the stability criterion obtained in this manner reduces to the condition

$$-\sqrt{\left(\frac{A}{6}\right)^2 - \frac{\beta R^2}{12a^2}} < x^2 - \frac{A}{6} < \sqrt{\left(\frac{A}{6}\right)^2 - \frac{\beta R^2}{12a^2}}, \tag{5}$$

where $A = (7 + 3\Gamma)/4$. From (5), as $\beta \to 0$, it follows that $x^2 < A/3$, whereas for β we get the limitation $\beta \leq \beta_{cr} = (A^2/3)(a^2/R^2)$. For the configuration considered in [1] we have $\Gamma = \sqrt{2}R/z_1 \approx 1$ and $A \approx 5/2$.

The limitations that follow from the required existence of equilibrium, and also the required stability against helical coiling of the plasma loop, are less stringent than those considered above, and are therefore not discussed here.

[1] L.A. Artsimovich and V.D. Shafranov, ZhETF Pis. Red. 15, 72 (1972) [JETP Lett. 15, 51 (1972)].
[2] C. Mercier, Int. Conf. Plasma Phys. and Contr. Nucl. Fus. (Salzburg), p. 95, 1961.
[3] L.S. Solov'ev, Zh. Eksp. Teor. Fiz. 53, 626 (1967) [Sov. Phys.-JETP 26, 400 (1968)].
[4] L.S. Solov'ev, ibid. 53, 2063 (1967) [26, 1167 (1968)].
[5] L.S. Solov'ev, Atom. Energ. 30, 14 (1971).
[6] A. Ware and F. Haas, Phys. Fluids 9, 956 (1965).

MEASUREMENT OF THE ENERGY LIFETIME OF THE IONS IN THE TO-1 TOKAMAK

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As is well known, an important characteristic of thermal insulation of a plasma in a closed magnetic trap of the Tokamak type is the time of conservation of the thermal energy in the ionic component of the plasma. Until recently, this quantity was usually determined from the energy-balance equation, based on the assumption that the energy is transferred from the electrons by the Coulomb mechanism in Joule heating of the plasma [1, 2]. Experiments with the TO-1 setup [3] yielded the dependence of the energy content of the plasma on the time in the case of magnetosonic heating of the ions, which permitted a second independent estimate of τ_{Ei}. It is of interest to compare the ion energy lifetime determined from this dependence with the value calculated from the energy-balance equation.

The equation of the energy balance of the ions, referred to the volume of the plasma filament, can be expressed as follows:

$$\frac{3}{2}\frac{d}{dt}\int nkT_i\,dV = P_{ei} + \tilde{P} - \frac{3}{2}\frac{\int nkT_i\,dV}{\tau_{Ei}}. \tag{1}$$

The quantity τ_{Ei} in (1) is a characteristic of the thermal insulation of the ionic component of the plasma filament as a whole. P is the HF power absorbed by the ions as a result of the magnetosonic heating. P_{ei} is the energy transferred from the electrons to the ions per unit time. If the energy transferred from the electron to the ion in each interaction act differs by a factor γ from the energy transferred in a Coulomb collision, then we have on the basis of [2]

$$P_{ei} = \gamma \frac{0{,}4 \cdot 10^{-17}}{A} \int \frac{n^2}{T_i^{1/2}} dV . \tag{2}$$

Here A is the atomic weight (hydrogen or deuterium), T_i is the ion temperature in °K, and n is the plasma concentration.

In Eq. (1), the ion temperature is made up of the temperature T_{i0} due only to the Joule heating, and of the increment ΔT_i due to the HF heating. If we confine ourselves in (1) to the linear term of the expansion in terms of $\Delta T_i/T_{i0}$ and assume τ_{Ei} to be constant, then Eq. (1) breaks up into two independent equations. The solution of the first of them, describing the energy balance of the ions at P = 0, yields in the stationary state, if the radial distributions of the plasma concentration and of the ion temperature are parabolic,

$$\tau_{Ei} = \frac{43 A}{\gamma} \frac{T_{io}^{3/2}}{n} . \tag{3}$$

In this formula T_{i0} and n are the plasma parameters on the axis of the filament. Solution of this equation yields the incremental energy content of the ionic plasma component due to the absorption of HF power

$$\Delta W_i = \frac{3}{2} \int n k \Delta T_i dV = \widetilde{P}\tau (1 - e^{t/\tau}). \tag{4}$$

If the radial distribution of T_i remains unchanged, the value of τ in (4) is given by

$$\tau = \frac{\tau_{Ei}}{1 + \frac{\gamma}{2}} . \tag{5}$$

Solution of the system of equations (3) and (5) with respect to the coefficient γ and the energy lifetime of the ions yields γ = 0.85, which does not differ from unity within the limits of the measurement error, and τ_{Ei} = 2 msec. In the calculations, we substituted in the equations the plasma parameters in the absence of HF heating, $T_{i0} = 10^6$ °K and $n = 1.15 \times 10^{13}$ cm^{-3}. The value τ = 2.5 msec was determined from diamagnetic measurements, as the growth time of the the increment of the ion energy content following HF heating to 70% of its maximum value. It should be noted that the total energy lifetime of the plasma in Joule heating, τ_E, is 1.5 msec under these conditions.

Thus, for the discharge parameters under consideration, the coefficient γ is equal to unity, pointing to a Coulomb mechanism of heat exchange between the electrons and ions in the plasma.

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[1] L.A. Artsimovich, A.V. Glukhov, and M.P. Petrov, ZhETF Pis. Red. 11, 449 (1970) [JETP Lett. 11, 304 (1970)].

[2] L.A. Artsimovich, E.P. Gorbunov, and M.P. Petrov, ibid. 12, 89 (1970) [12, 62 (1970)].

[3] N.V. Ivanov, I.A. Kovan, P.I. Kozlov, E.V. Los', V.S. Svishchev, and N.N. Shvindt, ibid. 16, 88 (1972) [16, 60 (1972)].