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EFFECT OF IMPURITIES AND EFFECTIVE CHARGE ON PLASMA HEATING BY ALPHA PARTICLES IN THERMONUCLEAR REACTORS *)

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In 1955, the British engineer J. D. Lawson [1] formulated his famous criterion, according to which for a positive energy yield from a thermonuclear DT plasma with an ion temperature of T_i =10 keV, it is necessary to achieve $n_i\tau_E \geq 10^{20}$ s/m^3. Fast neutrons, the main energy product of the fusion reaction (~80% of the released energy), leave the plasma, without any consequences for its ions and electrons. Only the charged part of the product, fast α-particles (helium nuclei), can transfer part of the fusion energy to plasma in the magnetic field of the tokamak, and at least 90% of their energy will be transferred to the electrons [2]. The main part of the ions will be heated by them due to Coulomb collisions [3].

Traditionally, the Lawson criterion is considered in the approximation of pure DT plasma, but due to the intense interaction of the plasma with the first wall [4], neutral atoms with a nuclear charge of Z>2 penetrate into the hot center of the plasma column, where they are ionized. Fully ionized atoms contribute to the bremsstrahlung with a power proportional to Z^2. With a significant content of impurities, this radiation constitutes a significant loss of power, which must be compensated for by stronger heating of the plasma.

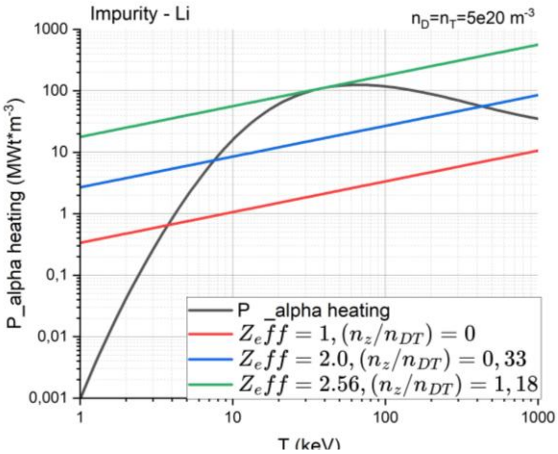

Figure 1. Comparison of bremsstrahlung losses and plasma heating due to alpha particles for thermonuclear DT plasma.

This work shows the possible limit of the content of various impurities (Li, B, O, etc.) in the plasma of future thermonuclear installations with reactor parameters to satisfy the Lawson criterion. Figure 1 shows a graph of the dependence of the power spent on heating the plasma due to alpha particles and the power of the bremsstrahlung X-ray radiation, taking into account the main impurity using lithium as an example. In the case of equality (green graph), it is possible to obtain the value of the maximum possible permissible concentration of impurities, as well as the value of the required temperature range for various impurities in DT plasma with a concentration of $n_D=n_T=5e20 m^{-3}$.

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