1.2 The FTU facilities

1.2.1 FTU Machine

Summary of the machine operation

During 2004, the machine operated at the same high level (about 90% of successful pulses) as last year.

The experimental activity started at the beginning of February but, after two weeks, it was stopped for a leak in the scattering window. The consequence was a venting of the vacuum chamber and, of course, a restart of the conditioning procedures.

After three experimental days, the activities were stopped again for the mounting of CO_2 interferometer.

After summer holidays, there were two months experimental campaign to test devoted to the achievement of long duration of electron transport barriers (ETB). LH and EWCRH systems were used together both to heat the plasma and to drive the current. The program was successful.
Concerning the control and data acquisition system, last year we carried out the following activities:

1. Implementation of a new module in the plasma position control system to minimize the RF-LH reflection power by the FTU plasma.
2. Completion and testing of a tool to simulate and generate new control modules, by means of Simulink tool box of Matlab application.
3. Design and first implementation of a general restyling of FTU plasma density and position control system.
4. Implementation of a three nodes AFS cell by means of all OpenSource software: this can be a first approach to study OpenSource systems for ITER and/or IGNITOR.
5. Upgrading the FTU archive from 1 TeraBytes to 3 TeraBytes by means a new disk system, to satisfy the growing physics requests.
6. Completion and testing of a Video Conference Server (VRVS reflector) allowing the participation at seminars or meetings from desktop PC, without firewall restrictions.

On the whole 2004, 1936 shots were successfully completed, out of a total of 2172 performed in 89 experimental days. The average number of successful daily pulses was 21.75.
Table 1.I reports the main parameters for evaluating the efficiency of the experimental sessions.

Fig. 1.1 reports the source of downtime in 2004. First analysis of the experimental data was the greatest cause of delay with 26,5% of the total.

Fig. 1.2 reports the indicators trend from 1999 up to 2004. After last year fall the experimental days Indicator [I(ed)] shows a light recovery. Experimental time Indicator [I(et)] still shows a light decrease, this time due to an increase in analysis time.

Summary of Machine maintenance

The maintenance of the FTU systems was carried out according to the FTU equipment maintenance schedule. At the end of June and October, the visual inspection of the vacuum chamber was done. Only three old type broken tiles were found inside the vacuum chamber and it means that the new solution adopted for the installation of the tile into the support has been successfully.

Some problems with thiristors, at the beginning of the year, were solved and now more than 1000 shots have been performed without ruptures

New installations and changes

During the shutdown in the first part of the year the installation of the new CO_2 interferometer system for electron density measure was completed and successfully tested. This new diagnostics allows a measure at higher density than the old system and a better reconstruction of density radial profile, with good space and time resolution.

A new fast valve of was assembled on lower hybrid antenna for coupling studies.

Tab. 1I – Summary of FTU operations in 2004

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Total pulses	0	184	220	262	358	310	0	15	375	448	0	0	2172
Successful pulses (sp)	0	151	205	247	312	282	0	13	325	401	0	0	1936
I(sp)		0,82	0,93	0,94	0,87	0,91		0,87	0,87	0,90			0,89
Potential experimental days	0	14	11	11,5	15	14	1	1	17	17,5	0	0	102,0
Real experimental days	0	9	8	11,5	14	13	0	1	15	17,5	0	0	89,0
I(ed)		0,64	0,73	1,00	0,93	0,93		1,00	0,88	1,00			0,87
Experimental minutes	0	2683	3631	4787	6075	4875	0	192	6355	8286	0	0	36884
Delay minutes	0	2455	1418	2378	2787	2979	0	207	2764	2618	0	0	17606
I(et)		0,52	0,72	0,67	0,69	0,62		0,48	0,70	0,76			0,68
A(sp/d)		16,78	25,63	21,48	22,29	21,69		13,00	21,67	22,91			21,75
A(p/d)		20,44	27,50	22,78	25,57	23,85		15,00	25,00	25,60			24,40

DELAY FOR SYSTEM (minutes)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total	%
MACHINE	0	393	48	95	423	161	0	0	217	91	0	0	1428	8,
POWER SUPPLIES	0	552	205	289	477	665	0	0	410	386	0	0	2984	16,
RADIO FREQUENCY	0	13	217	474	220	634	0	0	143	310	0	0	2011	11,
CONTROL SYSTEM	0	260	256	206	320	261	0	35	310	208	0	0	1856	10,
DAS	0	204	5	183	55	23	0	24	237	182	0	0	913	5,
FEEDBACK	0	41	65	6	98	188	0	0	0	0	0	0	398	2,
NETWORK	0	0	0	0	0	92	0	0	401	0	0	0	493	2,
DIAGNOSTIC SYSTEMS	0	498	176	283	185	189	0	54	157	276	0	0	1818	10,
ANALYSIS	0	247	441	623	1001	633	0	0	717	995	0	0	4657	26,
OTHERS	0	247	5	219	8	133	0	94	172	170	0	0	1048	6,
TOTALE	0	2455	1418	2378	2787	2979	0	207	2764	2618	0	0	17606	10

Fig. 1.1 - FTU delay for system in 2004

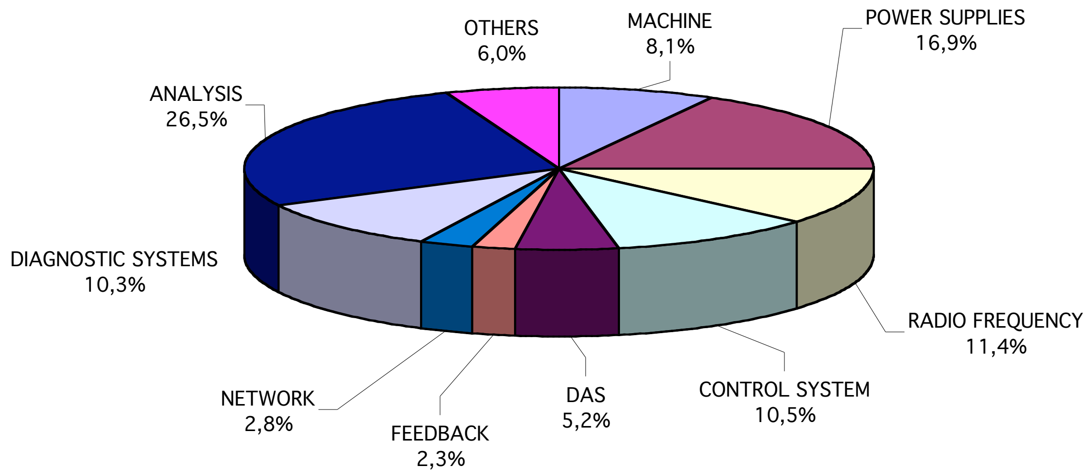
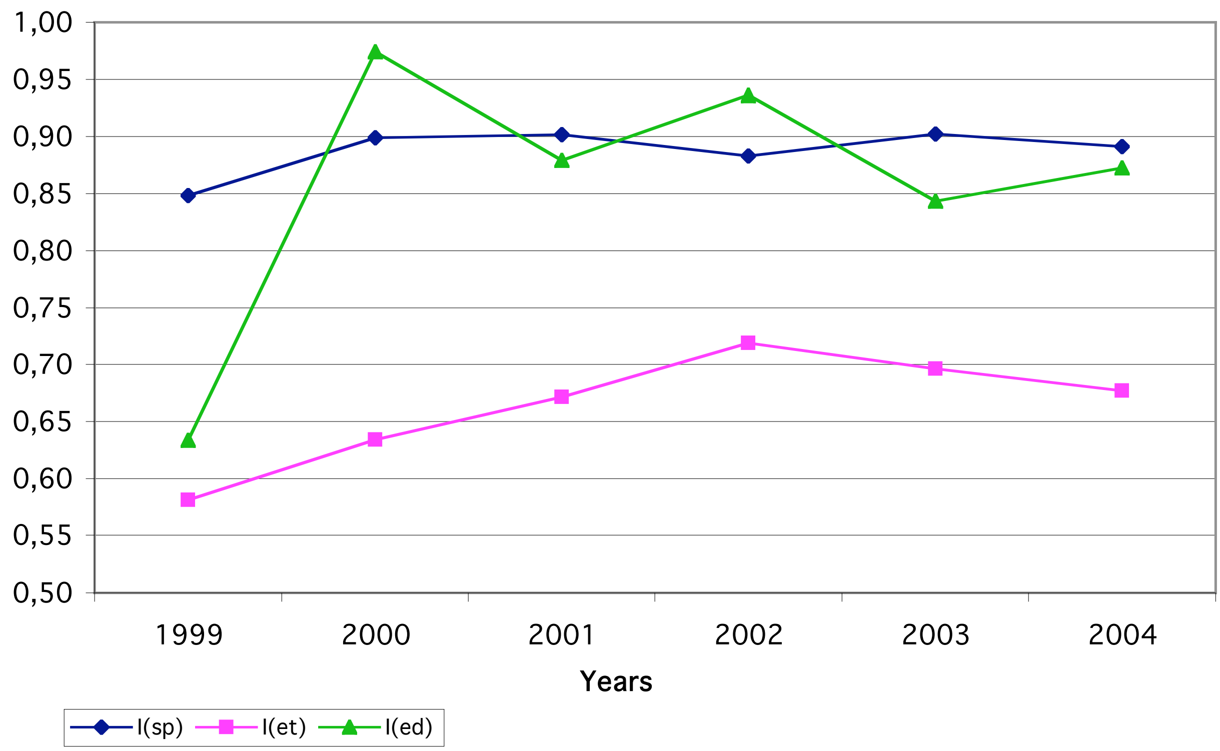


Fig. 1.2 - FTU Indicators trend



Future activities

Experiments on FTU with a liquid lithium limiter in CPS (Capillary Pore System) configuration.

The possibility of using liquid lithium as plasma facing component for the divertor target plates will be investigated on FTU employing an innovative solution [**1.1**]. It is based on the surface tension forces in capillary channels that may be used to compensate jxB forces induced in lithium. A high stability and resistance is foreseen for such a structure as well as an intrinsic property of the surface faced to the plasma to self-regenerate. The CPS limiter is realized as a matt from wire meshes of Stainless Steel 304 with pore radius 15 μm and wire diameter 30 μm. The liquid lithium flows inside these capillaries from one side of the system, which is in contact with a liquid lithium reservoir, to the other side that is faced to the plasma. FTU represents a very good opportunity to test for the first time this configuration called CPS (Capillary Porous System) in an ITER relevant experiment at the high plasma densities (up to 3.2×10^{20} m^{-3}), high currents (up to 1.6 MA) and high magnetic fields (up to 8 T) that are possible on FTU. The liquid lithium limiter will be used for the wall coating with a thin lithium film (named "litization") produced during a plasma discharge by a displacement of the LCMS (Last Closed Magnetic Surface) towards the lithium limiter. This experiment will allow to study important physical and technological issues such as: the wall conditioning efficiency of a lithium film to reduce plasma contamination and recycling; the lithium accumulation and distribution inside the plasma; the stability and resistance of CPS system in stationary regimes and during plasma disruptions, the liquid lithium erosion at tokamak conditions with high magnetic field and the thermal load reduction on the limiter due to the high latent heat of vaporization of lithium.

Accurate calculations have been performed to optimize the system configuration and to verify the feasibility of this system on FTU. This study, started by ENEA in collaboration with L.T. Calcoli, has been implemented by the Institute for Innovation and Fusion research in Troitsk (Moscow) together with the State Enterprise "Red Star" of Moscow, in the framework of one contract for the furniture of two lithium limiters for FTU. Thermal stress analysis in stationary as well as in transient conditions has shown that the ITER structural criteria limits for all the materials are satisfied. Furthermore electromagnetic calculations have shown that lithium is well confined in CPS structure also in presence of hard disruption (I_p=1.6 MA, B_T=8T) and that the contribution of electromagnetic forces to the total stresses is within the structural criteria limits [**1.2**]. Following these positive results, a prototype of lithium limiter has been developed and successfully tested in laboratory and the manufacturing of two lithium limiter sets is started. The installation and the first experimental tests on FTU are planned in the second half of 2005.

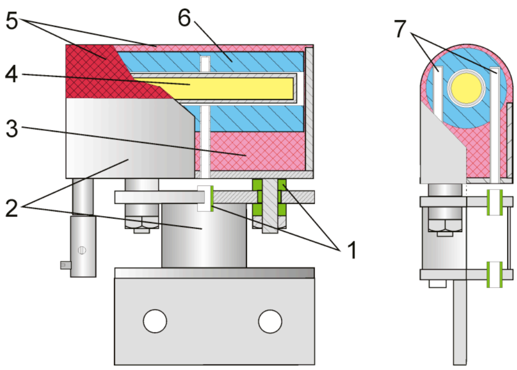


fig. 1.4

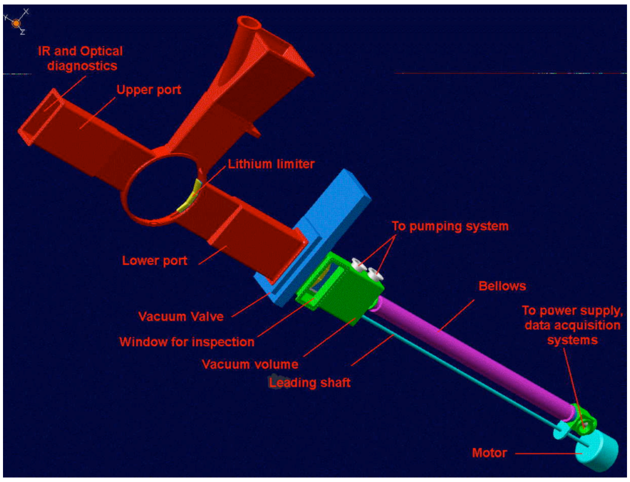


fig. 1.3

In **fig. 1.3** it is shown a general view of the FTU sector with a schematic drawing of the three units that compose the lithium limiter. The sections of these units are illustrated **in fig. 1.4**, where are indicated the main elements of the CPS structure: 1) a ceramic break for the electrical insulation of the unit from the common support panel, 2) a case with a cylindrical support, 3) the lithium filled capillary structure, 4) the heater, 5) the lithium evaporating surface, 6) the Mo heat accumulator 7) the seats for the installation of 2 thermocouples.

References

[**1.1**] V.A. Evtikhin, I.E. Lyublinski, A.V. Vertkov, S.V. Mirnov, V.B. Lazarev, N.P. Petrova, S.M. Sotnikov, A.P. Chernobai, B.I. Khripunov, V.B. Petrov, D.Yu Prokhorov and V.M. Korzhavin, Plasma Phys. Control. Fusion 44 (2002) 955-977.

[**1.2**] M.L. Apicella, G. Mazzitelli et al. paper presented to the 23rd Symposium on Fusion Technology 20-24 September 2004, (Venezia) Poster P4CF274