Lawrence Livermore Laboratory

DT FUSION NEUTRON IRRADIATION OF AI COBALT, ZIRCONIUM, GOLD, IRON, NICKEL, AND
NIOBIUM, LLL PYROGRAPHITE AND LLL SILICA

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ABSTRACT

The DT fusion neutron irradiation of an AI sample capsule containing cobalt, zirconium, gold, iron, nickel and niobium samples plus two LLL pyro-graphite samples, and eight LLL silica pieces is described. The sample position, beam -- on time, and neutron dose record are given. The maximum neutron fluence on any sample was 2.41×10^{17} neutrons/cm².

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DT FUSION NEUTRON IRRADIATION OF AI COBALT,
ZIRCONIUM, GOLD, IRON, NICKEL AND NIOBIUM,
LLL PYROGRAPHITE AND LLL SILICA

The LLL Rotating Target Neutron Source (RTNS) was scheduled for Drs. Harry Farrar and Dennis Kneff of Atomics International (AI) for the week of January 24, 1977. Their sample capsule was approximately 25 mm in diameter and 3.8 mm thick. It contained foils of Co, Zr, Au, Fe, Nb, and Ni as well as chunks of natural Ni, ⁵⁸Ni, ⁶⁰Ni, ⁶¹Ni, ⁶²Ni and ⁶⁴Ni. Niobium dosimetry foils, 12 mm in diameter and 0.03 mm thick, were centered on the front and back of the capsule.

Dr. Ralph H. Condit of LLL supplied two pieces of pyrographite and eight silica samples for irradiation. The pyrolytic graphite samples, C-5 and C-6, measured very approximately 10 × 7 × 2 mm thick. They had been irradiated at the RTNS during the period May 2-7, 1975. The samples were annealed prior to the current irradiation.

Four of the eight silica samples (Silica I package) were suprasil pieces measuring about 2.5 × 2.5 × 9 mm. They were packed as closely together as possible in a single layer with the third sample down displaced a little. The samples had been irradiated previously, October 11-15, 1976 and November 17-December 2, 1976. They were annealed at 750°C on January 9, 1977.

The Silica II package contained four samples of suprasil measuring approximately 3 × 3 × 8 mm. Two samples, S-48 and S-49, were Suprasil-W1 and the remaining two, S-58 and S-59, were Suprasil-1. These were packed in a manner similar to the first package.

The pyrographite and silica sample packages were sandwiched between niobium dosimetry foils measuring 12 mm in diameter and 0.14 mm thick. The order of stacking was as follows:

<u>Order</u>	<u>Sample</u>
1	Nb-812
2	AI capsule
3	Nb-813
4	Nb-809
5	Pyrographite

6	Nb-810
7	Silica I
8	Nb-811
9	Silica II
10	Nb-814

A copper foil with a 6 mm diameter hole was centered on cross hairs on the back of the target and irradiated briefly. An autoradiograph of the copper foil showed the position of the neutron beam so that the samples could be aligned with it. The neutron irradiation was carried out by the LLL E Division Accelerator Staff during the period January 24 to 28, 1977. Neutron production was monitored continuously with a proton recoil counter and recorded each hour. The dose record is attached. The total beam-on time was 76.73 hours.

A very few days following the irradiation, the AI experimenters unloaded their sample capsule. Two nickel foils were cut into five pieces and one nickel foil was cut into two pieces. These foil pieces and eight nickel chunks were wrapped in glassine and delivered to Ruth Anderson in the LLL Radiochemistry Division for gamma ray counting. The results were as follows:

LLL Gamma Ray Counting of Nickel
Samples from January 24-28, 1977
RTNS Irradiation

Sample	mass (gm)	area (cm ²)	Count		⁵⁸ Co		⁵⁷ Ni		Distance from detector (cm)
			length (min)	began (PDT 1977)	DPM/gm at t ₀	% error	DPM/gm at t ₀	% error	
FNi-1	0.01904	0.04	33.33	32.676	1.149×10^9	1.7	2.610×10^9	1.4	34.76
FNi-10	0.01231	0.50	33.33	32.714	6.272×10^9	3.2	6.831×10^9	2.8	34.76
FNi-11	0.00923	0.37	33.33	32.739	1.864×10^9	2.0	4.776×10^9	1.9	34.76
FNi-12	0.00923	0.37	33.33	32.764	5.047×10^9	3.1	5.453×10^9	2.8	34.76
FNi-13	0.00923	0.37	33.33	33.503	1.814×10^9	1.3	4.176×10^9	1.7	34.76
FNi-14	0.00923	0.37	33.33	33.527	2.709×10^9	2.8	3.254×10^9	2.4	34.76
FNi-20	0.01246	0.50	33.33	33.552	1.922×10^9	1.9	5.136×10^9	1.8	34.76
FNi-21	0.00934	0.37	33.33	33.576	1.218×10^9	1.5	3.118×10^9	1.6	34.76
FNi-22	0.00934	0.37	33.33	33.601	3.336×10^9	5.2	4.394×10^9	4.0	34.76
FNi-23	0.00934	0.37	33.33	33.625	1.510×10^9	1.1	3.678×10^9	1.4	34.76
FNi-24	0.00934	0.37	33.33	33.649	1.875×10^9	8.6	2.635×10^9	10.7	34.76
FNi-40	0.00868	0.34	33.33	33.674	1.467×10^9	1.5	3.982×10^9	1.7	34.76
FNi-41	0.02342	0.23	33.33	33.698	1.220×10^9	2.4	3.177×10^9	2.0	34.76
F58Ni-1	0.007220	0.02	33.33	33.760	2.291×10^9	1.5	6.357×10^9	1.5	29.76
F58Ni-2	0.003144	0.01	33.33	33.785	2.344×10^9	1.3	6.320×10^9	1.4	18.76
					⁶⁰ Co				
					DPM/gm at t ₀	% error			
F60Ni-1	0.008318	0.02	333.33	33.810	4.014×10^7	0.5			
F60Ni-2	0.005564	0.01	333.33	34.046	3.769×10^7	0.5			
					⁵⁹ Fe				
					DPM/gm at t ₀	% error			
F62Ni-1	0.005454	0.01	333.33	34.739	2.022×10^8	0.8			
					⁶¹ Co				
F61Ni-1	0.006563	0.02	167.67	34.621	cannot count - ⁶¹ Co is				5.16
F64Ni-1	0.002926	0.01	666.67	34.975	not in our library				5.16

Of five AI niobium sample foils, two were cut into nine pieces, two were cut into five pieces, and one was left whole. All pieces were wrapped in glassine and these along with the dosimetry foils were also given to R. Anderson for gamma ray counting.

Following the gamma ray counting samples FNi-1, FNi-10, FNi-12, FNi-20, FNi-40, F62Ni-1, F58Ni-1, F58Ni-2, F60Ni-1, F60Ni-2, FNb-10, FNb-12, FNb-20, FNb-28, FNb-40, and FNb-50 were shipped to Argonne National Laboratory for cross checking the gamma ray counting. The remaining nickel and niobium samples were returned to H. Farrar and D. Kneff at AI. The pyrographite and silica samples were returned to R. Condit at LLL.

The average fluence of each niobium foil was calculated using the method described in UCRL-51393, Rev. 1. However, the cross section used for the activation of the 10.16 day isomer of niobium by 14.8 MeV neutrons was changed to 458 millibarns. The results were as follows:

<u>Dosimetry Foil</u>	<u>Fluence (n/cm²)</u>
Nb-812	1.92×10^{17}
Nb-813	7.04×10^{16}
Nb-809	5.91×10^{16}
Nb-810	3.91×10^{16}
Nb-811	2.52×10^{16}
Nb-814	1.55×10^{16}

LLL Gamma Ray Counting of Al Niobium
Samples from January 24-28, 1977
RTNS Irradiation

Sample	mass (gm)	area (cm ²)	Count		DPM/gm at t ₀	% error	Fluence (n/cm ²)
			length (min)	began (PDT 1977)			
FNb-10	0.00394	0.22	66.67	46.137	2.866×10^{10}	1.1	2.38×10^{17}
FNb-11	0.00295	0.17	66.67	46.089	2.516×10^{10}	0.9	2.09×10^{17}
FNb-12	0.00295	0.17	66.67	46.040	2.909×10^{10}	0.9	2.41×10^{17}
FNb-13	0.00295	0.17	66.67	45.992	2.146×10^{10}	0.8	1.78×10^{17}
FNb-14	0.00295	0.17	66.67	45.944	1.813×10^{10}	0.8	1.50×10^{17}
FNb-15	0.00492	0.27	66.67	45.896	1.208×10^{10}	1.1	1.00×10^{17}
FNb-16	0.00492	0.27	133.33	45.701	1.794×10^{10}	1.3	1.49×10^{17}
FNb-17	0.00492	0.27	133.33	45.605	1.527×10^{10}	0.8	1.27×10^{17}
FNb-18	0.00492	0.27	133.33	45.510	9.026×10^9	0.8	7.48×10^{16}
FNb-20	0.00425	0.22	66.67	46.186	1.890×10^{10}	1.0	1.57×10^{17}
FNb-21	0.00318	0.17	66.67	46.235	1.491×10^{10}	0.9	1.24×10^{17}
FNb-22	0.00318	0.17	66.67	46.283	1.657×10^{10}	0.8	1.37×10^{17}
FNb-23	0.00318	0.17	66.67	46.476	1.748×10^{10}	1.0	1.45×10^{17}
FNb-24	0.00318	0.17	66.67	46.331	1.315×10^{10}	1.1	1.09×10^{17}
FNb-25	0.00530	0.27	66.67	46.379	1.103×10^{10}	0.9	9.15×10^{16}
FNb-26	0.00530	0.27	66.67	46.427	1.377×10^{10}	1.0	1.14×10^{17}
FNb-27	0.00530	0.27	66.67	46.524	1.155×10^{10}	0.9	9.58×10^{16}
FNb-28	0.00530	0.27	66.67	46.572	8.087×10^9	1.0	6.71×10^{16}
FNb-40	0.00614	0.32	66.67	46.620	1.337×10^{10}	0.8	1.11×10^{17}
FNb-41	0.00460	0.24	66.67	46.668	1.193×10^{10}	0.9	9.89×10^{16}
FNb-42	0.00460	0.24	66.67	46.716	1.264×10^{10}	1.1	1.05×10^{17}
FNb-43	0.00460	0.24	66.67	46.765	1.070×10^{10}	1.0	8.87×10^{16}
FNb-44	0.00460	0.24	66.67	46.812	9.299×10^9	1.0	7.71×10^{16}
FNb-50	0.02750	0.24	66.67	46.860	1.177×10^{10}	0.8	9.76×10^{16}
FNb-51	0.02062	0.18	66.67	46.913	9.486×10^9	0.8	7.87×10^{16}
FNb-52	0.02062	0.18	66.67	46.963	1.075×10^{10}	0.7	8.91×10^{16}
FNb-53	0.02062	0.18	66.67	47.014	1.036×10^{10}	0.8	8.59×10^{16}
FNb-54	0.02062	0.18	66.67	47.064	8.968×10^9	1.2	7.44×10^{16}
FNb-60	0.11008	0.97	66.67	47.115	8.879×10^9	0.6	7.36×10^{16}

The estimated overall uncertainty of these results is $\pm 7.5\%$. The relative uncertainty between any two values is about $\pm 2\%$. The fluences given here represent average fluences over the volume of each dosimetry foil.

RTNS IRRADIATION OF JANUARY 24 TO 28, 1977

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