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ENERGY SPECTRA OF FUSION NEUTRONS FROM PLASMAS DRIVEN BY REACTING ION BEAMS

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MASTER

In the two-energy-component tokamak reactor (TCT), fusion energy is produced principally by reactions between injected energetic deuterons and the relatively cold ions of the target plasma (D, T, or ^{3}He). The large deuteron energy results in considerable width of the energy spectrum of D-D or D-T neutrons in the laboratory frame.[1] This spectrum is important for plasma diagnostics, and for optimum utilization of the neutrons in various blankets surrounding the reacting plasma (such as fissile or tritium breeding blankets).[2] In this study, we calculate neutron spectra for TCT reactors, using appropriate steady-state velocity distributions for the fast deuterons.

General expressions for the angular and energy distributions of fusion neutrons in terms of the distribution functions of the reacting ions are given in Ref. 1. For the target ions, we use a Maxwellian distribution of temperature T_i. Since we are concerned only with angle-averaged neutron energy spectra, we use the hot-ion distribution function averaged over all angles, $\bar{f}_h(v)$. If energy diffusion during slowing-down is neglected, then regardless of the angle of injection into the tokamak plasma, the

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED steady-state solution of the Fokker-Planck equation for $\bar{f}_h$ is

$$\bar{f}_h(v) = \left(v^3 + v_c^3\right)^{c/\tau-1}, \qquad v \le v_o$$
$$\bar{f}_h(v) = \left(v_o^3 + v_c^3\right)^{c/\tau-1} \exp\left[-M_D(v^2-v_o^2)/2T_i\right], \qquad v > v_o \tag{1}$$

where v_o is the injection velocity, v_c is the velocity at which ion drag = electron drag, and $T_e = T_i$. The exponent $(c/\tau - 1)$ is appropriate for a fast-ion loss rate τ^{-1} (e.g., charge-exchange loss, unconfined orbits) which is assumed here to be independent of v; c is a constant. We have also used a form for $\bar{f}_h(v)$ that takes into account energy diffusion during slowing-down;[3] the neutron spectra are almost identical to those calculated from Eg. (1) with $c/\tau = 0$.

Angle-averaged neutron energy spectra are shown in Figs. 1 and 2. For injection at W_b = 150 keV, the spectra have a FWHM $\simeq$ 1.3 MeV for D→T and 0.65 MeV for D→D. Other conclusions are: (1) Increasing W_b greatly broadens the spectrum, especially for D→D [Figs. 1(a), 2]. (2) Increasing T_i "rounds" the spectrum, and slightly hardens it [Fig. 1(b)]. (3) Given T_i and W_b, the spectrum is relatively insensitive to $\bar{f}_h(v)$ [Fig. 1(c)], so that angular distribution measurements may be necessary to deduce the nature of the energetic-ion distribution.

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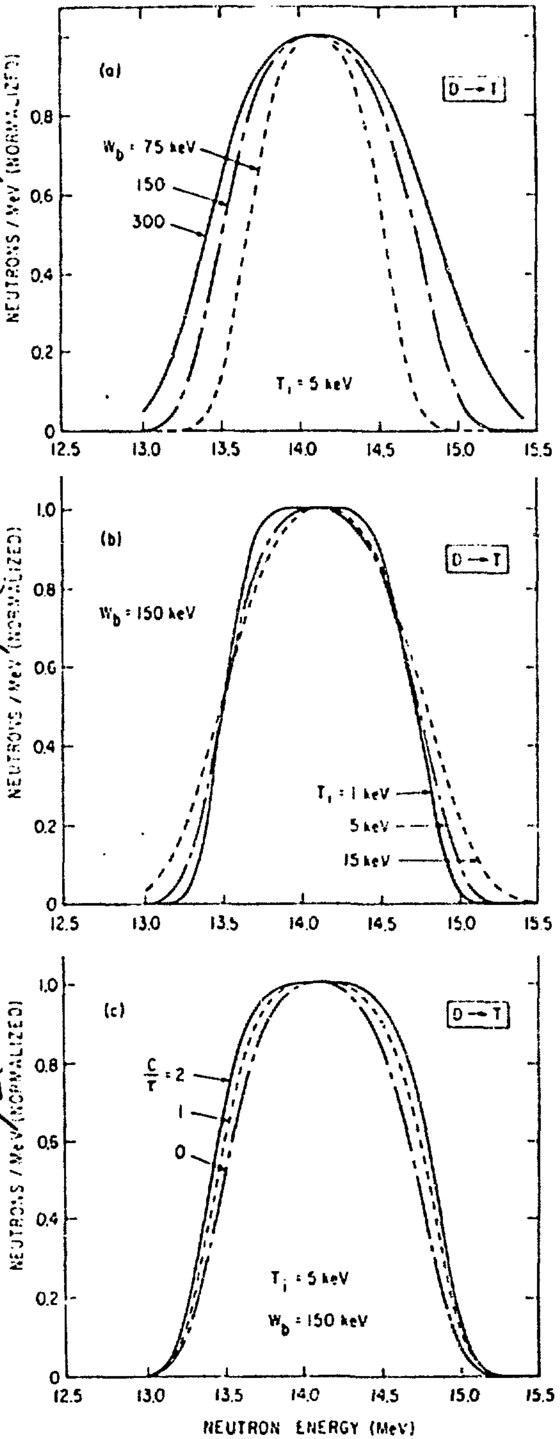
References

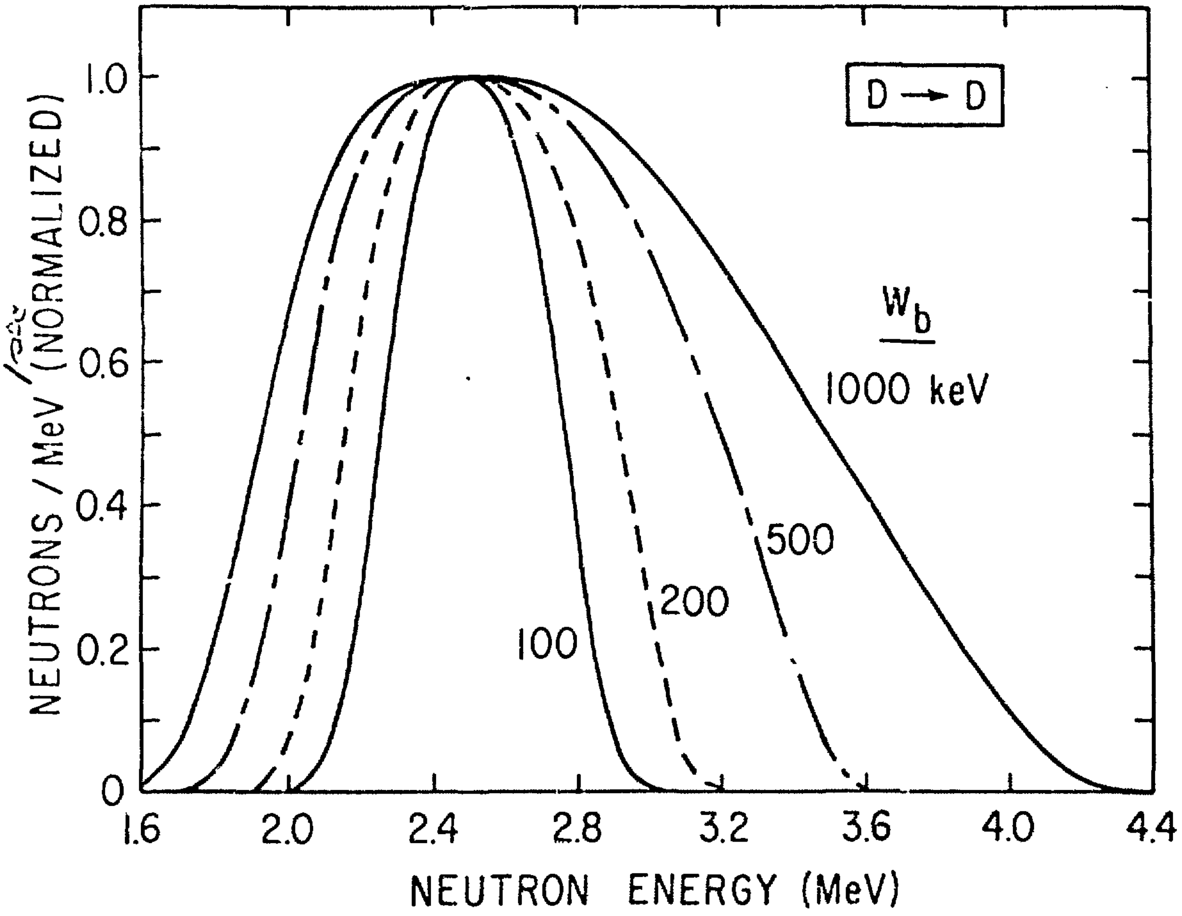
1. G. LEHNER, Z. Physik 232, 174 (1970); H. BRYSK, Plasma Physics 15, 611 (1973); D.L. LESSOR, Battelle Northwest Lab. Report BNWL-B-409 (1975).
2. D.W. MUIR, Proc. First Topical Meeting on the Technology of Controlled Nuclear Fusion (San Diego, 1974), Vol. II, p. 166.
3. E.A. FRIEMAN, unpublished.

Figure Captions.

Fig. 1. Angle-averaged neutron spectra for D→T TCT reactors. (a) Variation with injection energy. $c/\tau = 0$. (b) Variation with bulk-plasma temperature. $c/\tau = 0$. (c) Variation with energetic-ion distribution function. The parameter c/τ refers to Eq. (1).

Fig. 2. Angle-averaged neutron spectra for D→D TCT reactors, showing variation with injection energy. $c/\tau = 0$. $T_i = 10$ keV.


(a)
D → T
W_b = 75 keV
150
300
T_i = 5 keV
(b)
D → T
W_b = 150 keV
T_i = 1 keV
5 keV
15 keV
(c)
D → T
C/T = 2
1
0
T_i = 5 keV
W_b = 150 keV
NEUTRONS / MeV / sec (NORMALIZED)
0
0.2
0.4
0.6
0.8
1.0
12.5
13.0
13.5
14.0
14.5
15.0
15.5
NEUTRON ENERGY (MeV)


D → D
W_b
1000 keV
500
200
100
NEUTRONS / MeV / (NORMALIZED)
0
0.2
0.4
0.6
0.8
1.0
1.6
2.0
2.4
2.8
3.2
3.6
4.0
4.4
NEUTRON ENERGY (MeV)