$$\tau_E = \frac{\frac{3}{2}\int_V (n_e T_e + n_i T_i)\,dv}{P_{OH} - \frac{3}{2}\frac{d}{dt}\int_V (n_e T_e + n_i T_i)\,dv}$$

Density scans were performed on JET at different B_t and I_p values. No clear dependence was found for the confinement of the inner plasma on I_p, in contrast with previous results [5]. The scaling of τ_E with density is shown in fig.4; τ_E appears to scale as $n_e^{0.6}$; uncertainties at higher densities (∿30%) are related to higher ion losses.

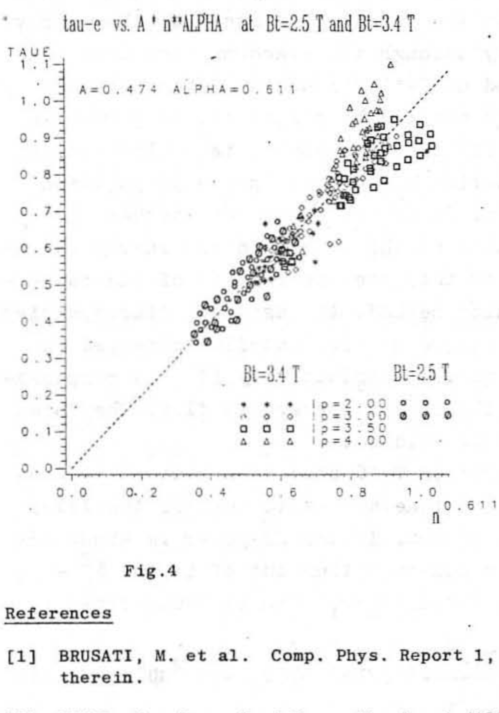

Fig.4

Summary

It is found that in JET ohmic plasmas, ion losses exceed neoclassical values and become dominant, at higher plasma currents, at lower electron densities than previously reported [6]. The total energy confinement time in the radiation free region of the plasma scales less than linearly with n_e, without saturation effects at higher densities. No clear dependence is observed as yet on plasma current and toroidal field.

References

[1] BRUSATI, M. et al. Comp. Phys. Report 1, (1981) 345 and references therein.

[2] TAMOR, S. Journal of Comp. Physics 1 (1981) 104.
GOLDSTON, R., TOWNER, H. Private communication.

[3] CHANG, C.S., HINTON, F.L. Phys. Fluids 25 (1985) 1493.

[4] CORDEY, G.G., STRINGER, T.E. To be published.

[5] EFTHIMION, P.C. et al. "Plasma Physics and Controlled Nuclear Fusion Research", London 1984, Vol.1, IAEA-CN-44/A-I-2 page 29.
EJIMA, S. Nucl. Fusion 22 (1982) 1627.

[6] GONDHALEKAR, A. et al. "Plasma Physics and Controlled Nuclear Fusion Research", Innsbruck 1978, Vol.1, IAEA-CN-37/C-4, page 199.

Study of Electron Heat Conductivity on T-10 by Propagation of a Heat Pulse from ECRH

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Usual method of determination of the local K_e^B from the energy balance is valid only in low density plasmas when the energy flux is transported largely through the electron (not ion) channel. The K_e^p-value estimated on T-10 /1/ and on other tokamaks by propagation of cooling wave excited by pellet is, as a rule, a few times higher than K_e^B. Similar discrepancy is registered in some experiments when measuring K_e^{ST} by heat pulse propagation from an internal disruption. It is not clear yet whether those discrepancies are the results of the errors in the energy balance component measurements or they are the results of plasma perturbation by such a "dynamic" method. At last, the discrepancies may indicate a complex structure of the heat flux observed in the Ohmic phase: the outward heat conductivity flux is compensated to a great extent, by the inward convective flux. The "heat injection" could destroy this balance.

The K_e^{EC}-value is measured on T-10 also by a heat pulse propagation from ECRH. This technique allows to control the level of perturbation of initial plasma. If the HF-power is absorbed in a narrow region near the ECR-zone then out of it the K_e^{EC}-value averaged through the layer (r_2-r_1) can be found from:

$$K_e^{EC} = 2.3\,\frac{(r_2-r_1)^2 \cdot n_e}{t_2-t_1}\cdot /\ln^{-2}\psi(t_2)-\ln^{-2}\psi(t_1)/, \quad (1)$$

where $\psi(t)=(r_2/r_1)^{0.6}\cdot\frac{\Delta T_e(r_2,t)}{\Delta T_e(r_1,t)}$. The T_e-increase, $\Delta T_e=T_e-T_{eOH}$, with ECRH was measured by the EC-radiometer at 4 radii simultaneously. The multidetector imaging system was also used. Additionally, both techniques were used to determine $K_e^{ST}=n_e(r_2-r_0)^2/8\Delta t$, ($r_0$ is the mixing radius, Δt is time of a heat pulse propagation from r_0 to r) /2/. Two regimes were chosen to study K_e^{EC}:

	I_p, kA	$\bar{n}_e$, cm^{-3}	B_t, T	q_L	K_e^B	K_e^{ST}	K_e^{EC}	
					10^{17} cm^{-1}s^{-1} ($r<a_L/2$)			
A	270÷290	2.10^{13}	3.15	4.3	2	0.8÷1.8	2	OH
					$2\sqrt{T_e/T_{eOH}}$	-	$2\sqrt{T_e/T_{eOH}}$	ECRH
B	170÷180	3.10^{13}	3.0	6.5	0.3÷0.5	0.3÷0.5	0.3	OH
					2	4÷5	drastic rise	ECRH

In A-regime /3/ the K_e^B-value has been shown to be equal to 2.10^{17} cm^{-1}s^{-1} in the Ohmic phase and to vary slightly with r. The results of measuring $\Delta T_e(r_j,t)/T_{eOH}(r_j)$ during ECRH with P_{HF}=360÷380 kW are given in Fig.1 (curves 1, the data are averaged over 5 discharges). Fig.2 shows the relative T_e-increase $\Psi^*=\Delta T_e(r_j,t)/\Delta T_e(r_k,t)$ for different pairs of r_j, r_k. The Ψ^*-value does not tend to zero at $t\to 0$, what is the result of a wide absorption layer. As

$$\frac{\Delta T_e(r_j)}{\Delta T_e(r_k)}\bigg|_{t\to 0} \approx \frac{Q(r_j)}{Q(r_k)} \cdot \frac{n_e(r_k)}{n_e(r_j)} ,$$

the profile of the specific HF-power, Q(r), can be determined from the data shown in Fig.2 and from the measurements of $dT_e/dt\,_{t\to 0}$ within the layer of the maximum deposit of HF-power (Fig.3). The Q-profile turns out to be too wide to allow the K_e^{EC}-calculation by (1), therefore the transport code was used to determine K_e^{EC}. The good agreement with the experimental results took place at $K_e^{EC}=2.10^{17}\sqrt{T_e/T_{eOH}}$ cm^{-1}s^{-1} (Fig.1, curves 2). Thus, the "dynamic" method gives in A-regime the K_e^{EC}-value which is close to K_e^B. In this regime, the radius r_0 of a region affected immediatly by an internal disruption was shown to be 2÷2.5 times larger than that predicted by heuristic theory of /4/. At larger radii a diffusive propagation of heat pulse takes place. However, too rough estimation of r_0 leads to an uncertainty in K_e^{ST}= (0.8 ÷ 1.8).10^{17} cm^{-1}s^{-1}.

In B-regime specified in /5/ and in the Table, K_e^B is equal to (0.3÷0.5)10^{17} cm^{-1}s^{-1} in plasma interior, $0<r<16$ cm. The X-ray detector signals given in Fig.4^a indicate that sawteeth can be well described by a diffusive propagation of heat within the region r=7÷10 cm (r_s=2.5 cm) in the Ohmic phase of this regime. The perturbation due to internal disruption is small and allow to measure K_e^{ST} which is shown to be equal to $(0.3\div 0.5)10^{17}\ cm^{-1} s^{-1}$ ($r=7\div 10$ cm). With ECRH the electron heat conductivity rises up to $(4\div 8)10^{17}\ cm^{-1}s^{-1}$ in a time not longer than 10 ms (Fig.4^a). The K_e^B-value close to K_e^{ST} was calculated at a steady state of ECRH. At ECRH start-up (Fig.4^b), an increase in a delay time and a rise in the slope of X-ray intensity signals with a distance from the ECR-zone were observed out of the power deposition zone. The simulation pointed out to possibility of appearance of the enhanced transport region which followed the wave front. The enhanced transport appears to be the result of a rise in ∇T_e (or ∇p_e).

Summary.

1. In the regime with high electron heat conductivity $K_e=2.10^{17}$ $cm^{-1}s^{-1}$, K_e^{EC} measured by a heat pulse propagation from ECRH coincides with K_e^B determined from the energy balance. That points to the diffusivity nature of the heat transport in this regime. An increase in K_e under ECRH can be described by the scaling $K_e \propto \sqrt{T_e}$.

2. In the low current regime with high n_e and low K_e /5/ ECRH leads to a steep rise of the electron heat transport. The enhanced transport is saved during the whole ECRH-pulse. The region of the enhanced transport follows the thermal wave front. A possible reason of the enhancement is an instability development due to a rise in ∇T_e (or in ∇p_e). Another reason can consist in that the heat flux directed toward the center can compensate, to a great extent, the heat conduction losses in the Ohmic phase, but this balance is broken when ∇T_e rises under ECRH.

3. Too large value of K_e^p determined by a cooling wave propagation from a pellet is, probably, explained by an extremely strong plasma perturbation by the injection.

References.

/1/. Andreev A.P. et al. Pis'ma JETPh. 10, 1199 (1984)

/2/. Soler M., Callen J.D. Nucl. Fusion. 19, 703 (1979)

/3/. Alikaev V.V. et al. In Plasma Phys. and Contr. Nucl. Fusion Res. 1984, IAEA, Vienna, 1985, v.1, p.419.

/4/. Kadomtsev B.B. Fizika Plasmy. 1, 710 (1975)

/5/. Alikaev V.V. et al. The paper presented to this Conference