APEX Common Task B Summary: Liquid Wall-Bulk Plasma Interactions

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Outline of APEX Task Support Scope

- **Task I. Explore options and issues for implementing a flowing liquid wall in NSTX**
  - I.1 Characterization of NSTX operating conditions
  - I.4 LM experimental facility set up & initial exploratory experiments with and without a magnetic field gradients and applied currents
  - I.5 Identification of key issues and development of an R&D plan for implementing liquid walls in NSTX
- **Task II. Exploration of High-Payoff Liquid Wall Concepts**
  - II.1 Exploration of thin and thick LM wall concepts
  - *II.1.c Other flow conditions for better performance during startup*
- ***Task III. Practical Engineering Issues Associated with the Design of a Liquid Wall***
  - *III.1 Mechanical Design, Maintenance, Integration*
  - *III.3 Liquid Wall Fluid Flow Configuration and Design*

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I.1 Characterization of NSTX operating conditions

- Predicted NSTX high beta EFIT equilibria and magnetic field components have been provided by PPPL personnel to University of California at Los Angeles (UCLA) for determining an operating window for non-insulated lithium flow under these conditions.

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I.4 Liquid metal experimental facility set up at UCLA

- Power supply for LMMHD coils sent by PPPL to UCLA.
- Report prepared on possibilities with TARA field coils - promising enough to use for LMMHD at UCLA.
- Report prepared on LN_2 enhancement of coil performance - too technically complex for present implementation.
- Report prepared on LMMHD toroidal facility forces and torques - centering forces more of a concern than overturning moments in present LMMHD.

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I.5 Identification of key issues and development of an R&D plan for implementing liquid walls in NSTX

- Draft systems requirements document prepared to describe issues which need to be addressed if NSTX decides to implement flowing liquid walls.
  - See presentation **"APEX Task I: Summary of Draft NSTX System Requirements Document for Flowing Liquid Walls"** by R. Kaita at this meeting.

II.1 Exploration of thin and thick LM wall concepts

- Tokamak Simulation Code (TSC) successfully used to simulate time evolution of 1 MA NSTX plasma.
  - Calculation will be baseline case when code is modified to simulate liquid lithium wall and investigate fluid motion during plasma startup.

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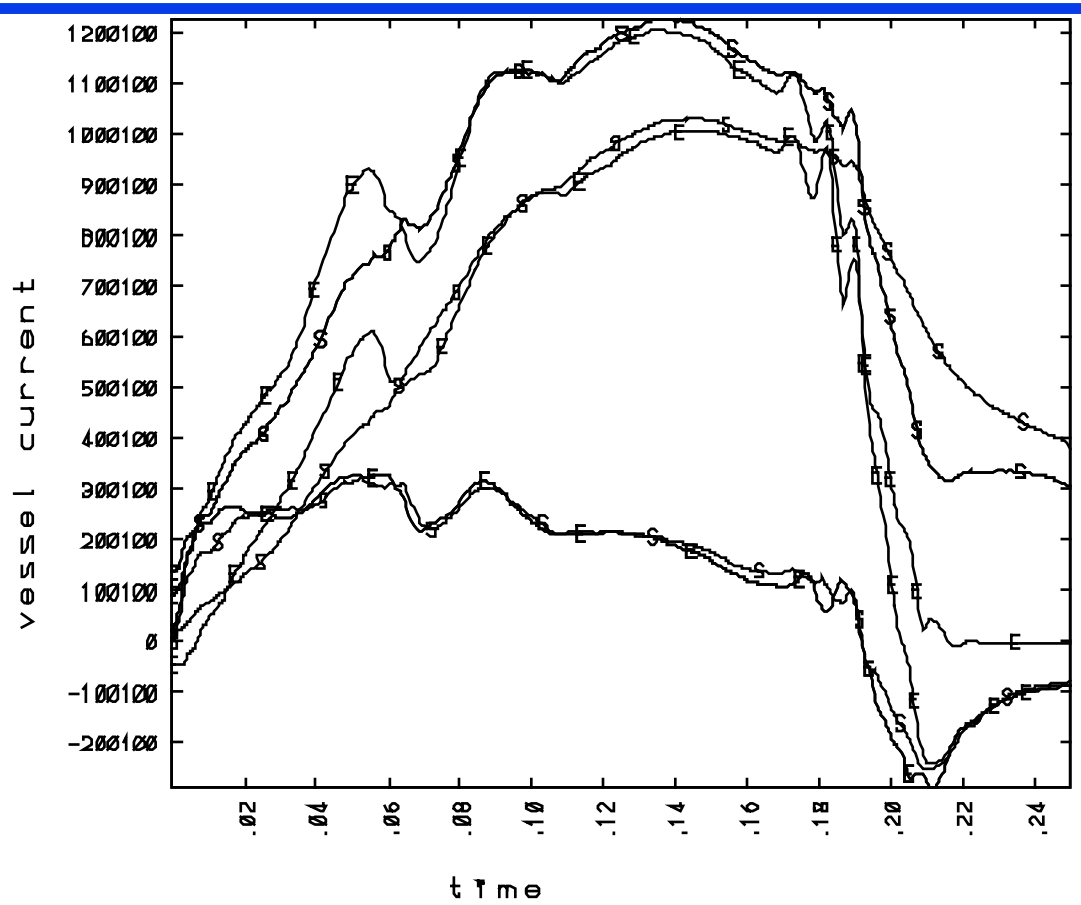
II.1 Exploration of thin and thick LM wall concepts (continued)



Comparison of TSC results (S) with experiment (E) for NSTX plasma + vacuum vessel current (upper), vacuum vessel current (lower), & plasma current (middle).

II.1 Exploration of thin and thick LM wall concepts (continued)

- Stabilizing effects of liquid walls in simplified (straight) geometry investigated at Institute for Fusion Studies (IFS)
  - Liquid wall is less stable than solid wall against Kelvin-Helmholtz instabilities (but apparently not significant).
- Resistive MHD analysis of vertical stability in highly-elongated plasmas (starting from ARIES-RS design) at IFS
  - Conducting wall over 75% of surface area needed for vertical stability to keep feedback (FB) system modest.
  - 2 cm thick lithium all right if (wall separation)/a_{mid}=0.2.
- FB system for vertical instability can reduce B_{normal} by factor of 10 with ~12 sensors within ~10 cm of the wall & ~12 FB loops ~1 m away (low conductivity wall material is best).

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II.1 Exploration of thin and thick LM wall concepts (continued)

- FB code for BOTH vertical instability & kink modes modified to accept output from a slightly modified MHD code for resistive wall calculations & feedback stabilization.
  - Will modify to study LW kink mode stabilization.

- Ideal MHD calculation of wall distances for kink stability: PPPL to do preliminary PEST runs & provide code to IFS.

- Microinstability calculations indicate substantial reduction in instability strength in edge at lower density.
  - Low-recycling edge could improve global confinement.
  - Will investigate for CDX-U parameters.

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II.1 Exploration of thin and thick LM wall concepts (continued)

- Further simple experimental tests of magnetic propulsion performed at the University of Illinois.
  - Experiments performed with liquid gallium in a magnetic field that varies uniformly from 0.95 T to 0.55 T in 2 cm.
  - Up to 9 A passed through gallium in direction of magnetic field gradient with flat stainless steel electrodes to improve uniformity of current distribution.
  - Gallium motion of a few mm in direction of field gradient observed: will repeat at higher currents.
  - Future experiments include having a thin rod extending into a pool of liquid metal and letting the current generate the large magnetic field that gives propulsion.

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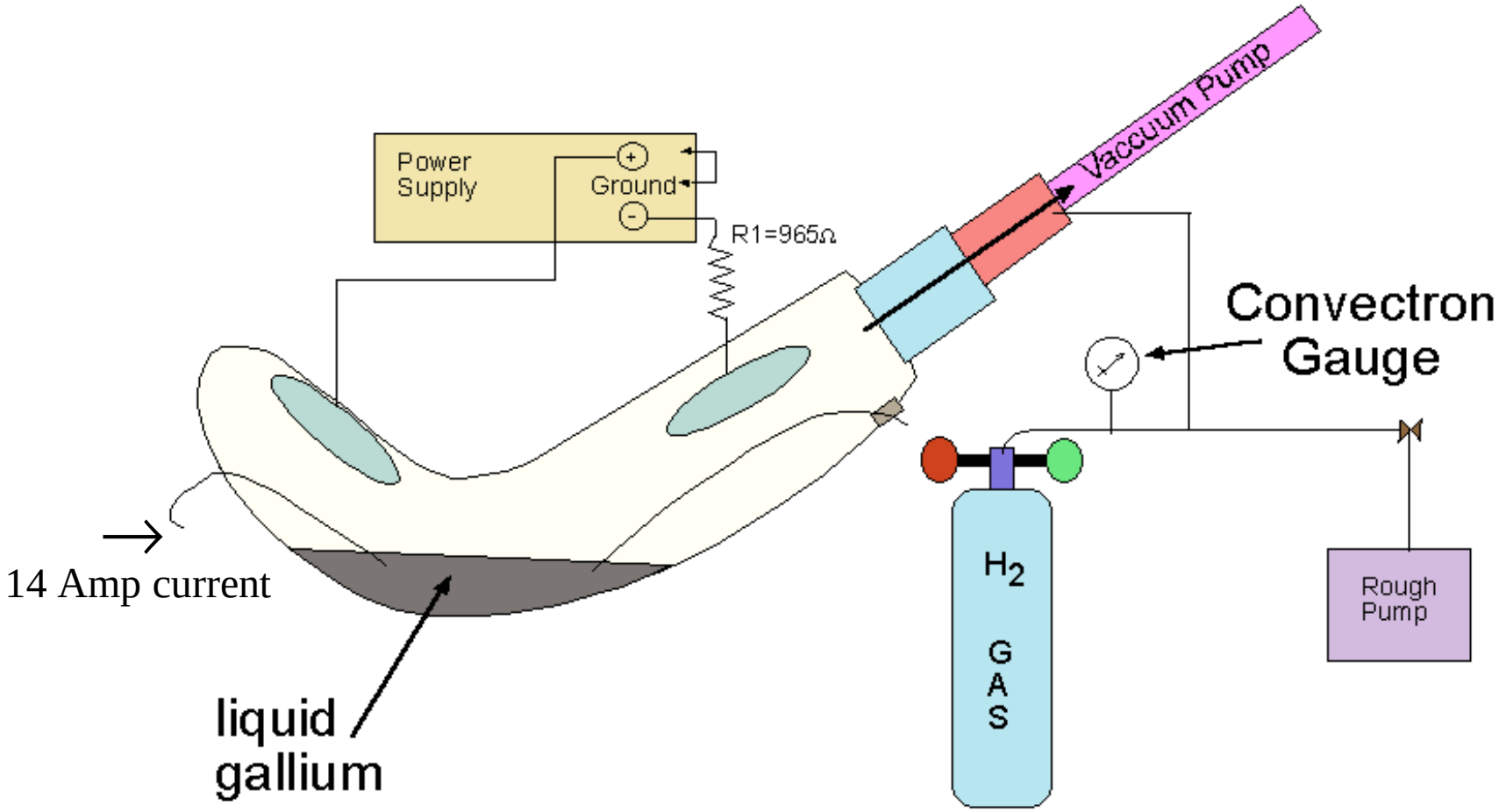
General Schematic of Experiment



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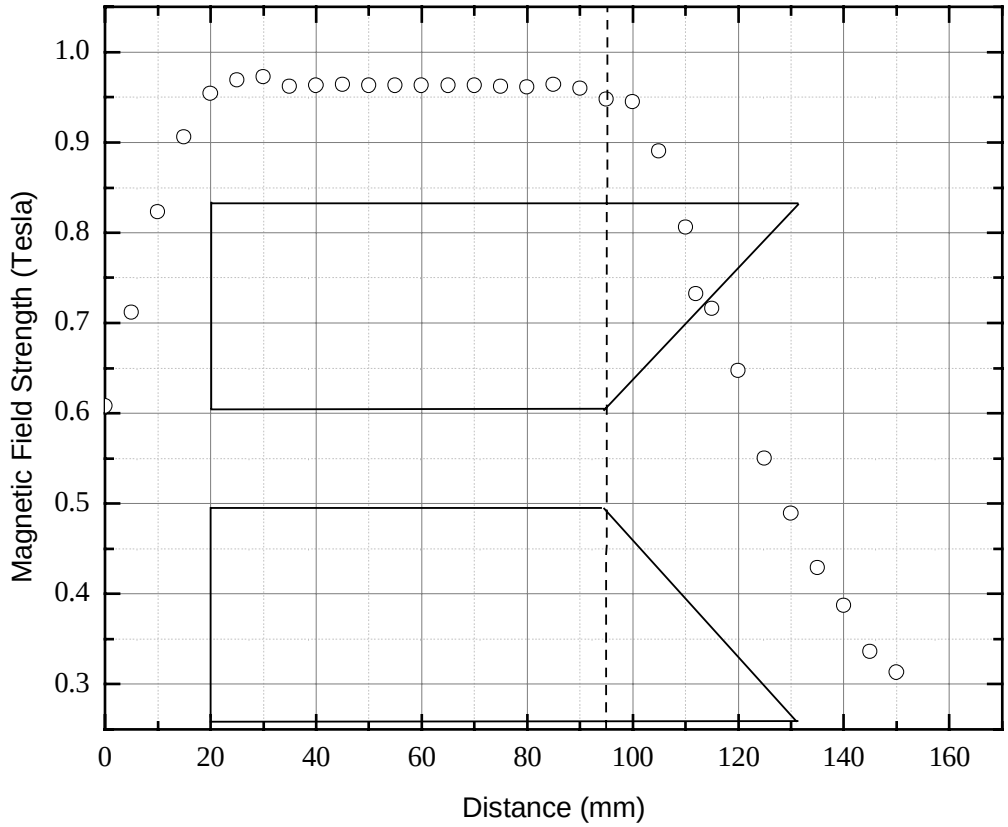
Results with Liquid Gallium

- Metal in gradient area is not pushed down as hard as metal in stronger field.
- Level rises about 3 mm.
- Metal does not flow up the curved wall.



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Summary

- **Progress in Common Task B activities:**
  - I.1 Provided information on NSTX operating conditions.
  - I.4 Contributed to LM experimental facility set up.
  - I.5 Reported on key issues for implementing NSTX LW
  - II.1 Exploration of thin and thick LM wall concepts
    - » 1) Investigated stabilizing effects of liquid walls in simplified (straight) geometry (IFS)
    - » 2) Simulated NSTX discharge startup with TSC
    - » 3) Resistive MHD analysis of vertical stability in highly-elongated plasmas begun (IFS)
    - » 4) New simple experimental tests of magnetic propulsion performed (University of Illinois)

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