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XP LLD-1 Commissioning

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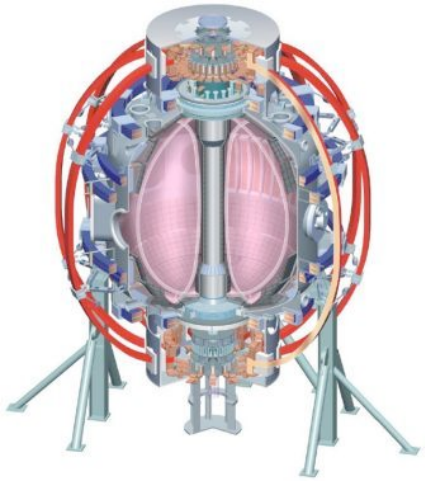
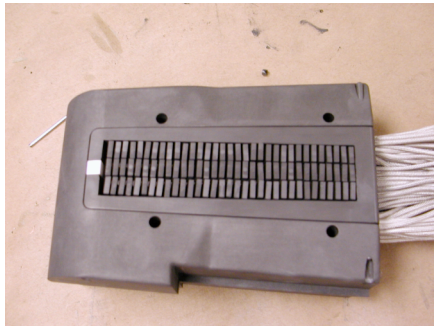
NSTX Research Forum
PPPL
December, 1-3, 2009



LLD-1 Installation Proceeding on Schedule for FY10 Operation

4 LLD-1 Plates Installed

LLD-1 Control Rack in NSTX Test Cell



99 Probe (3X33) Langmuir Probe Array

- Mo porosity provides ***surface tension*** to hold Li in presence of JxB forces.
- clean Mo allows liquid Li to flow across metal surface (***wetting capability***).
- initial operations are designed to minimize peak temperature of Li.

Diagnostic tools

• LLD-1 In Vessel Diagnostics

Listed CCW starting at Bay H

- GAP-H Tile
  - 5 magnetic sensors
  - 2 TC (in IR Camera FOV)
- GAP-E Tile
  - 2 BEAP bias electrodes
  - 2 TC (in IR Camera FOV)
  - 5 Langmuir Probes
- GAP-B Tile
  - 99 Langmuir Probes
    (33 sets of 3 toroidal rows)
    [triple (UIUC) and single LPs]
- GAP-K Tile
  - 2 BEAP bias electrodes
  - 5 Langmuir Probes
  - 2 TC (in IR Camera FOV)
- Halo Current Shunt Tiles
  - array of 12, one every 60°

• LLD-1 External Diagnostics

- IR Cameras
  - Fast IR Camera (downward FOV)
  - 2 Slow IR Cameras (upward and downward FOV)
- Fast Visible Cameras (Phantoms)
  - 2, 180° apart, reentrant, giving 360° downward FOV
- Lyman-α Diode Array
- Divertor Spectrometer
- Divertor Region PMI Probe
- 3 Quartz Deposition Monitors

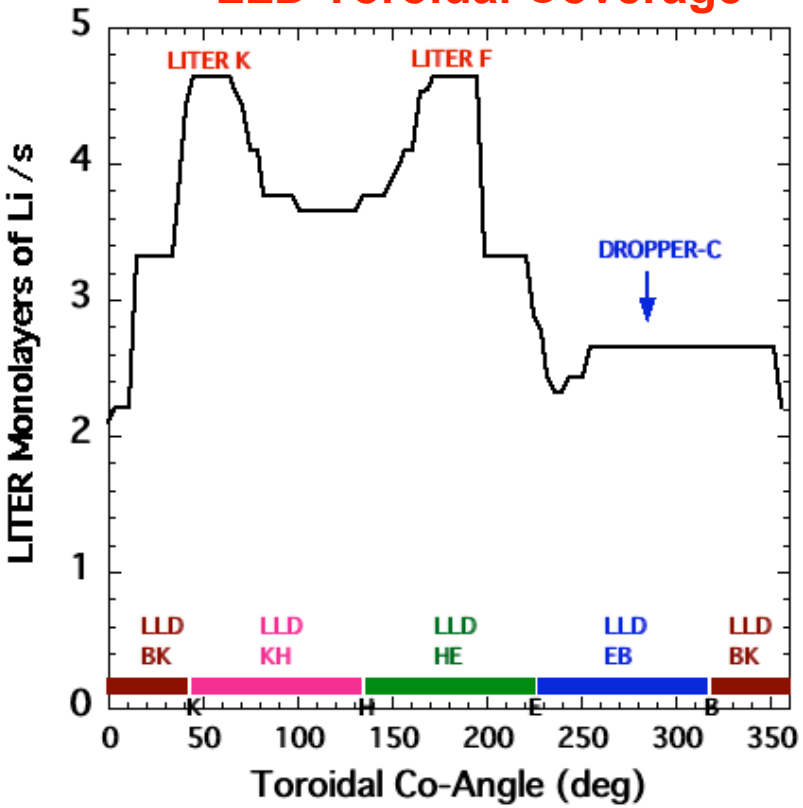
The LLD-1 Commissioning XP is for Initial Characterization, Qualification for Operation, and Achieving LLD Milestone

- **Purpose**
  - **Characterization**
    - Use XP827(09) to obtain initial LLD-1 performance data
  - **Qualification**
    - Qualify LLD-1 for use as an operational tool to support XPs for the duration of the 2010 Run
  - **Achieve LLD Milestone**
    - Install LLD-1
    - Determine the relationship between lithiated surface conditions and edge and core plasma conditions
    - Understand LLD-1 pumping, by a study of D retention as 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

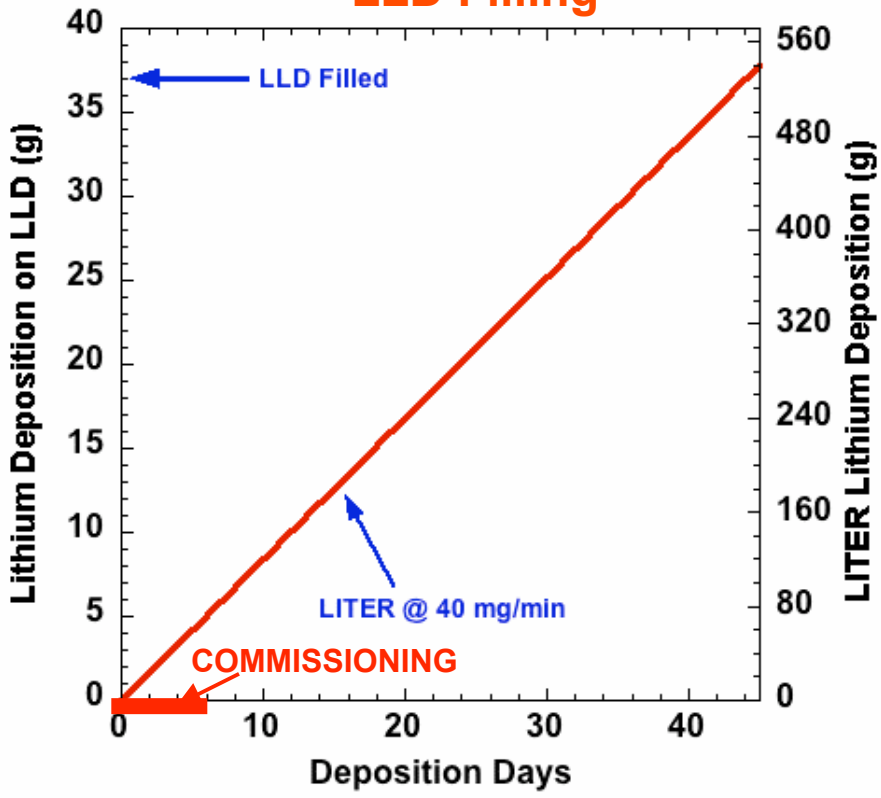
Lithium Needs to Liquefy on Surface, Fill Porosity, & Spread Using a Normal LITER Deposition Rate

- LITER deposition is asymmetric.
- Lithium needs to wet LLD-1 so surface tension can spread the coating.
- Initial lithium coating binds to carbon, oxygen, and impurity compounds to allow subsequent lithium deposition to become liquid.

LLD Toroidal Coverage



LLD Filling



Method and Required Run Time

- Day 0 [LLD 210°C]
  - Start LITER @40mg/min to provide wall conditions for first plasma
    - 10 hr evaporation, no plasma
- Day 1 [LLD room temperature ("cold")]
  - First plasma
  - Use XP-827(2009): High-δ, to Medium-δ discharges
  - LITER @40mg/min (sometimes no LITER for ref shot)
  - Test Outer Strike Point cases (HFS and SGI for 2, 4, 6 MW NBI):
    - Inner divertor: R=0.35m, R=0.50m (Open Field-line Pumping)
- Days 2-3 [LLD 210°C ("warm")]
  - Repeat Reference shots of Day-1.
  - Match $n_e(t)$ by fueling with both HFS & SGI as required.
  - Proceed to lower fueling for lower $n_e(t)$ using both HFS & SGI.
  - Power variation as needed to stay below beta limit.
    - inner divertor: R=0.35m, R=0.50m (Open Field-line Pumping)
- Day 4 [LLD 210°C ("warm")]
  - Select best fueling and LITER from Days #2 & #3
  - Slowly extend 2 MW NBI pulse length: 100ms, 150ms, ...
    - Outer Divertor: R=0.63m (on Bullnose tile next to LLD)
    - Outer Divertor: R=0.75m (On LLD: ohmic , 2 MW/50,100…ms)

Method and Required Run Time

- Day 5 [LLD room temperature ("cold")]
  - Repeat Day-4 Reference Shots
    - Outer Divertor: R=0.63m (on Bullnose tile next to LLD)
    - Outer Divertor: R=0.75m (On LLD: ohmic , 2 MW/50,100…ms)
- Day 6 [LLD 210°C]
  - LLD lithium maintenance
  - Need n_{Li} (0) measurement
    - Outer Divertor: R=0.75m (On LLD: ohmic , 2 MW/50,100…ms)
- Required Run Time
  - Start LITER to provide wall conditions for first plasma
  - Next, Commission LLD-1 for 6 full days starting from first plasma
  - Thereafter do 4 reference shots daily
    - 2 ref discharges at R=0.35m
    - 2 ref discharges at R=0.75m

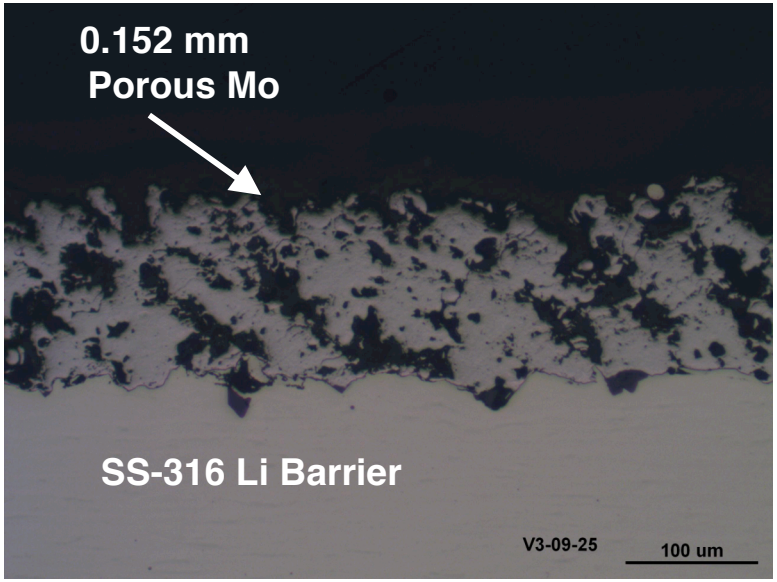
Backup

XP Plan Minimizes Possibility of Damaging LLD-1 Porosity and Wetting Capability with Inert Depositions

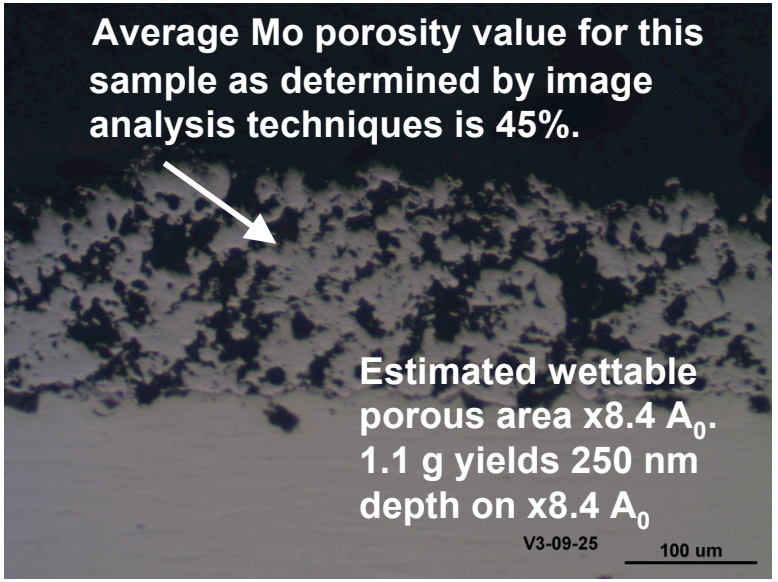
- **Key properties for an acceptable LLD-1 lithium surface**
  - **sufficient *surface tension* to hold Li in presence of JxB forces**
  - **ability of liquid Li to flow across metal surface (*wetting capability*)**
  - **minimize temperature rate of rise of Li ->rapid heat transfer to base**

LLD-1 Plates: 0.165 mm Mo plasma sprayed with 45% porosity on a 0.25 mm SS barrier brazed to 1.9 cm Cu 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**

Shot List for Day-0 (Coat LLD-1) and Day-1 (Reference Shots with Cold LLD-1)

DAY	State of LLD	Outer Strike Pt R (m)	LLD °C	LITER 20-40 mg/min	Li g Deposited	Fueling	Pnbi MW	No. of Shots
Coat LLD surface to facilitate wetting.								
0	warm		210	20-40	9.6-19.2			
Do Reference Shots.								
1	cold	0.35	Rm temp	NO/YES		HFS	4	2
							6	2
							2	2
						SGI	4	2
							6	2
							2	2
						HFS	4	2
		0.50					6	2
							2	2
						SGI	4	2
							6	2
							2	2

Shot List for Day-2 and Day-3 (Warm LLD-1)

1) Repeat Reference shots of Day-1.
2) Match $n_e(t)$ by fueling with both HFS & SGI as required.
3) Proceed to lower fueling for lower ne(t) using both HFS & SGI.
4) Power variation as needed to stay below beta limit.

DAY	State of LLD	Outer Strike Pt R (m)	LLD °C	LITER 20-40 mg/min	Li g Deposited	Fueling	Pnbi MW	No. of Shots
2-3	warm	0.35	210	NO/YES		HFS	4	2
							6	2
							2	2
						SGI	4	2
							6	2
							2	2
		0.50				HFS	4	2
							6	2
							2	2
						SGI	4	2
							6	2
							2	2

Shot List for Day-4 (on Warm LLD-1)

1) Select best fueling and LITER from Days #2 & #3

2) Slowly extend 2MW NBI pulse length: 100ms, 150ms, ...

DAY	State of LLD	Outer Strike Pt. R (m)	LLD °C	LITER 20mg/min	Li g Deposited	Fueling	Pnbi MW	Pulse ms	No. of Shots
4	warm	0.63	210	NO/YES			2	100	2
		0.63					2	100	2
		0.75>0.63					2	100	2
		0.75>0.63					2	100	2
		0.75					2	100	2
							2	100	2
							2	150	2
							2	150	2
							2	200	2
							2	200	2
							2	250	2
							2	250	2

Shot List for Day-5 and-6 (on LLD-1)

Repeat Day-4 Reference Shots

DAY	State of LLD	Outer Strike Pt R (m)	LLD °C	LITER 20-40 mg/min	Li g Deposited	Fueling	Pnbi MW	No. of Shots
5	cold	0.63	Rm temp	NO/YES			2	2
							2	2
							2	2
							2	2
							2	2
							2	2
		0.75					2	2
							2	2
							2	2
							2	2
							2	2
							2	2

1) LLD lithium maintenance.
2) Need nLi (0) measurement.

DAY	State of LLD	Outer Strike Pt R (m)	LLD °C	LITER 20-40 mg/min	Li g Deposited	Fueling	Pnbi MW	No. of Shots
6	warm	0.75	210	NO/YES			2	2
							2	2
							2	2
							2	2
							2	2
							2	2
							2	2
							2	2
							2	2