Important Factors for FY10 Startup Planning

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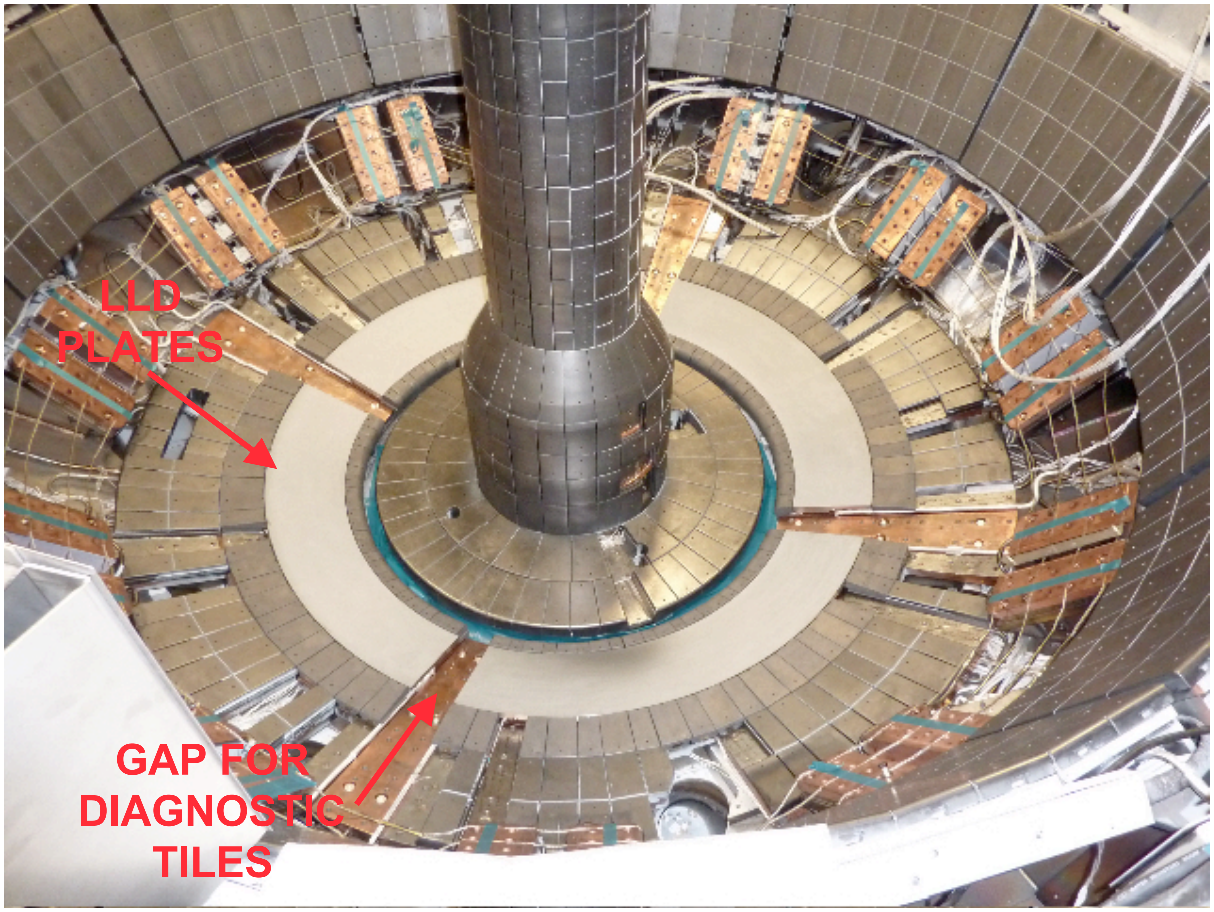
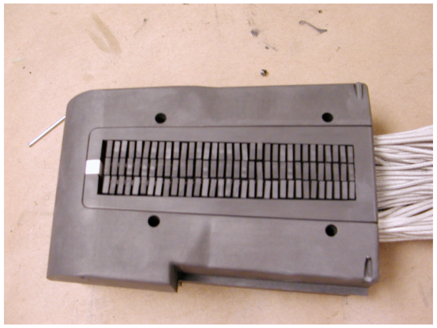
Nov. 20, 2009

LLD-1 Installation Proceeding on Schedule for FY10 Operation



4 LLD Plates Installed

Control Rack Installed



99 Probe LP Array

LLD-1 FY10 Test Plans

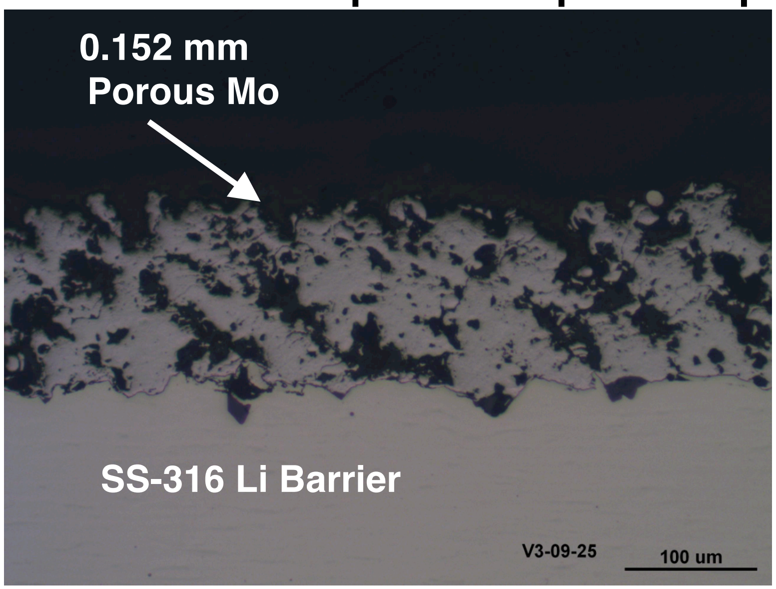
- Testing LLD-1 in air (room temp+10° for seconds) starts 11/23/09.
- LLD-1 will be tested in vacuum prior to Bake (350°C).
- Vessel Bake for 3 weeks is proposed (to minimize effect of no TMB).
- LLD-1 will be tested during Bakeout (360°C to avoid condensation).
- LLD-1 will be tested after Bake cooldown at initial op temp (205°C).
- LLD-1 will be tested during plasma ISTP at initial operation temp. (205°C).

Run Plan Should Avoid Damaging LLD-1 Porosity and Wetting Capability with TMB (BC_3^+) and Inert Depositions

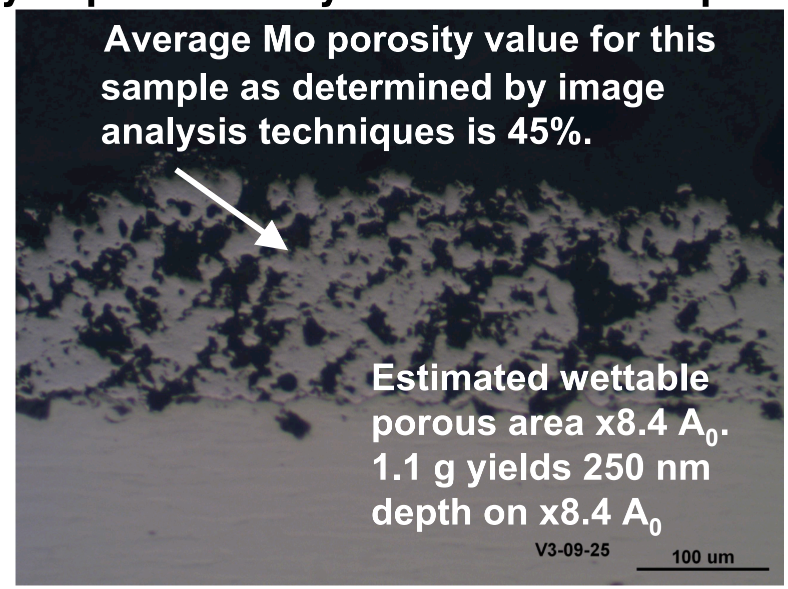
- **Key properties for an acceptable LLD-1 lithium surface**
  - **sufficient *surface tension* to hold Li in presence of JxB forces**
  - **ability of liquid Li to flow across metal surface (*wetting capability*)**
  - **minimize temperature rate of rise of Li -> rapid heat transfer to base**

> - Thin plasma sprayed porous Mo, on a thin SS-316 Li barrier, on thick Cu baseplate thermal sink is highest confidence initial approach

Cross sectional photos of plasma sprayed porous molybdenum LLD sample



Longitudinal

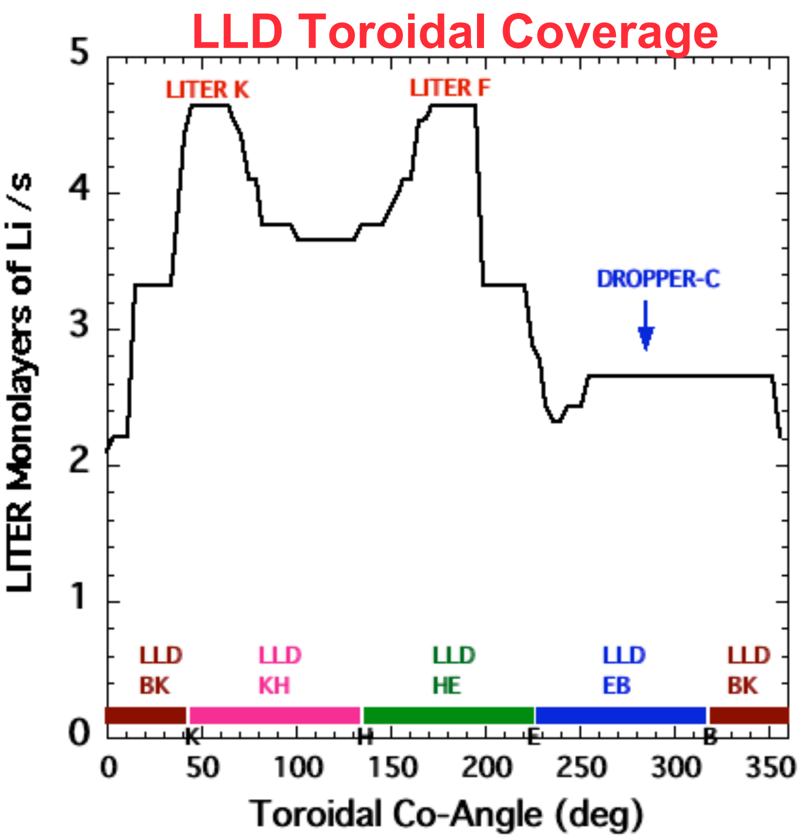


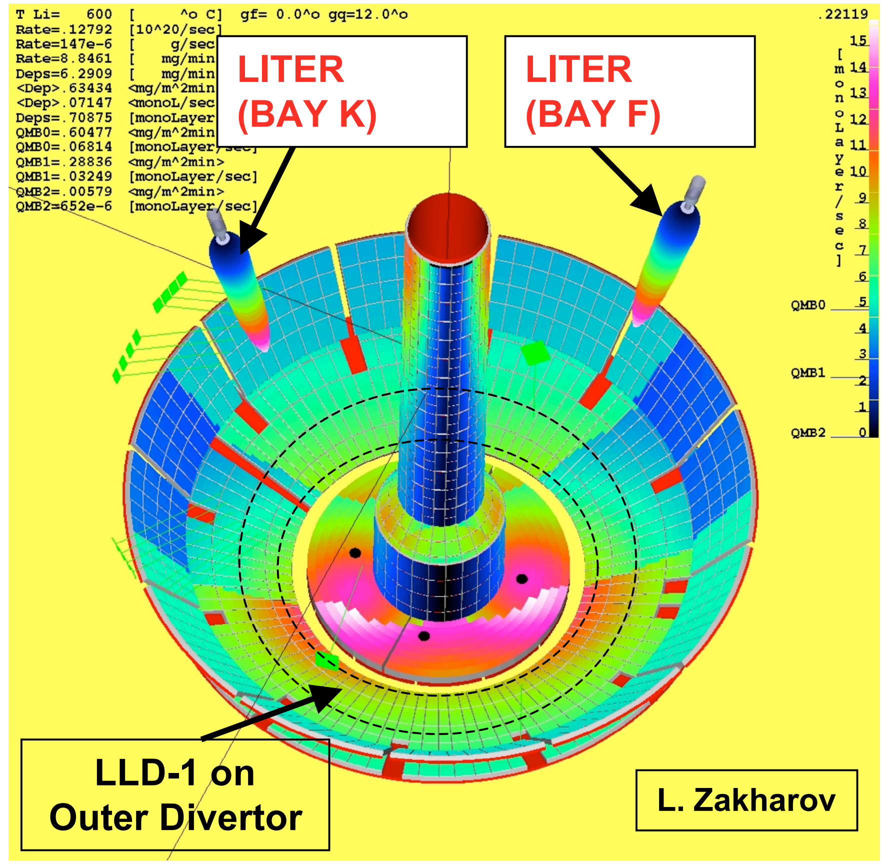
Transverse

- **37 gm lithium deposition required to fill available LLD-1 porous volume**

LLD-1 LITER Loading Has 7% Efficiency

- LLD-1 Li fill capacity is **37 g**
- LITER deposition amount to fill LID-1 is **530 g**

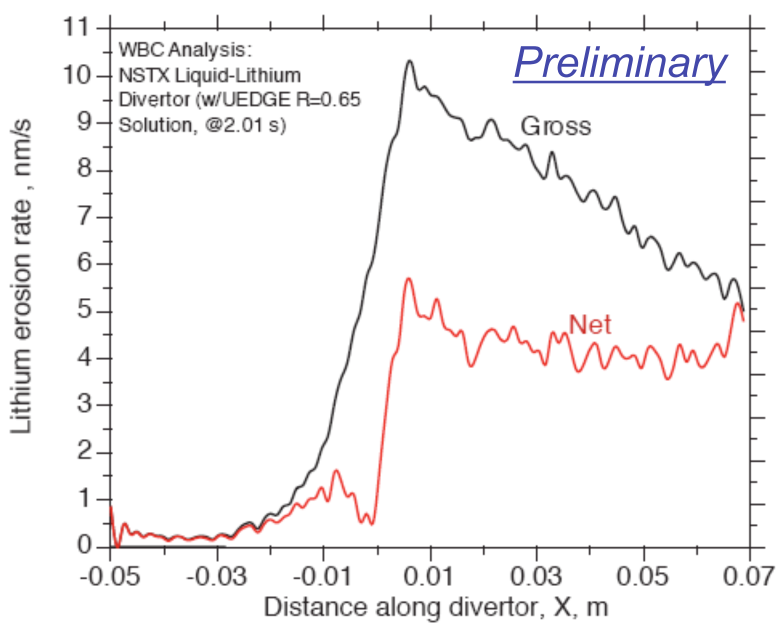




- The ability liquid Li to wet the porous Mo surface will spread the asymmetric LITER deposition.

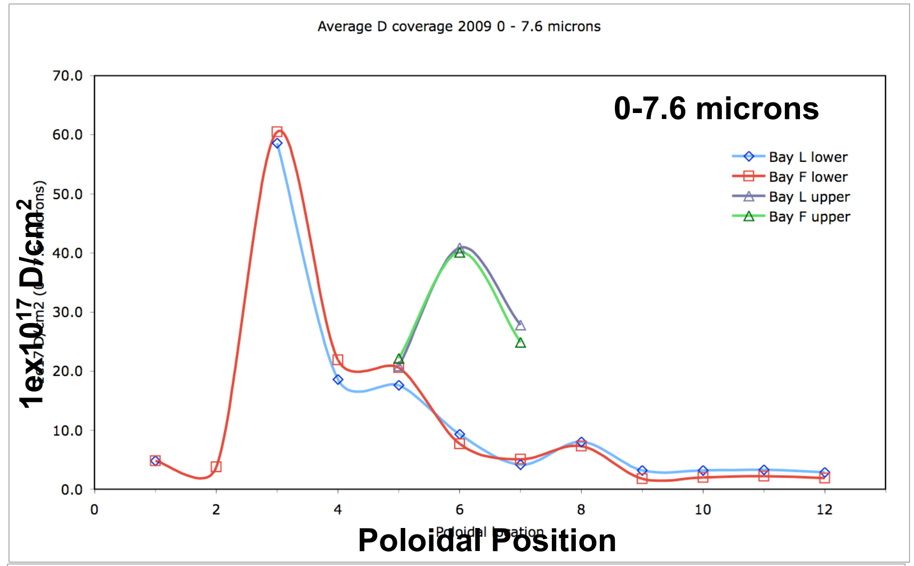
• Simulation Finds 50% of Li Sputtered from LLD Redeposited on Outer Divertor
• Ion Beam Analysis of NSTX 2009 Tiles Finds Li Redeposition on Outer Divertor

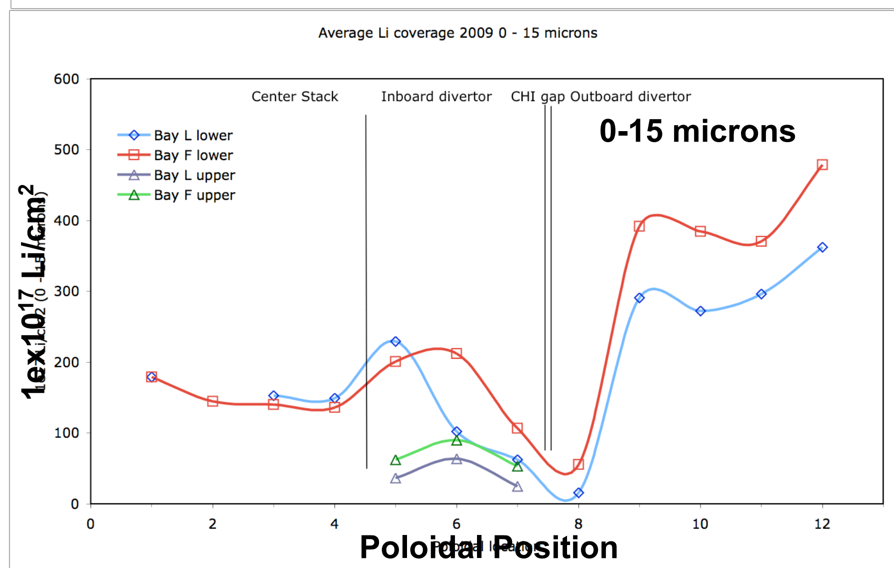
- 50.3% of sputtered (neutral) lithium is ionized within the computation zone (LLD and associated near-surface grid). 49.7% of sputtered lithium “escapes”.



Gross and Net Erosion Rate Along LLD

- J.N. Brooks, J.P. Allain, Purdue Univ, PFC Meeting 7/09



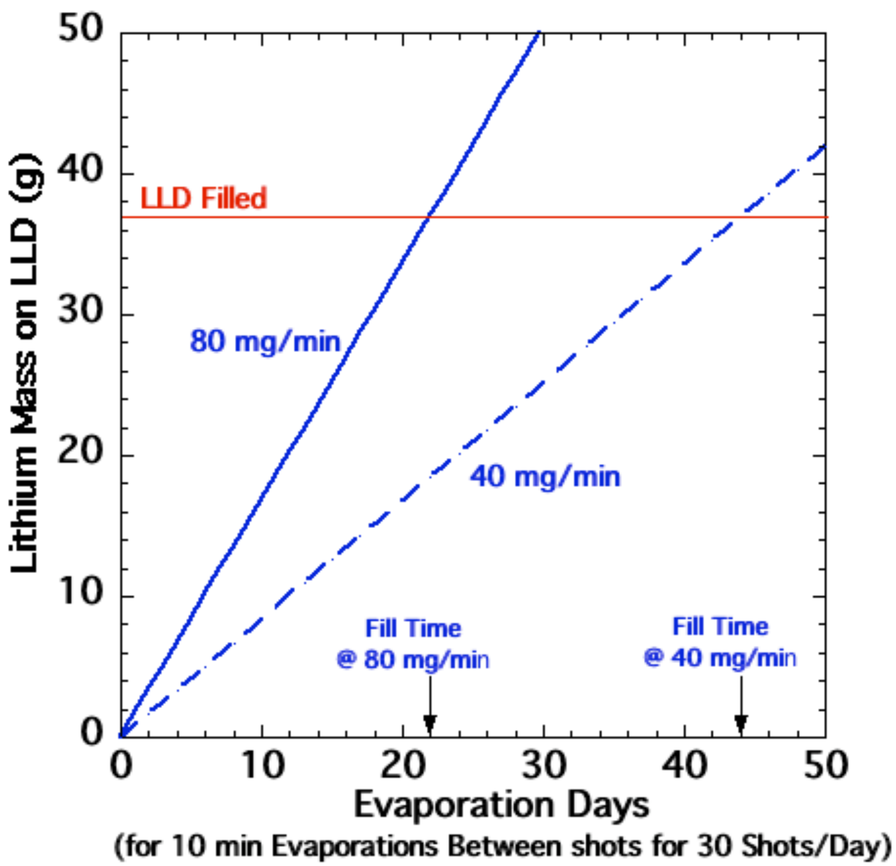


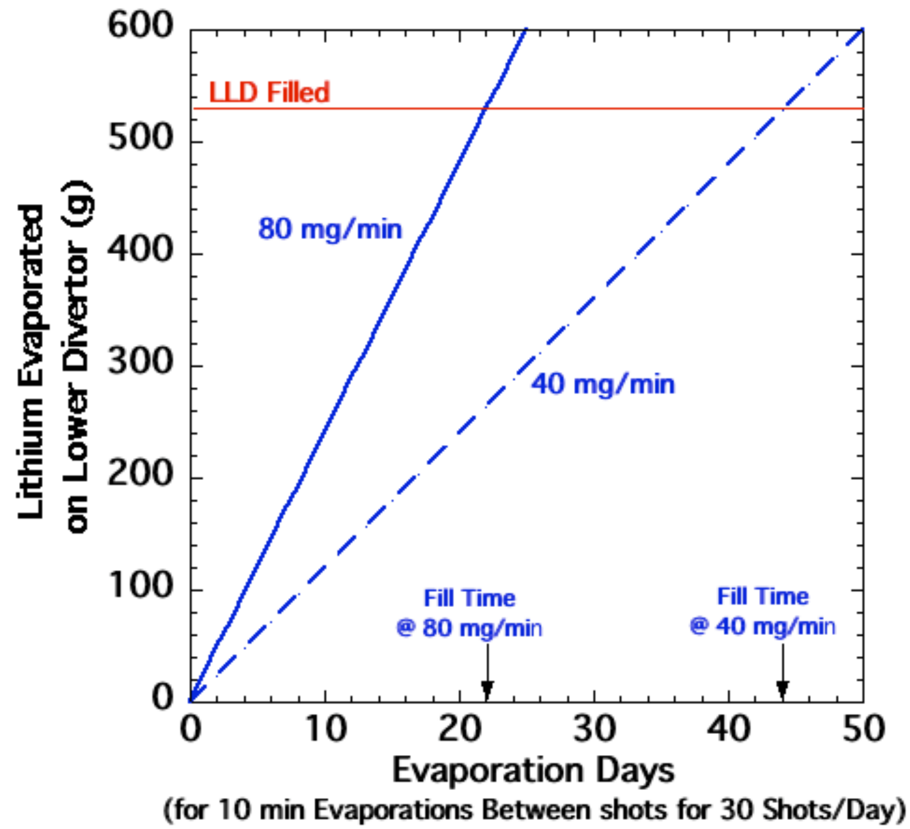
IBA of NSTX 2009 Tiles

- W. R. Wampler, SNL, 11/09

Scenario Using Between Shot Evaporations to Load LLD-1
• Evaporate for 10 mins Between Shots until LLD-1 Full

- Fast Fill Rate for Fully Loaded LLD Li Physics
  - 22 days to load @80mg/min (4.4 run wks, 530g)
- Intermediate Fill Rate - 44 days to load @40mg/min (8.8 run wks, 530g)
- Normal Fill Rate (Maintain Contact with 2008-2009 Li Database)
  - 88 days to load @20mg/min (17.6 run wks, 530g)



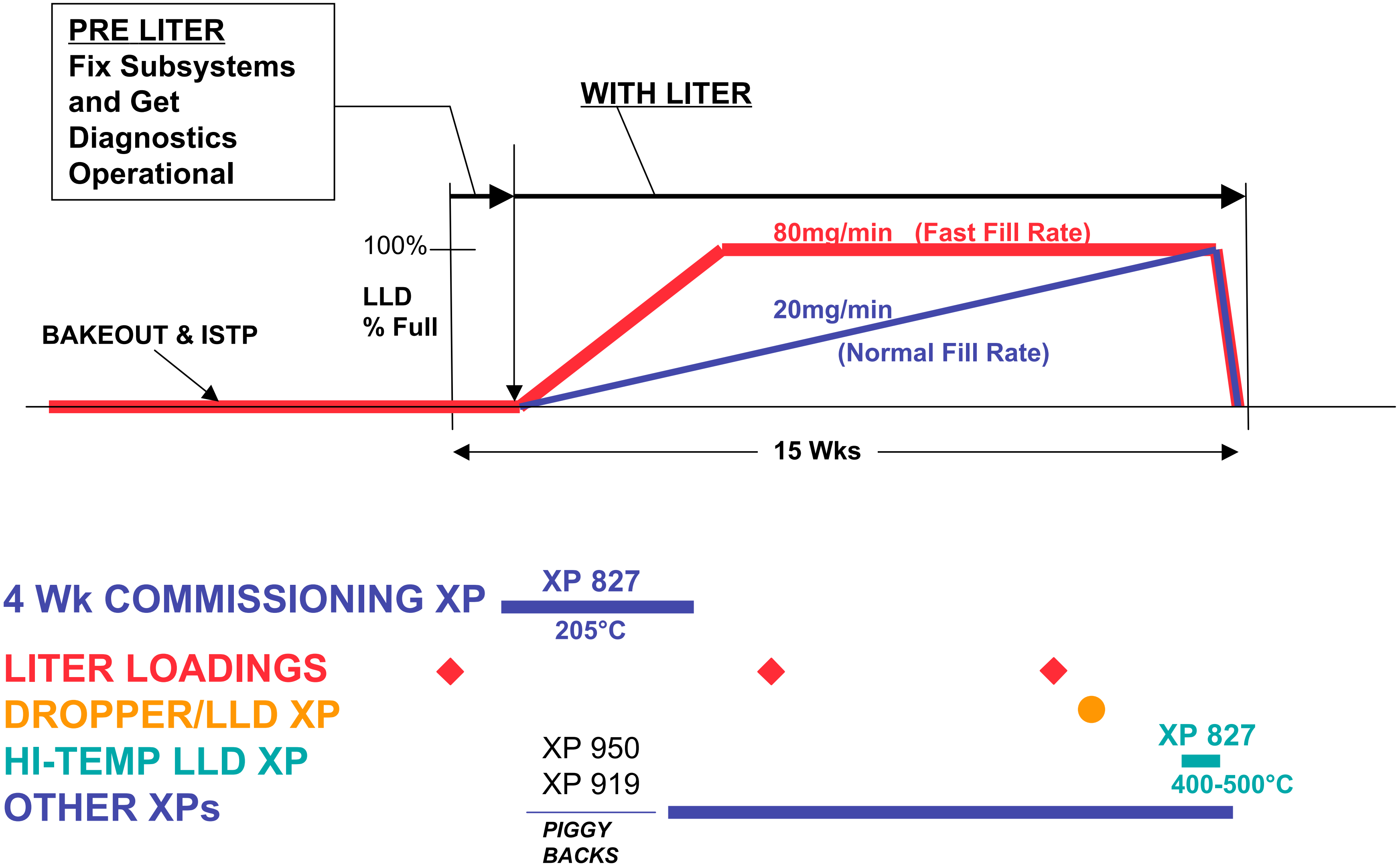


Key Issues: • Achieve First Plasmas Without Boronization • Minimize Duration to LLD Commissioning

- The probability of achieving successful LLD-1 results and the Milestone is maximized by minimizing the duration between first plasma and the start of lithium deposition (Commissioning)
  - No boronization *to hinder wetting*
  - Minimal GDC and Discharge sputtering *to hinder wetting*
  - Minimal thermal and MHD stresses *to hinder mechanical damage*

- Even a few, brief, Pre-lithium XPs requiring *research-grade* plasmas may require 3-6 weeks of conditioning before suitable NBI plasmas are obtained (No TMB; using only HeGDC). For example:
  - discharges to finish FY 2010 Joint research milestone using bake calibrations for the IR thermography. (Plan is to have 2-color IR ready, but availability at the beginning of the run is uncertain).
    - a few days of work before lithium, e.g. high delta discharges with drsep variation, high Ip, and Bt scan, some at constant q95.

In This Scenario, Pre Lithium Phase is Only Long Enough to Bring Up All Systems Required for Start of LLD Commissioning



Decision Tree: After Bakeout While Awaiting Subsystems and Diagnostics to Get Ready for Commissioning

- Assume LLD has passed the engineering ISTP (side 3), no TMB, try HeGDC

1) Aim for high triangularity ohmic D diverted plasmas ~ 1-2 days of fizzles.
2) If fizzles continue for 3nd day, try ohmic He diverted plasmas.
3) If fizzles continue consider more HeGDC
4) Check H/D and O/C of ohmic plasmas with VIPS2, SPRED, LOWEUS and XEUS.
5) Continue ohmic plasmas to see if impurities decrease.
6) As soon as suitable NBI target plasma achieved,
   start high triangularity NBI
7) If subsystems and diagnostics ready, start lithium deposition and LLD commissioning.

Planned LLD-Related External Startup Diagnostics

- **Visible Cameras**
  - **Phantom-V710, Bay-E, Top re-entrant window**
  - **Phantom-V7.3, Bay-J, Top re-entrant window**
- **IR Cameras**
  - **Fast IR Camera, Bay-H Top**
  - **Slow IR Camera, Bay-I Top**
  - **Slow IR Camera, Bay-G Bottom**
- **Lyman-α Diode Array**
- **Divertor Region Sample Probe**
- **3 Quartz Deposition Monitors**

Automated IR Camera Calibrated Temperature Waveforms Needed Between Discharges

Li thermal conductivity is low. (~ W/m-°K 400 Cu, 150 Mo, 45 Li, 15 SS)

- **Power Handling: SNL thermal analysis for cases with the strike point on the LLD with peak Li temperature set at 400 °C,**
  - **- can sustain a peak of ~2MW/m^2 for 10s and 4 MW/m^2 for ~3s.**
  - **- Less Li, higher heat transfer.**

- **Lithium evaporation from LLD is very high above 400°C and LiD starts decomposing. Need to monitor temperature profiles during NBI.**
  - **- LLD evap = LITER evap @ ~370°C**

- **Automated IR Camera calibrated temperature waveforms critical to monitoring LLD operation and benchmarking thermal simulations against initially short low, low power, NBI on LLD.**

Near Term Startup Events

- **Preliminary Test Procedure (PTP):** While vented, end-to-end controls, instrumentation, PLC, and EPICS testing using mild heating of the plates (5-10°C).

- **Integrated System Test Procedure (ISTP):** Starts after pumpdown.Redo the PTP under vacuum prior to bakeout, during bakeout, after bakeout, and during initiaol plasma operations.

- **Commissioning:** Under controlled discharge conditions, obtain preliminary LLD performance data to meet FY10 Milestone, and qualify LLD for use as an operational tool for the duration of the 2010 Experimental Campaign.

- **Milestone:** a Liquid Lithium Divertor (LLD) will be installed in FY2010, and the relationship between lithiated surface conditions and edge and core plasma conditions will be determined. To understand pumping, D retention will be studied as a function of surface conditions such as: Li coverage and LLD surface temperature, and plasma exhaust parameters such as: scrape-off layer density, temperature, strike-point location, and flux expansion.

Summary of Key Timeline for Discussion

- LLD tested in air before pumpdown (room temp+10°).
- LLD tested in vacuum prior to Bake (350°C).
- Bake for 3 weeks.
- LLD tested during Bake (360°C).
- LLD tested after cooldown at initial operation temperature (205°C).
- Important to start with clean LLD (unclogged porosity) to maximize wetting.
- No Boronization to clog LLD porosity.
- D and He Startup plasmas for ~1 week or until required subsystems online.
- Start Commissioning: Turn on LITER, start loading LLD, get Milestone data.
- All XPs scheduled so as to fit into the LLD loading plan.
- At end of run, raise LLD temp to 400-500°C to unload Li.