balance: $P_{ei}^{cal} + P_{RAD} > P_{OH}$. This discrepancy could be connected with several effects. The most probable of them will be discussed below. Firstly, some uncertainty in the energy balance follows directly from a non-perfect stationarity of $\bar{n}_e$ at sufficiently large gas puffing. However, a simple estimation of the term $\partial W_e/\partial t = \frac{3}{2}\,\partial(\bar{n}_e T_e)/\partial t$ shows that this effect is not substantial. Another cause could be connected with charge-exchange power losses P_{ex}. This loss channel is included in the term P_{ei}^{cal} but, on the other hand, the charge-exchange atoms are registered by the pyroelectric detector, i.e., they enter the P_{RAD} as well. However, as the radiative power losses measured spectroscopically [4, 5] in the same discharges correspond well to the raw output data from the pyrodetector, the charge-exchange plays probably an insignificant role in the power balance. In this way, the most probable cause of the discussed discrepancy seems to be a strong deviation of the real power P_{ei} from the calculated value P_{ei}^{cal} in this high density region. Therefore to fulfil the power balance at the highest densities, we determined the power P_{ei} as the difference between the OH-input and radiative losses. The observed decrease of the power P_{ei} transferred from electrons to ions with increasing density (fig.3) indicates an equilibration of the temperatures of both components.

2.2. A simple model of the high density discharge

As it was already emphasized above, we have not possibility of investigating the local energy balance of the electron component. Nevertheless, to understand and to demonstrate some local phenomena in more detail, especially at high densities, a simplified model of the energy balance of electrons is discussed below. The main aim is to correlate the radial profile of the electron temperature with the value of the measurable parameter $\phi = P_{RAD}/P_{OH}$.

The model assumes an OH power dissipation $p_{OH} = \sigma E^2$ predominantly in the central region of the plasma column and transport of this energy by a thermal conductivity towards the periphery, where it is lost by radiation of impurities ions P_{RAD}. The corresponding equation of the local energy balance for the power densities is the following:

(2) $$-r^{-1}\frac{\partial}{\partial r}\left(rK_e\, n_e(r)\frac{\partial T_e(r)}{\partial r}\right) = p_{OH}(r) - p_{RAD}(r)\,.$$

Supposing the termal conductivity K_e in the form (1), electron temperature profile $T_e(r) = T_e(0)\,\theta(r)$ and denoting $x = r/a$, eq. (2) can be rewritten in the normalized form:

(3) $$-x^{-1}\frac{\partial}{\partial x}\left(x\frac{\partial\theta(x)}{\partial x}\right) = p_{OH}^*(x) - p_{RAD}^*(x)\,,$$

where $p^* = pa^2/\gamma\, T_e(0)$ are the normalized power densities. The normalized OH power density can be expressed in the form $p_{OH}^*(x) = p_{OH}^*(0)\,\theta^{3/2}(x)$ (assuming E independent of minor radius r and using Spitzer conductivity formula $\sigma(x) \sim T_e^{3/2}(x)$).

Next we take, as an approximation of $T_e(r)$, a function $\theta(x)$ in the form $\theta(x) = \exp(-x^2/\Delta^2)$, which corresponds for $\Delta < 0{\cdot}8$ usually very well to the experiment and simultaneously permits us to find a simple analytic solution of the problem. Here Δ characterizes the relative "width" of the electron temperature radial profile. Introducing $\theta(x)$ into eq. (3), we determine $p_{OH}^*(0)$, supposing $p_{RAD}(0) \ll p_{OH}(0)$:

(4) $$p_{OH}^*(0) = \lim_{x\to 0}\left[-\frac{1}{x}\frac{\partial}{\partial x}\left(x\frac{\partial\theta}{\partial x}\right)\right] = \frac{4}{\Delta^2}\,.$$

Now, integrating eq. (3) over the plasma cross-section, we obtain

(5) $$-2\pi x\left.\frac{\partial\theta}{\partial x}\right|_{x=1} = P_{OH}^* - P_{RAD}^*\,,$$

where P_{OH}^* is the normalized OH power dissipated per unit length of the plasma column (the meaning of P_{RAD}^* is corresponding):

(6) $$P_{OH}^* = 2\pi\int_0^1 p_{OH}^*(0)\,\theta^{3/2}(x)\,x\,dx = \frac{8\pi}{3}\left\{1 - \exp\left(-\frac{3}{2\Delta^2}\right)\right\}.$$

The left-hand side of eq. (5) is the normalized thermal flux through the plasma boundary per unit length

(7) $$-2\pi x\left.\frac{\partial\theta}{\partial x}\right|_{x=1} = \frac{4\pi}{\Delta^2}\exp\left(-\frac{1}{\Delta^2}\right).$$

Combination of eqs. (5)–(7) gives the following relation between the width of the electron temperature profile Δ and the radiative parameter $\phi = P_{RAD}/P_{OH} = P_{RAD}^*/P_{OH}^*$:

(8) $$\phi = 1 - \frac{3}{2\Delta^2}\cdot\frac{e^{-1/\Delta^2}}{(1 - e^{-3/2\Delta^2})}\,.$$

This relation, shown in fig. 5, indicates a contraction of the $T_e(r)$ profile with an increase of the parameter ϕ. Qualitatively similar results have been obtained by a numerical calculation of the energy balance in papers [6, 7].

The peaking of the electron temperature profile is consequently followed by a current shrinking. Some experimental aspects of this phenomenon (the existence of a density limit, the onset of the disruptive instability, etc.) on the CASTOR tokamak are discussed in the next chapter.

3. CRITICAL DENSITY

It is well known that increase of the plasma density in a tokamak above some limit results in an instability [8]. In this section we discuss the results of a preliminary investigation of such high density regimes in which the discharge becomes unstable.

Fig. 6 presents the time evolution of the toroidal current, loop voltage, radiative