Plans for Liquid Lithium Experiments in CDX-U

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Outline

- Introduction
- CDX-U
- The UCSD “point” limiter
- A liquid lithium “belt” limiter
- Diagnostics
- Issues
- Schedule
- Summary

Introduction

- Liquid metal walls and divertors have been identified as a potentially revolutionary solution to the plasma-wall interaction problem.
- Revolutions are seldom bloodless.
  - Someone has to fire the first shot.
  - We all know what often happens to the one who “volunteers” to lead a charge.
- No large fusion device is likely to venture into a full liquid metal divertor or wall without tests on a smaller scale device.
  - Even the ST program, which has an acute need for high heat load divertor/wall systems, is not likely to conduct a first test of liquid metals at the NSTX scale.
- As an intermediate step, the CDX-U program has now been given over *entirely* to the testing of liquid metal limiter, divertor and wall concepts.

PPPL
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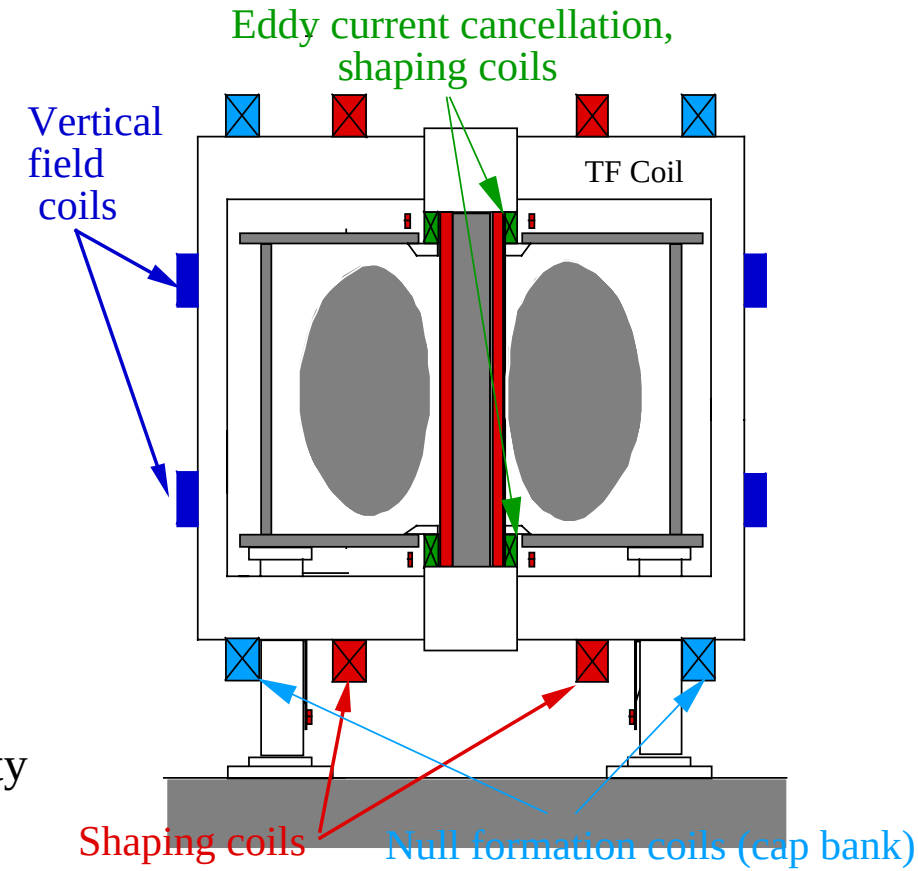
CDX-U parameters

- R_0 = 34 cm
- a = 22 cm
- $A \equiv R_0/a \geq 1.5$
- $\kappa \leq 2$
- $\delta > 0.2$
- $B_t \leq 0.23$ Tesla (present)
  upgrade: ≤ 0.45 T (~0.5 sec)
  - CW fields at 1 kG
- Ohmic $I_p \leq 150$ kA
- $P_{auxilliary} \leq 300$ kW (rf)
  - Significant upgrade capability
- Discharge duration: 20-40 msec
  - Upgrades under investigation

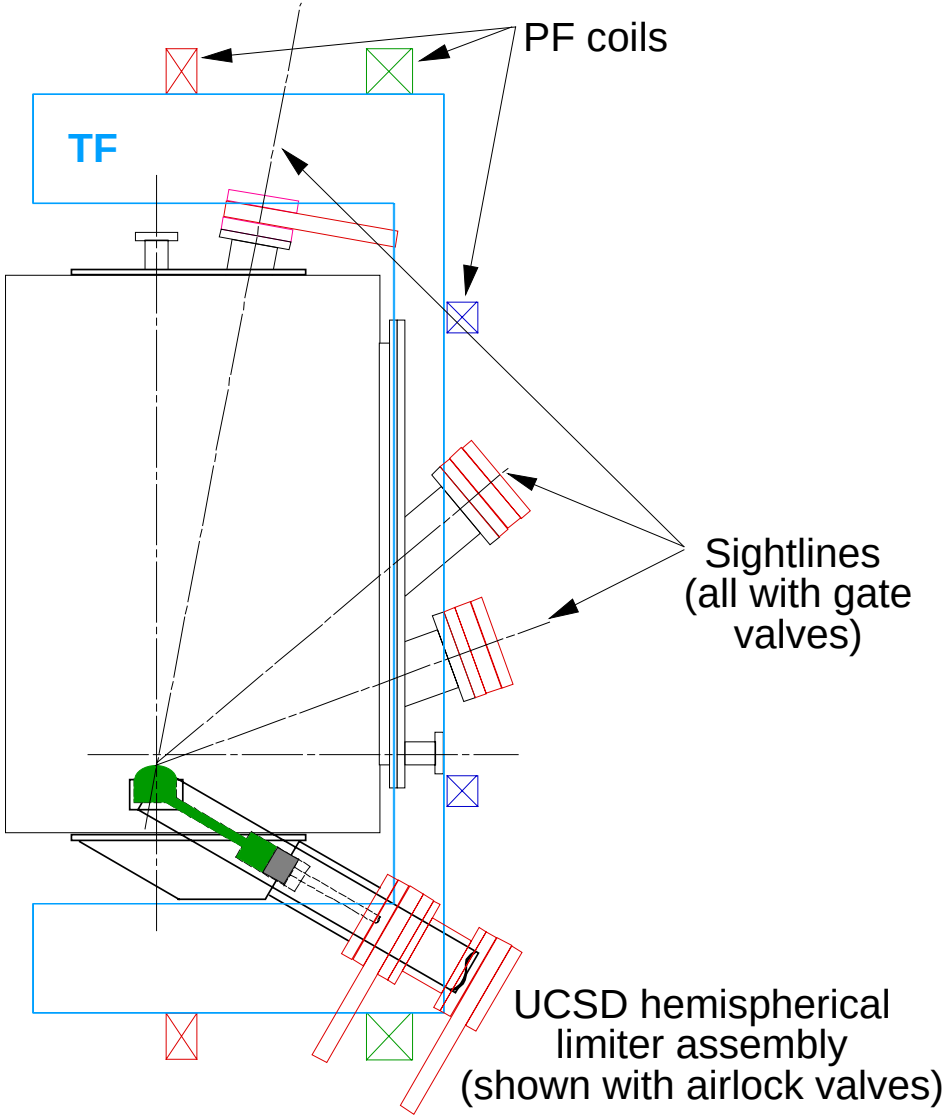


Programmable 12ϕ power supplies for preprogramming, possible feedback control

UCSD removable limiter

- First lithium system scheduled to be tested is a heated hemispherical lithium limiter system now under design at UCSD.
  - Primary limiting surface for the discharge.
  - Preliminary design calls for a ~6 cm diameter lithium hemisphere.
  - Lithium crucible will be temperature controlled.
  - Lithium will be fed from a reservoir in the “probe” assembly.
- The porting on one toroidal sector of CDX-U will be reworked to accommodate the liquid lithium limiter (“L3”) and the associated diagnostics.
- Design can accommodate an airlock (dual gate valve) to minimize lithium contamination, if necessary.
- Preliminary schedule: installation in February.

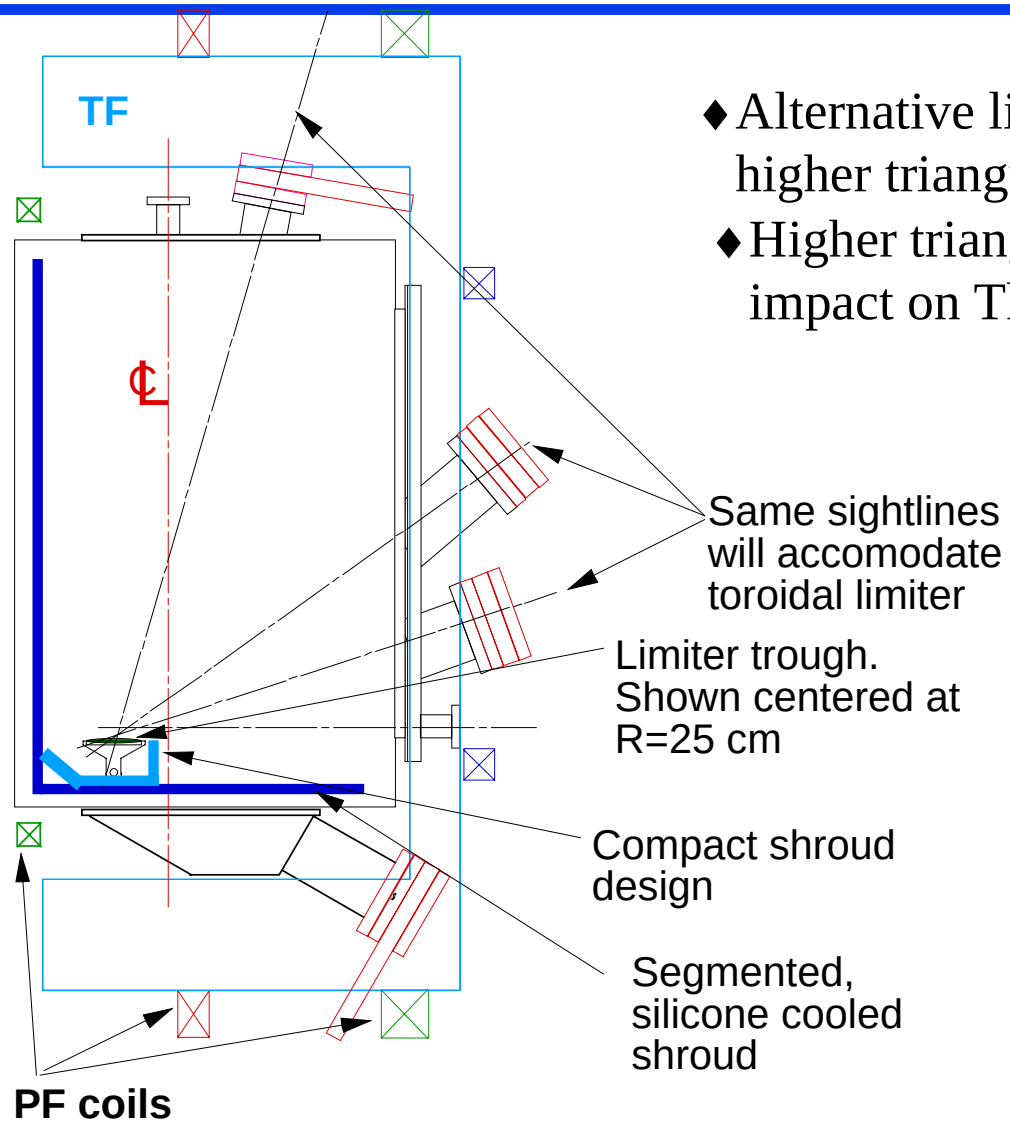
Preliminary layout of the hemispherical lithium limiter



Full toroidal lithium limiter target will be installed following the L3 experiments

- Preliminary design calls for a 10 cm wide x ~1 cm deep lithium pool.
  - Heated (T<500 ^{o}C) trough with provision for a removable liner.
  - Silicone cooled shroud will protect the center stack, lower vacuum vessel.
  - Lithium will be loaded into the trough under argon, evacuated, and melted.
- Removable liner will permit subsequent installation of insulated systems with various electrode arrangements to test the effects of MHD-induced mixing.
  - Sequential testing of several trough designs is feasible.
- Possible coexistence of the trough and L3 requires further study.
  - Primary issue: flexibility of the PF system.
- Preliminary installation schedule calls for initial operation in late spring.

Alternative toroidal limiter design is under study

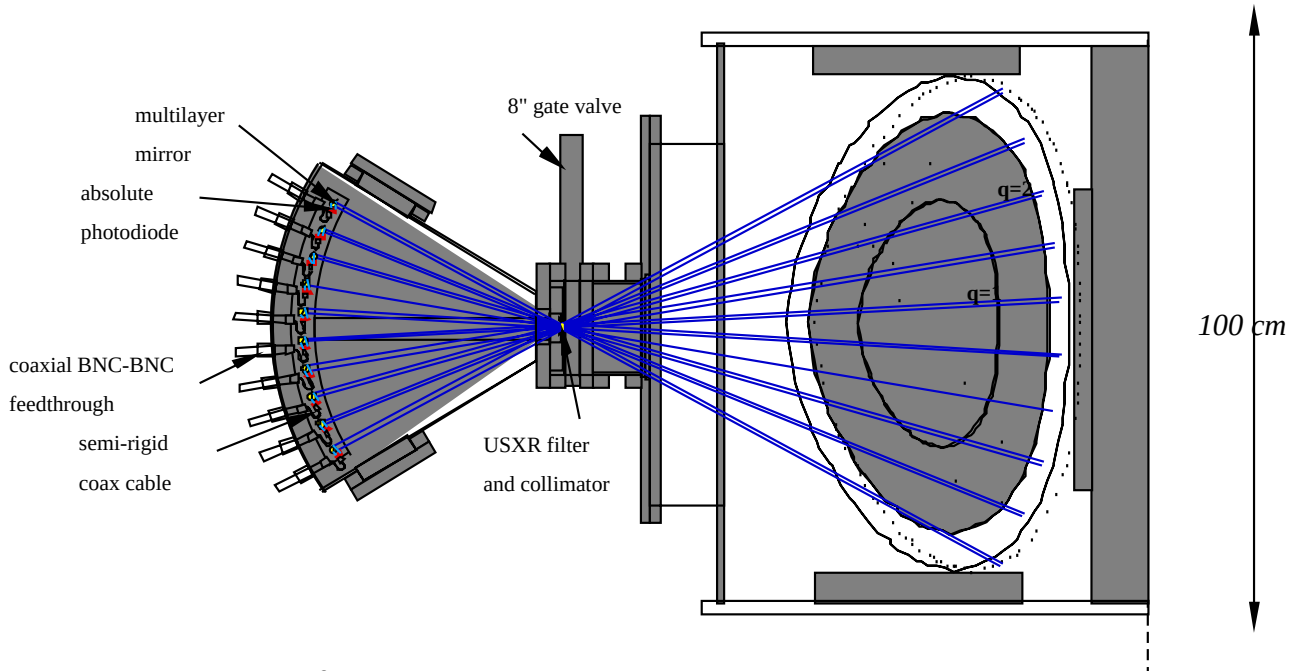


- Alternative limiter geometry requires higher triangularity discharge.
- Higher triangularity also reduces impact on Thomson system.

Diagnostics

- CDX-U diagnostic set will be augmented for the liquid metal studies.
  - Diagnostic set already includes a multi-layer mirror array with lithium imaging capability.
- Suggestions for additional diagnostics have already been received from Oak Ridge, Sandia, and Johns Hopkins University.
  - 5 channel visible spectroscopysystem, fast “ASDEX” type pressure gauge (ORNL).
  - IR camera and couponing system (Sandia).
  - Mirrors for additional lithium resonance lines for the MLM (JHU).
- Implementation of EFIT will be completed for magnetic reconstruction.
- Installation of toroidal lithium belt limiter <u>may</u> require reorientation of multipoint Thomson scattering system.
- Suggestions for the diagnostic set will be discussed this evening.
  - » <u>Which metals and/or salts?</u>

Multilayer mirror array for ultrasoft x-rays (JHU)



Wavelength range	*Mirror*	*Reflectivity (%)*	*Resolution (Å)*	*Application example*
12-30	W/B4C	5-20	0.4-0.6	O VII-VIII, injected Ne IX-X
30-45	Ti/Cr	7-25	0.6-1.5	C V-VI
45-100	Ni/C	20-30	1.5-3	injected B V-VI

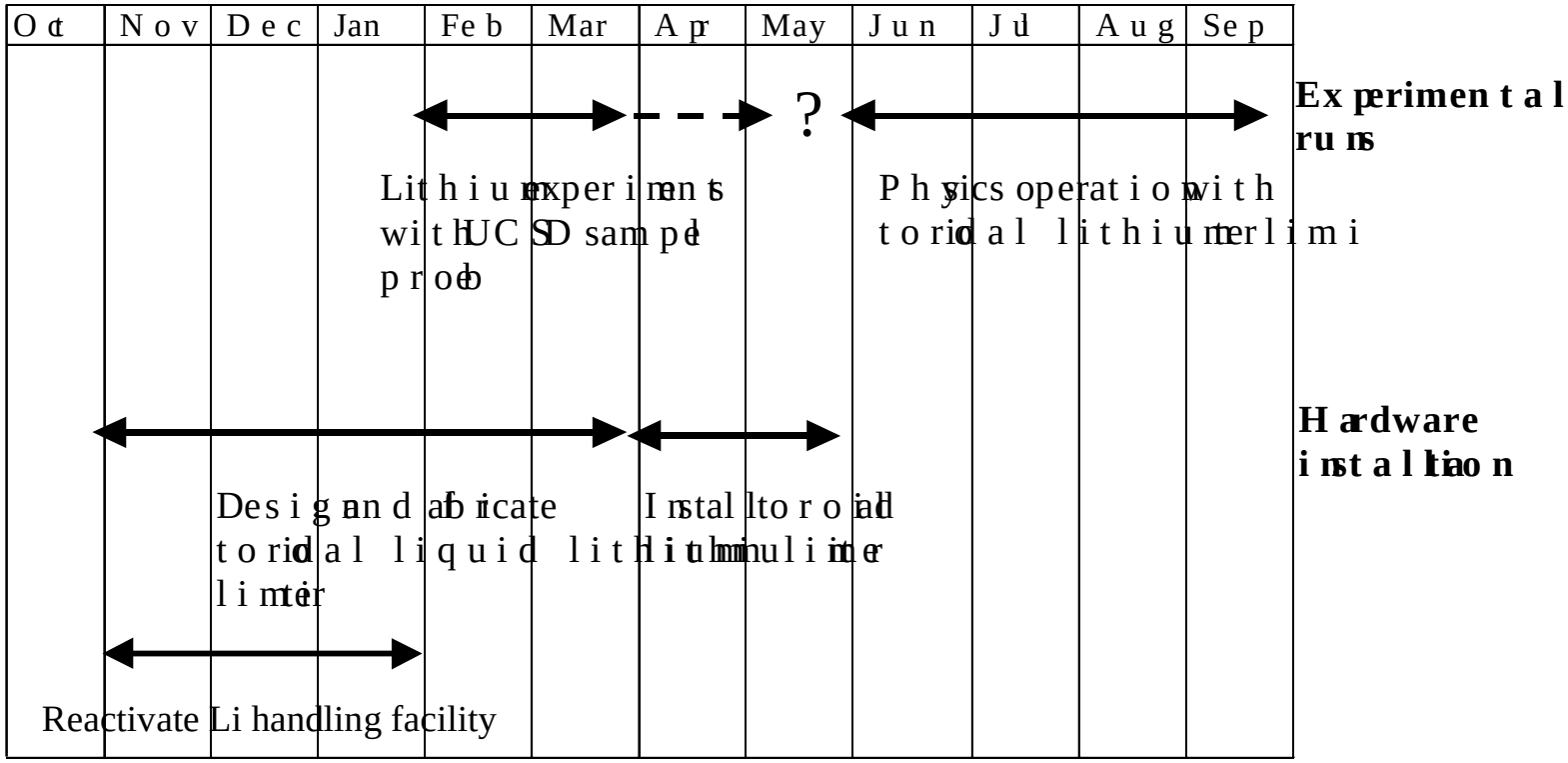
Issues

- Can lithium or any other liquid metal PFC be forced to behave during a tokamak discharge?
  - Liquid motion during PF coil ramps.
    - » Toroidal currents can flow within continuous lithium divertor target.
    - » Might affect position control or MHD stability (partial conducting shell).
  - Motion during a VDE.
  - Halo current - induced j x B forces.
    - » Lithium propulsion is not a research goal.
  - Halo currents from disruptions might cause lithium to “splash”.
  - Large surface tension and adhesion may prevent this in practice.
- We must be able to accommodate lithium splatter during these experiments.

Issues

- Lithium plasma fueling and core impurity accumulation.
- Behavior of the plasma edge with a very low recycling limiter.
  - Not the same as a well-conditioned carbon limiter; carbon still provides recycling sites.
- Fueling with hydrogenics.
  - CDX-U utilizes gas puffing; no core fueling at present.
  - Is gas puffing sufficient?
- Lithium handling.
  - Loading, purification, pacification.
- Temperature rise during plasma operation will ramp evaporation rate.
- Consequences of possible surface coatings formed in situ.
  - Lithium nitride layer may form during introduction into vessel.
  - Lithium deuteride surface may form during plasma operation.
  - LiD melts at 688°C but is highly soluble in lithium.

CDX-U Schedule for Fiscal Year 2000



Summary

- Liquid walls and/or divertors may prove to be an essential component of an economic fusion reactor.
  - A task force to facilitate the installation of liquid wall systems in NSTX has been proposed.
- The CDX-U facility will serve as a small-scale test bed for liquid systems.
  - User facility for many interested institutions.
- The results obtained on CDX-U, when combined with data from large-scale liquid metal/salt flow and heat load facilities, will answer many of the physics and technology questions posed by the use of liquids in a fusion facility.