Issues for Fueling and Particle Control

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Goal is to formulate plan for FY06 decision point

- What are NSTX particle control requirements?
  - Experimental evidence to date
  - Near-term and long-term needs
  - Adequacy of present and planned capabilities
    - Surface conditioning (bakeout, boronization, helium GDC, pellet injection, etc.)

- What are NSTX power handling needs?
  - Near-term and long-term needs
    - "Realistic" schedule for long-pulse (≈5 s) operations
  - Adequacy of existing PFC's and planned upgrades

Common understanding of results to date needed

- What are implications of past lithium experiments?
  - "Uniqueness" of TFTR results
  - Research on other magnetic confinement devices
  - Experience from PFC community

- Is cryopump experience sufficient for predicting future performance?
  - Past efforts appear to be based on installation of cryopump, collection of comprehensive data set, and adjustment model for "best fit"
    - Extensive modifications required for implementation on NSTX may preclude such "cut and try" approaches

Possible conclusion may be that neither cryopumping nor flowing liquid lithium divertor module may be necessary

- Evaporative coating may be sufficient for particle control
  - Primary means of particle control in LTX
  - Implementation already planned for NSTX Experience from PFC community
  - UEDGE-2-D code combined with 3-D REDEP/WBC code by Brooks at ANL predict lithium to be confined to divertor region

- Cryopump requires extensive and expensive modifications to passive plate geometry
  - Little flexibility for testing various "throat" configurations in absence of reliable predictive modeling

- Flowing liquid lithium divertor module loses primary
  - Five-second pulses may not be realistic for NSTX or necessary for its mission
  - Argument for prototyping reactor chamber technology becoming less compelling with growing focus on ITER needs

Urgent immediate issue concerns installation of new divertor PFC's this opening

- Evaporative lithium coatings require surfaces other than carbon to prevent intercalation
  - High velocity oxygen fueled (HVOF) spraying of molybdenum on carbon tiles may be possible

- Need to determine how much of divertor surface can be covered by evaporator(s) planned for upcoming run
  - Will coverage have measurable effect on recycling even with "perfect" substrate?

- "Technology testing" rather than consequences for plasma performance may be more realistic goal for upcoming run
  - Reliability of evaporator probe drive operation and performance of lithium oven or e-beam on lithium sample can be checked
  - NSTX run time *not* required to confirm well-established intercalation results

Arguments could be made for *not* replacing any tiles this opening

- "Technology testing" rather than consequences for plasma performance may be more realistic goal for upcoming run
  - Reliability of evaporator probe drive operation and performance of lithium oven or e-beam on lithium sample can be checked
  - NSTX run time *not* required to confirm well-established intercalation results

- Useful results could still be obtained with carbon tiles
  - Might reported upper limit of ≈30% lithium at "saturation" of carbon still have measurable effect on recycling?

Question for upcoming run concerns usefulness of devoting some of limited run time to "duplicating" TFTR lithium results

- **Will extensive conditioning and pellet injection to coat center stack for limiter plasmas be sufficient?**

- **Will developing such scenarios be informative and useful if NSTX program emphasizes divertor plasmas?**

Need to include preparation for FY06 decision point on particle control options in FY05 run planning

NSTX Issue	Cryopump Assessment Status	Cryo Assessment Basis or Schedule for Achievement	Liquid Lithium Module Assessment Status	Liquid Lithium Module Assessment Basis or Schedule for Achievement
Capability for Particle Control	Ability established with operational caveats (see comments under "Operation" in next table)	DIII-D (GA) results on edge plasma modification available - although *predictive* capability for "first principles" NSTX design needs more work	Ability established	UCSD (PISCES) and UIUC results on hydrogen retention and PPPL (CDX-U) results on recycling reduction
Capability for Power Handling	Not applicable (must be protected from high heat flux)	Not applicable	Required flow rate is 7-12 m/s from analysis	PISCES results on temperature dependence of lithium evaporation confirm temperature limits; power handling tests at LIMITS facility (Sandia) planned but not started
Safety	Cryogens handled routinely	Experience on DIII-D, NSTX, and elsewhere	1) Static "pools" of liquid lithium handled safely 2) Circulating Li system assessment required	1) CDX-U has safe handling experience with static fully-toroidal liquid lithium limiter 2) Tests of flowing lithium hardware in progress at LIMITS facility; assessment to be completed in mid-FY05

NSTX experiments in FY05 can investigate operational issues that need to be addressed for FY06 decision point

NSTX Issue	Cryopump Assessment Status	Cryo Assessment Basis or Schedule for Achievement	Liquid Lithium Module Assessment Status	Liquid Lithium Module Assessment Basis or Schedule for Achievement
Installation	In-vessel modifications substantial but potentially straightforward: • Close passive plate gaps and redesign secondary passive plate supports	Preliminary assessment completed – Menon (ORNL - ret.)	In-vessel modifications could be limited but have special requirements: • Permit lithium flow into, through, and out of NSTX • Accommodate CHI "gap" and diagnostic penetrations	Preliminary assessment completed – Nelson (ORNL); prototype flowing liquid metal systems being tested at MTOR (UCLA) and LIMITS; conceptual design for NSTX flow configuration requires experimental data and MHD modeling results for NSTX divertor geometry (UCLA/Hypercomp)
Operation	Pumping dependence of separatrix distance to plenum limits achievable plasma geometries	Preliminary assessment completed – Menon (ORNL - ret.)	MHD effects on liquid lithium may limit permissible magnetic field ramp rate; ***assess ELM, thermoelectric current, and plasma wind effects; control external current loops***	Experimental and computational assessment of MHD effects on liquid lithium flow in NSTX fields in progress at SNL and UCLA; ***ELM effects and other issues related to NSTX plasmas require further investigation on large MFE facilities***