Tokamak Neutron Source Based Spent Nuclear Fuel Transmutation Reactors

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The (neutron) transmutation of spent nuclear fuel is a potential intermediate-term goal for the magnetic fusion program. We have made design scoping studies for a series of sub-critical fast reactors that would be driven by tokamak fusion neutron sources. These studies were constrained to use existing fusion physics and technology (except for the AT case) and to use reactor and materials technologies that either exist or are being developed in the nuclear program. As shown in Table 1, the ITER physics database and the existing fusion technology are adequate for the design of a fusion neutron source for this application, with the exception of the bootstrap current/current drive efficiency needed for steady-state operation.

Table 1 Tokamak Neutron Source Parameters for Transmutation Reactors

Parameter	FTWR[a]	FTWR-SC[b]	FTWR-AT[c]	GCFTR[d]	ITER[e]
Fusion power, P_{fus} (MW)	≤ 150	≤ 225	≤ 500	≤ 200	410
Neutron source, $S_{fus}(10^{19}$ #/s)	≤ 5.3	≤ 8.0	≤ 17.6	≤ 7.1	14.4
Major radius, R (m)	3.1	4.5	3.9	4.2	6.2
Minor radius, a (m)	0.9	0.9	1.1	1.0	2.0
Elongation, κκ	1.7	1.8	1.7	1.8	1.8
Current, I (MA)	7.0	6.0	8.0	7.2	15.0
Magnetic field, B (T)	6.1	7.5	5.7	6.3	5.3
Confinement, H(y,2)	1.1	1.0	1.5	1.0	1.0
Normalized beta, β_N	≤ 2.5	≤ 2.5	4.0	≤ 2.5	1.8
Plasma Power Mult., Q_p	≤ 2.0	≤ 2.0	4.0	2.9	10
Electric Power Mult, Q_e	1	5		3.6	
Current-drive effic.η_{cd} (A/W)	0.03	0.024	0.05	0.078	
" , γ_{cd} $(10^{20}$ A/Wm$^{-2})$	0.19	0.20	0.28	0.5	
Bootstrap I fraction, f_{bs}	.67(.38)[f]	0.56(0.24)	0.25	0.35	
Neut. flux, Γ_n (MW/m^2)	≤ 0.8	≤ 1.0	≤ 1.7	≤ 0.9	0.5
Heat flux, q_{fw} (MW/m^2)	≤ 0.4	≤ 0.3	≤ 0.5	≤ 0.3	0.15
Availability (%)	≥ 50	≥ 50	≥ 50	≥ 50	

[a] ITER physics, LN-cool Cu magnets, PbLi cool, metal fuel fast reactor.(FS&T,41,116,2002).
[b] ITER physics, SC magnets, PbLi cooled, metal fuel fast reactor. (FS&T, 45, 55, 2004).
[c] AT physics, SC magnets, PbLi cooled, metal fuel fast reactor. (Ga. Tech rpt GTFR-167, 2003).
[d] ITER physics, SC magnets, He cooled, coated pellet fuel fast reactor (NT, sub., 2004).
[e] ITER design parameters.
[f] required (estimated from present database)