Sensitivity of Neutron Heating in Fusion Reactor Blankets to Nuclear Data

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A study of the sensitivity of neutron heating in CTR blankets to basic nuclear data has been carried out.[1]

Table 1 shows the percentage contribution to neutron heating by reaction type for the most important CTR materials for two reference spectra. These calculations were carried out with kerma factors processed by MACK[2,3] from ENDF/B3[4] data. The general conclusion from these results is that reactions such as (n,α) and (n,p) while relatively unimportant for determining the neutron flux are extremely important mechanisms for local energy deposition as they contribute more than 50% in most materials. A relative change in σ for charged particle producing reactions (for which σ is usually small) results in a greater change in neutron heating than that produced by the same relative change in a large σ such as that of elastic scattering.

The Li^7 (n,n'α)t is the most important neutron producing reaction in most blankets. Rosen and Stewart's[5] data for the secondary neutron energy distribution of Li^7 (n,n'α)t was used as the basis for the ENDF/B3 (MAT 1116) representation. Table 2 shows that the ENDF/B3 representation consistently overestimates the average secondary neutron energy, $\overline{E}_{n',1}$, compared with the original data. The effects of such changes in $\overline{E}_{n',1}$ on kerma factors are shown in table 2. The pointwise kerma factor for the (n,n'α)t reaction changes by about 15 to 25% when the Rosen and Stewart data is replaced by the ENDF/B3 representation. The resulting change in the neutron heating in Li^7 is about -8%. The relative change in neutron heating in Li^7 was found to be roughly one-third of that in $\overline{E}_{n',1}$ for the (n,n'α)t reaction. A 90% change in the nuclear temperature for all neutron producing reactions in Li^7 results in 30 to 40% change in the neutron heating in Li^7.

The sensitivity of neutron heating to changes in the angular distribution of elastic scattering in Li^7 was also studied. Ignoring the center of mass anisotropy of elastic scattering increases the neutron heating in Li^7 by about 80% in lithium regions close to the first wall and by 40% in regions close to the shield.

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TABLE 1 PERCENTAGE CONTRIBUTION OF REACTION TYPES TO NEUTRON

HEATING IN SOME CTR MATERIALS FOR

a - Typical First Wall Spectrum

Reaction Type / Material	Elastic Scattering	Inelastic Scattering+	n,2n	n,γ	n;n' charged particles	n,charged particles
Li-6	5.6	10.5	0.0	0.0	1.8	82.1
Li-7	42.2	7.8	0.09	0.04	47.3	1.8
Be-9	37.7	—	55.1*	0.004	—	7.2
Al-27	13.9	25.7	0.35	.25		59.7
Cr	9.8	9.9	2.3	.03	5.53	72.5
Fe	8.8	8.2	3.3	.01		79.7
Ni	4.3	2.8	0.14	.01	16.9	75.7
Nb	17.6	16.4	15.5	.09		50.5
V	24.8	12.7	12.6	3.8		46.4
Cu	12.1	11.8	4.9	30.5		40.7

b - C/E Spectrum (C = 1.0 above 0.11MeV, C = 0.25 below .11MeV)

Reaction Type / Material	Elastic Scattering	Inelastic Scattering+	n,2n	n,γ	n;n' charged particles	n,charged particles
Li-6	0.2	.001	0.0	0.0	.24	99.6
Li-7	57.7	10.9	0.3	1.8	29.0	0.4
Be-9	50.0	—	36.6*	.003	—	13.4
Al-27	28.6	21.3	0.1	3.1		47.0
Cr	31.0	17.5	0.6	0.1	2.04	49.8
Fe	19.7	19.4	1.0	0.03		59.8
Ni	8.0	4.6	.03	0.03	4.5	82.9
Nb	30.6	33.3	5.8	0.2		30.1
V	18.7	13.4	1.3	56.1		10.5
Cu	9.2	8.3	22.9	4.0		55.6

+Includes the (n;n', charged particles) contribution for some materials.

*(n,2n)α plus (n,n')α plus inelastic.

TABLE 2 Comparison of Rosen & Stewart[5] and ENDF/B III Average Secondary Neutron Energy of the Lithium-7 (n,n´)αt Reaction and Effect on Kerma Factors

Energy (MeV)	Average Secondary Neutron Energy			Lithium-7 (n,n´α)t Kerma Factor*			Lithium-7 Total Kerma Factor*		
	A	B	$\frac{A-B}{B} \times 100$	A	B	$\frac{A-B}{B} \times 100$	A	B	$\frac{A-B}{B} \times 100$
5.11	1.005	0.635	58.02	0.368	0.451	-18.40	2.035	2.118	- 3.920
5.62	1.191	0.811	46.85	0.675	0.806	-16.25	2.190	2.321	- 5.640
6.01	1.504	0.882	70.52	0.778	1.015	-23.35	2.199	2.436	- 9.730
7.03	2.354	1.512	55.69	0.927	1.281	-27.63	2.149	2.503	-14.140
8.05	3.044	2.315	31.49	1.077	1.386	-22.29	2.257	2.567	-12.076
9.03	3.543	2.748	28.93	1.264	1.597	-20.85	2.458	2.791	-11.930
10.06	4.066	3.048	33.40	1.459	1.880	-22.39	2.690	3.111	-13.530
12.00	5.041	4.285	17.64	1.707	1.994	-14.39	3.007	3.294	- 7.880
13.92	6.007	4.953	21.28	1.834	2.189	-16.22	3.285	3.604	- 9.750

A -- refers to data obtained using ENDF/B3 secondary neutron energy distribution

B -- refers to data obtained using Rosen & Stewart[5] secondary neutron energy distribution

* in units of MeV . barn/atom