Alcator C-Mod Quarterly Review

Videoconference
November 10, 2004
Agenda

- FY04 PEA Summary
- FY05 Operations Schedule
- Engineering Status and Plans
- Lower Hybrid
1. Operate the facility for 19 weeks (+/- 10%) of single shift research (4 days/week, 8 hours/day). September 2004 ✔
   — JOULE Milestone: 18 weeks ✔
2. Compare confinement and H-Mode thresholds in single-null, double-null and inner-wall limited discharges. September 2004 ✔
   — JOULE Milestone: September 2004 ✔
3. Complete detailed design of advanced ICRF antenna. September 2004 ✔
   — JOULE Milestone: September 2004 ✔
4. Install first lower hybrid microwave launcher. September 2004 (Parker)
5. Operate to 2 MA plasma current. July 2004 ✔
6. Investigate the dependence of scrape-off layer flows on magnetic topology, and their influence on core rotation. May 2004 ✔
7. Test all-digital real-time control system. September 2004 ✔
8. Initial tests of ITER-prototype tungsten brush tiles. September 2004 ✔
9. Complete migration to linux computing environment for data acquisition and analysis. September 2004 ✔
### FY05 Operations Schedule

<table>
<thead>
<tr>
<th>ID</th>
<th>Task Name</th>
<th>Duration</th>
<th>Start</th>
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<td>Wed 1/19/05</td>
<td>Tue 2/1/05</td>
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<td>Thu 2/24/05</td>
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14 Weeks Research Operation
Alternate Schedule
(Latest Pumpdown with Vacuum Opening during Campaign)

<table>
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<th>ID</th>
<th>Task Name</th>
<th>Duration</th>
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<td>Thu 7/1/05</td>
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<td>Wed 8/24/05</td>
<td>Thu 9/15/05</td>
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14 Weeks Research Operation
C-Mod APS-DPP04 Presentations


• Invited
  – Wolfe: Non-axisymmetric field effects on Alcator C-Mod (Mon AM)
  – Grulke: Dynamics of spatiotemporal fluctuation structures in the scrape-off layer of C-Mod and NSTX (Mon AM)
  – LaBombard: Transport-driven scrape-off layer flows and the x-point dependence of the L-H power threshold in C-Mod (Tue AM)
  – Snipes: Active and passive fast particle driven Alfven eigenmodes in C-Mod (Thu AM)
  – Wukitch: ICRF mode conversion physics in C-Mod – measurements and model validation (Fri AM)
  – Bonoli: Full-wave electromagnetic field simulations in the Lower Hybrid Range of Frequencies (Fri AM)
• 9 contributed oral
• 21 contributed poster
Engineering Status and Plans

Presented by Jim Irby
for the C-Mod Group
Outline

- Introduction
- Boron Nitride to Moly Comparison
- Tungsten Brush Tiles
- Data System
- New Digital PCS
- Status of up-to-air work
- Plans
Introduction

• During the last quarterly review an extensive list of up-to-air activities was presented
• At this quarterly review I will update you on the progress of this work
• Primary task is still the installation of the lower hybrid launcher, which will be covered in detail in a separate presentation
• Comparison of plasma performance with boron nitride vs molybdenum tiles is a major research goal
• Plasma operation with ITER relevant W-Brush tiles is another important research goal
Measure plasma behavior with high-Z antenna guards and input power > 3.5 MW (FY05 level 1 target)

- Does boron nitride affect C-Mod performance?
  - BN antenna protection tiles have reduced rf induced discharges and injections at antenna surfaces
  - But BN is a soft porous material that is easily fractured and can spread dust throughout the machine
- During this up-to-air we have replaced all BN tiles with moly so that a direct test of performance can be made (FY05 Q1 target)
W-Brush Tiles (PEA #8)

- ITER relevant tile design capable of handling 25 MW/m²
- Tile modules will be installed in C-Mod at several toroidal locations in the outer divertor
- Working with Sandia, Albuquerque to test tiles
  - Initial tests complete, Sept 04
Data System Status

- The quantity of data taken per shot continues to grow exponentially and now exceeds 1.1 GByte per shot
- Much of the engineering data acquisition hardware is being replaced with CompactPCI digitizers
  - Hardware has arrived from the vendor
  - A server has been purchased to handle the data acquisition tasks
- We have created a set of web based tools for integrating and interrogating information from mini-proposals, run plans and summaries, shot logs and run comments from the electronic logbook.
  - These tools improve the efficiency of post-run analysis
  - They also allow campaign status information to be easily obtained
Digital Plasma Control System

• An all digital replacement for the existing analog/digital hybrid control system has been designed and implemented
• System configured with 128 inputs and 32 outputs has been extensively tested
  – Small upgrades to the hardware are being done by the vendor
  – We expect hardware back in-house this week
• This system will become fully operational during the next campaign
• Successful testing of this system completed FY04 PEA #7 (September 2004)
Status of Up-to-Air Work

Engineering Systems

• ICRF Systems
  – 4-strap antenna design complete (FY04 Q4 JOULE milestone)
  – All BN replaced with moly (FY05 Q1 JOULE milestone)
  – Improve tuning capability of FMIT#3 and FMIT#4 transmitters when operated at 50 MHz
  – Improvements to J-Port antenna voltage limits
  – Inspect, clean, refurbish all transmitters
  – Improvements to crowbar trigger circuits
  – Development of fast-ferrite-tuner prototype
  – Because of the untimely loss of Charley Schwartz
    • Moving to hire a new electrical engineer
    • PPPL has offered support
      – 0.6 FTE ICRF engineering
      – 0.2 FTE LH OPS
      – 0.2 FTE LH Tech support
• MIT Alternator
  – Add backup water cooling system for alternator to reduce down-time if primary system fails
  – Clean, inspect, refurbish all auxiliary systems
• Inspect, clean, refurbish hi-yard breakers
• Improvements made to bus instrumentation
• Upgrade to TF power supply gate drive boards
• Upgrade of PC to PLC interface software for engineering systems (power systems, cryo and vacuum)
• Installation of 8th non-axisymmetric control coil
• Upgrades to engineering data acquisition hardware (CPCI)
• Procurement and installation of brazing/sintering oven
• Power room air conditioning (MIT financed at $250,000)
• Long pulse DNB
  – Installation of breaker, contactor, and transformer
  – Control and power wiring ongoing
  – Installation of long pulse DNB in C-Mod cell

Bob Granetz and Dexter Beals obtained spectra from new beam during commissioning in Novosibirsk

Early stages of conditioning
Invessel/Vacuum

- Installation of massive gas puff
- Installation of cryopump baffles
- Clean and refurbish first wall moly tiles
  - New tile keeper hardware installed
  - Tiles returned to clean moly surface
- Clean and refurbish vacuum windows, shutters, etc
- Refurbish inner wall probes
- Install boron powder injector (particle size ~40 μm)
- Characterization of dust (> 2 μm) collected from first wall surfaces
Diagnostics

- Relocation of diagnostics to accommodate lower hybrid launcher
  - Mods to HIREX
  - Relocate lithium pellet injector
  - Relocate Hα, CII, and periscope from C-Hor
  - Relocate gas feeds
- Installation of inner wall retro-reflectors for polarimetry experiment (procurement and design complete)
- Refurbishment of bolometer array
- Refurbishment of 2π bolometer
- Addition of high resolution firewire based video systems to monitor ICRF antennas and lower hybrid launcher grill
- MSE invessel calibration
• Upgrade and refurbish two color interferometer (TCI) including new CO$_2$ laser
• Upgrade to PCI diagnostic including new CO$_2$ laser
• Upgrade to YAG Thomson scattering system including new integrators
• Installation of compact neutral particle analyzer (TCNPA)
  – Designed
  – Reviewed
  – Fabrication underway
• Installation of hard X-Ray camera (superthermal electrons)
  – Designed
  – Fabrication underway
• Driver/electronics for MHD antenna
Operations and Engineering Plans

• Up-to-Air
  – LH launcher installation
  – Installation of W-brush prototype tiles
  – Diagnostic set upgrades and invessel refurbishments
  – Massive gas puff at ITER-level high absolute pressures
    (in collaboration with D. Whyte, U. Wisc.)
• Install long pulse DNB December 2004
• Pumpdown mid January 2005
• Measure plasma behavior with high-Z antenna guards
• First plasma operation with lower hybrid power
Status of Lower Hybrid Launcher and Plans for Installation

Presented by Ron Parker
For the Lower Hybrid Engineering Group

Alcator C-Mod Quarterly Review

10 November 2004
The Launcher Consists of Three Main Components: Couplers and Front Waveguide and Rear Waveguide/Splitter Assemblies.

- **Couplers (4)**
- **Front Waveguide Assembly**
- **Rear Waveguide Assembly**

- Gold Seal
- Microwave Window
- Gaskets
- 3 dB Power Splitter
- E plane Transformer 22 to 5.5 mm
- H-plane Transformer 4.75 to 6 cm
Titanium couplers are copper plated to reduce $\text{H}_2$ takeup and release during plasma operation.

Half-wave thick $\text{Al}_2\text{O}_3$ windows are brazed into guides after plating.

Vacuum barrier provided by gold seal between coupler and vacuum flanges.

Stress on bolts maintained with sleeves to compensate for temperature excursions.
Forward and Rear waveguide assemblies are completed, power tested and ready for Installation.

A new tensioning mechanism has been designed and fabricated to increase the pressure on the RF gasket between the forward and rear waveguide assemblies. This is being installed this week. Power testing and phase calibrations will begin next week.

Windows have been brazed into three of the original PPPL couplers. Two couplers are vacuum tight, the third leaks. The vacuum leaks are due to the loss of plating in areas that were filed in fitting up the windows.

Repairing vacuum leaks with InCuSil braze that is vacuum-drawn into the gaps shows promise. This technique will be used in attempt to repair the 3rd coupler. The fallback position is to use the PPPL spare coupler (which is vacuum tight.)

The fourth coupler was copper-plated to prepare for brazing windows. The copper plating showed blistering in a 500 degree bakeout and was rejected. It is being stripped and replated, and will be available for brazing early next week.
Perfecting the Brazing Process Requires Extensive R&D

Many trials are required to develop a brazing process. Some issues are:

- Gap between window and titanium waveguides
- Type of braze, active vs. passive
- Preparation of windows and plating of titanium guides
- Coefficient of thermal expansion differential and minimizing braze temperature
- Other choices for ceramic
- Repair with lower temperature brazes

To minimize the turnaround time, a used oven suitable for brazing was purchased and installed at the PSFC. This has greatly shortened the time required to resolve these issues.

A reliable brazing process has been developed, but is still dependent on quality of copper plating on titanium waveguides.
Brazing Al₂O₃ Ceramic Windows into Titanium Waveguides

Required Special Procedures Due to Difference in CTE’s.

Stresses induced by cooling after braze reaches solidus temperature on cooldown induced cracks in outer windows

Problem was solved by thinning walls at end windows and brazing thin ceramic strip to outside of window
Copper plating the couplers before brazing has several advantages:

- Braze wets Cu surfaces better
- Eliminates uncertainty in quality of copper plating
- Poor plating can be removed and coupler can be replated without risk to coupler

There are issues with copper plating that are poorly understood and can impact the quality of the braze. But there is not sufficient time in the schedule to carry out the needed R&D to clarify the process.

We will continue with empirical approach in the expectation that an acceptable plating will be produced (as was done for the first two PPPL couplers.)
Upcoming Milestones for Launcher Installation

Grills 3 and 4 ready for installation in forward waveguide flange 12/07/04

Complete integrated power tests

  Upper half 12/07/04
  Lower half 12/16/04

Install Launcher in C-Mod Cell 01/06/05

Complete installation of new split limiter for launcher protection 12/31/04

Install Launcher in C-Mod 01/13/05

Pumpdown of C-Mod with installed launcher 01/19/05