71e-07
Cr	Cr 51	1.44e-03	1.49e-05				
	V 49	6.81e-05	4.64e-05	2.16e-05	1.01e-05	4.68e-06	2.18e-06
	H 3 B		1.77e-06	1.68e-06	1.59e-06	1.50e-06	1.42e-06
Mn	Mn 54	2.48e-03	1.65e-03	7.34e-04	3.26e-04	1.45e-04	6.44e-05
Fe	Mn 54	3.70e-02	2.47e-02	1.10e-02	4.87e-03	2.17e-03	9.62e-04
	Fe 55	7.42e-03	6.52e-03	5.03e-03	3.89e-03	3.00e-03	2.32e-03
Co	Co 60 B	1.59e-01	1.49e-01	1.31e-01	1.15e-01	1.01e-01	8.81e-02
	Fe 59 B	5.31e-03					
	Co 58 B	3.28e-03					
Ni	Co 58 B	7.10e-01	1.19e-01	3.35e-03	9.44e-05		
	Fe 55	1.15e-02	1.01e-02	7.81e-03	6.03e-03	4.66e-03	3.60e-03
	Co 60 B		3.33e-03	2.92e-03	2.56e-03	2.24e-03	1.97e-03
	Co 57		2.04e-03	8.02e-04	3.16e-04	1.24e-04	
	Ni 63 B			1.43e-04	1.42e-04	1.41e-04	1.40e-04

END

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