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INSTABILITY OF PLASMA ON TRAPPED PARTICLES

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As is well known, flute instability can set in in magnetic-mirror traps and in toroidal traps with closed force lines [1,2]. This instability is the result of the oppositely directed drifts of the electrons and ions in the inhomogeneous electric field (force-line curvature radius R) with velocities $v_j = cT_j/e_jHR$ (H = magnetic field, T_j = temperature, e_j = charge of particle of species j). This drift causes polarization of the plasma in perturbations of the "tongue" type on the plasma surface, and if the magnetic field decreases in the outward direction, then the electric field due to the polarization causes plasma to be ejected. Flute instability was investigated experimentally by Ioffe et al. [3,4].

Analysis in the hydrodynamic approximation [5,6] has shown that in toroidal systems with open force lines lying on toroidal surfaces the plasma should be stable if the pressure is low enough. In a rarefied plasma, however, when the hydrodynamic approximation does not hold, the deduction that flute instability is stabilized by the crossing of the force lines is no longer valid. In fact, this deduction is based on the notion that in a high-temperature plasma the charges due to the magnetic drift should cancel each other as a result of flow along the force lines. Such a cancellation effect does indeed occur, but it applies only to the so-called transit particles, which move freely along the force line. If the magnetic field varies along the force lines, then there is present, besides the transit particles, also a group of "trapped" particles, which oscillate between the magnetic mirrors, i.e., between regions with stronger magnetic fields. If the change of the magnetic field along the force lines is small, then the mirror ratio $P = H_{max}/H_{min}$ is close to unity, and the fraction of particles trapped between mirrors is small, $\epsilon \cong \sqrt{P - 1}$. Since the captured particles are trapped between the mirrors, they cannot move freely along the force lines, and consequently an instability of the flute type can develop on them, and can be naturally called trapped-particle instability.

It differs from flute instability in that the charges due to the trapped particles are cancelled out to a considerable degree by the transit particles. Owing to this effect, the growth increment becomes small, and the transit particles have time to acquire a Boltzmann distribution, i.e., the perturbation of their density is equal to $-e_j\varphi n/T_j$, where φ is the electric field potential and n the unperturbed density. For the perturbation n_t' of the trapped-particle density we have in the quasiclassical approximation, when the perturbation of the potential is in the form of a plane wave, and neglecting the scatter in the drift velocities, the following continuity equation: