FTU Machine

Summary of the machine operation

The experimental campaign started at beginning of February but it stopped after three days for some problems to the criogenic and vacuum sistems. Then there were some problems with MFG3, so the experimental campaign started again around the middle of March, but it immediately stopped for a serious problem at MFG3.

A short circuit on rotor electrical bars was detected by visual inspection and electrical measurements. To repair it was necessary to extract the rotor from the stator: a very complex action performed by ANSALDO. Then it was possible to substitute the damaged parts and to reassembly the rotor in the Frascati site without moving it to the factory. At the same time a complete overhaul of the device was made to guarantee the full efficiency.

It should be pointed out the great effort and support given by ANSALDO that permitted to have on line MFG3 at the beginning of September, i.e. five months after the major accident.

The second campaign started in the middle of September and it was characterized by many events that prevented to have a good experimental campaign.

Last, but not the least, the second of December it was decided to stop the experimental campaign for a trouble to the cooling system that extended beyond the time of cooling. In order to overcome the cooling problems, the cryostat was opened to inspect the ducts and the filters of the cooling circuit. The cause of the slow cooling of the chamber modules was due to obstruction from “perlite”.

On the whole 2008, 449 shots were successfully completed, out of a total of 522 performed in 25.5 experimental days. The average number of successful daily pulses was 17.61. **Table 1.1** reports the summary data.

- Control and Data Acquisition System

  Regarding the Control and Data Acquisition System the following activities were carried out:

  - The control and data acquisition group went on proposing new solutions and enhancements to the existing systems. The new architecture of the general Data Acquisition System (to replace old CAMAC based systems) is in progress: a Compact PCI system has been bought and it will be used as a prototype, using the LabView development software. This system is made up of 128 analog inputs, 12 timers/counters and a Intel Core Duo CPU.

  - Other applications for a general use were implemented, using current software technologies: a new statistical and messaging system (hardware and software) was made to provide information in the FTU Control Room during the experiments and produce useful statistical data about the FTU availability.

  - Moreover a new MATLAB tool has been provided to display slow analog signals from the FTU plants, such as temperatures and vacuum measurements.

  - In the current experimental sessions the F coil anti-windup algorithm, designed to

suppress the current control instability appearing in the low regime of working, is still in debugging.

- In order to control the FTU plasma elongation using the V coil, a new algorithm has been implemented and will be under test according to the experimental session needs.

- Also in 2008 the participation to the ITER CODAC review process, as regards to the contribution to the formal documentation, has been assured.

- Web activity

  ENEA-Fusion website english version and revision, following Italian law and international directives about the site "accessibility", is nearly completed.

  A first simple solution of a Web file sharing facility (for documentation and organization purposes), usable also from external users, has been released.

  Under way a complete version of a Web file sharing facility with archive and data base functions.

- ITM Task Force Gateway

  The EFDA ITM Gateway Project started on October 2007 has been commissioned at the end of January 2008 allowing to access of restricted ISIP Users Group to install and configure ITM software tools composed of scientific libraries, public domain software and message passing middleware for parallel applications. It was carried out since the end of February 2008.

  The Gateway hardware resources, delivered at commissioning date, were composed of a Cluster of 16 HPC nodes in a multicore architecture with interconnection Infiniband based with achieved peak performance of ≈ 1 TFlops, 3 front-end nodes and ≈100 TB of shared and fast storage data area, including servers infrastructures, housed in ENEA CRESCO Data Center that have supplied all hosting services such as: 1Gbps WAN link, electrical and cooling systems and data backup service.

  The Gateway hardware final costs remained within budget of the Project (≈360 k€).

  The Gateway Hardware/Software resources were delivered to the ITM Users Group at beginning of March 2008 and standard operations started under the responsibility of Gateway Operation Steering Group supporting the Gateway User Board requests.

  The Gateway operations have provided a full scale support to ITM users that allows them to develop ITM software and data access facilities. Furthermore users accounts and software repository projects management tools were delivered as well as a ticketing trouble system to support users help desk.

  A number of ≈100 users accessed to the Gateway at the end of 2008 beginning to make compilation of their own codes and to test the ITM software tools with successful.

- Liquid Lithium Limiter

In the last two years the experiments performed on FTU, with a liquid lithium limiter, have got extremely positive results. The Capillary Porous System (CPS), proposed by the Russian colleagues, has demonstrated its capability to counteract the JXB force on the liquid lithium so that no droplets or strong influx of lithium were observed when the limiter was inserted in the SOL between 1 and 3 cm from the LCMS. New plasma regimes characterized by strong peaked electron density profiles were spontaneously obtained when the electron density raises over 1.10^{20} m^{-3}. In all the plasma current (.5-.7 MA) and electron density ranges ($0.15\text{-}3.010^{20}m^{-3}$) explored up to now on FTU, the plasma is extremely clean (Z_{eff} <1.5) and the only impurity detected by the VUV survey instruments is lithium also in discharges with additional heating up to 1.2 MW. Furthermore the liquid lithium limiter has withstand heat loads up to 5 MW/m^3 for hundred milliseconds. [1,2]

Also if the experiments and the theoretical explanations are ongoing, it is well assessed that plasma performance are consequence of a reduce recycling due to the pumping capability of the lithium and the low Z of lithium (Z=3) and, on the other hand, it is mandatory to go ahead in experiments to establish if a liquid surface could be used as plasma facing component.

The technological aspects for utilizing a metallic liquid divertor on FAST and/or the first wall of DEMO require new developments. First step is to built for FTU, a limiter able to act as main limiter and to demonstrate its capability to be cooled and refuelled during the plasma discharge. The proposal is to insert into FTU a wide panel (~60º in toroidal direction) in the bottom of the machine as illustrated in Fig. 1.1.
This proposal will be developed in two steps. In the first, the single base element of the panel will be tested on FTU. This element will be inserted on FTU utilizing the same mechanical structure built for the actual liquid lithium limiter but with the cooling and lithium refilling system tailored also for the second step. This first step is crucial for a positive assessment of the Capillary Porous System as possible plasma facing candidate for future devices. It will be very important, also in a single element system, to demonstrate that the cooling and the refuelling systems fit the requirements keeping the temperature in the right range and avoiding damages to the CPS structure by continuous lithium refuelling.

However the single element limiter can't act as main limiter, that will be possible only with the panel limiter, many single elements put together, that will be mounted on FTU if the tests on the single element will be positive. The main goal of the panel will be the proof of principle that a liquid metallic limiter is able to act as main limiter, i.e. the liquid lithium surface geometrically defines the last closed plasma magnetic surface.
In fig. 1.2 the new liquid lithium limiter is shown and in table 1.2 the main parameters are summarized.

The project for the single base element has been completed in this year and the next year should be implanted on FTU.

Parameter	**Value**
Initial lithium surface temperature	≥200ºC
Lithium surface temperature during plasma interaction	≤450-550ºC
Power of heat removal	up to 100 kW

Plasma interacting area	~ 100 cm^2
Lithium amount (volume/weight)	up to 70 cm^3 / 35 g
Element dimensions (L × H × W)	330 × 205 × 32 mm

Table 1.2 - Main parameters of the new liquid lithium limiter

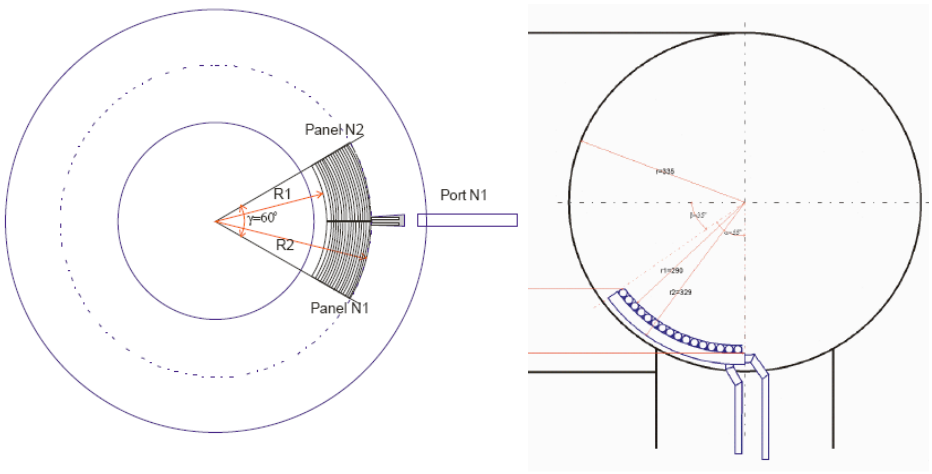

Fig 1.1 - Top view and cross section of the panel liquid limiter for FTU

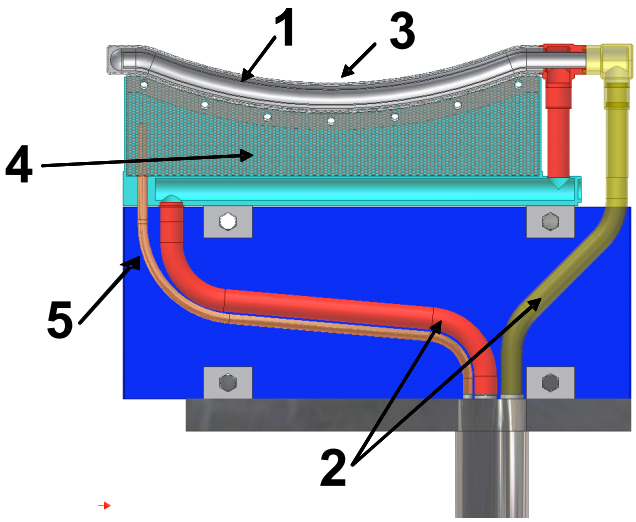

Fig. 1.2 - The new liquid lithium limiter; 1 Mo Single structural element - 2 Inlet and outlet liquid cooling system tubes - 3 CPS (Capillary Porous System) 4- Li reservoir 5- Li filling tube.

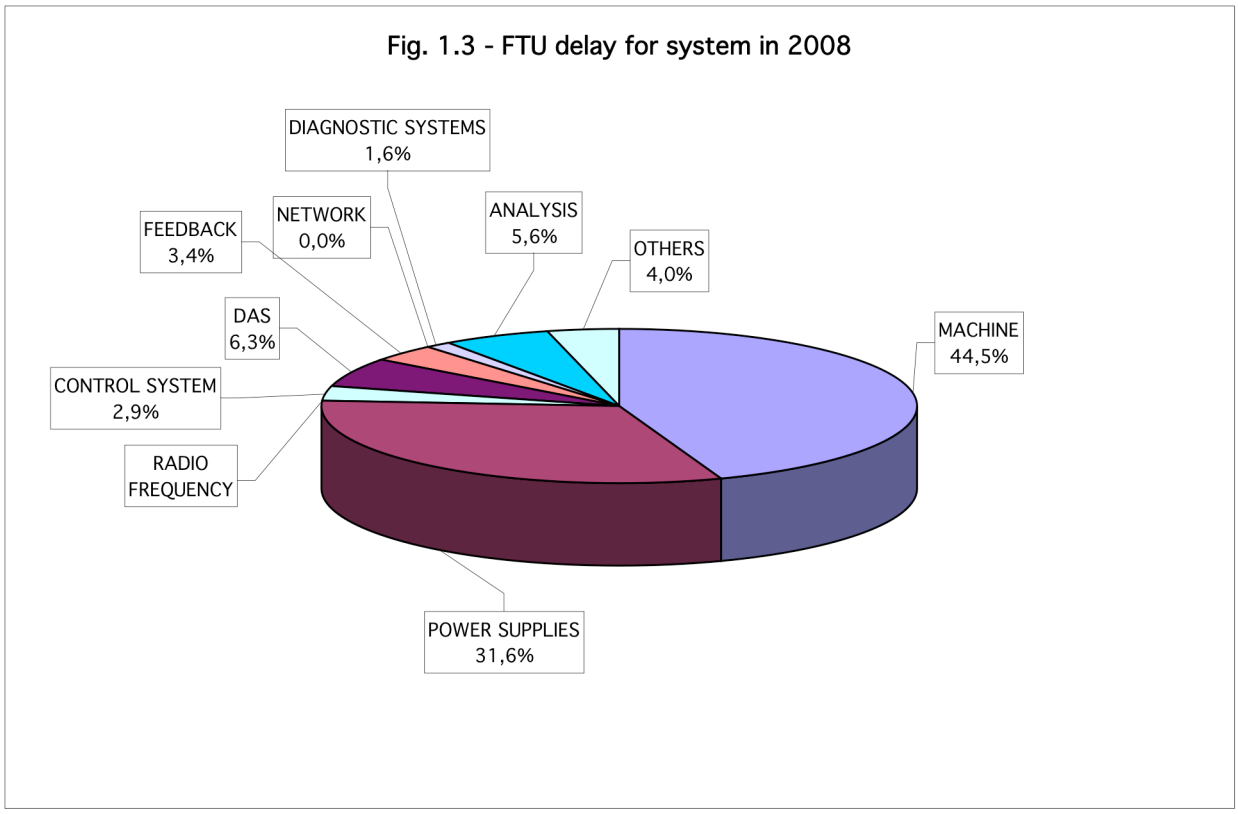

Fig. 1.3 - Source of downtime in 2008. Machine is the greatest cause of delay with 44,5% of the total.

[1] M.L. Apicella et. al. J. Nucl. Materials **363-365** (2007) 1346-1351

[2] MAZZITELLI, G., et al 2008 "Status and perspectives of the liquid material experiments in FTU and ISTTOK", *Proc. 22nd Int. Conf. on Fusion Energy 2008 (Geneva, Switzerland, October 2008)* (Vienna:IAEA) file EX-P4-6 http://www-naweb.iaea.org/napc/physics/FEC/FEC2008/html/index.htm