APEX FY2000 Task II:

Exploration of
High Payoff Liquid Walls

Task Leader:
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SubTask Coordinators:
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S. Zinkle

APEX Electronic Meeting
Friday, March 24, 2000

task II summary

Scope:

- exploring high payoff liquid wall concepts that increase the attractiveness of fusion energy, with emphasis on understanding the key scientific issues

- both liquid metals and Flibe, and thin and thick liquid walls that have the potential to improve the physics performance of plasma

- Other new APEX concepts that are advanced this year

Approach:

- development and application of much-needed, generic modeling tools for liquid walls and plasma interaction with liquid walls

- initiation of experiments that address fundamental LW issues identified in last year’s effort that are key to the understanding of liquid wall phenomena

- conceptualization of LW implementation

task II subtasks

II.1 Exploration of thin and thick Liquid Metal wall concepts

a) Bulk Plasma-Liquid metal wall interactions – **Kaita and Kotschenreuther**

b) Plasma-liquid surface interactions with lithium (covered under ALPS/APEX PLSI) – **Rognlien**

c) LM-MHD numerical tool development and analysis of LM wall designs – **Smolentsev** **(Morley)**

d) LM experiments (also Task I) – **Morley** **(Woolley)**

II.2 Exploration of thick Flibe blanket concepts

a) Identification and analysis of potential thick Flibe concepts – **Ying / Gulec**

b) Plasma-Liquid Surface Interactions (covered under ALPS/APEX PLSI) - **Rognlien**

c) Flibe simulant experiments in basic poloidal flow LW geometries – **Gulec**

d) Mechanical configuration issues and drawings – **Nelson**

RED - presentation under another task
BLUE - presentation to be made here

task II subtasks (continued)

II.3 Exploration of Liquid Walls for non-tokamak confinement schemes

a) Continuation of FRC work - **Moir**
b) RFP, Stellarator – **Moir**

II.4 Materials, safety, and nuclear analysis for high payoff Liquid walls

a) Identifying compatible liquid-structure combinations and temperature and other operating limits for a variety of applications: flexible vs. rigid, hermetic vs. non-hermetic, etc. – **Zinkle**

b) Preliminary assessment of erosion rates for various coolant/material combinations as a function of temperature and coolant velocity – **Ghoniem**

c) Analysis of safety issues for liquid walls – **McCarthy**

d) Nuclear analysis and activation {some overlap with Task III nuclear work} – **Youssef**

RED - presentation under another task
BLUE - presentation to be made here

task II milestone report, March

- Modification of the current k-ε model and the code for the developing MHD

  status: code modifications completed and benchmarked, producing results for tasks I, II, and III

- Development of a 2-D or quasi 3-D MHD model for analyzing local flow effects and field gradients, begin analysis of cases at UCLA

  status: 2D code modifications completed for toroidal, producing results for limited cases in task I and II.

  More work on VOF free surface tracking needed and significant testing required. Multi-component not yet begun

- Extension of 1.5-D MHD model to the case of a 2-component magnetic field, begin analysis of cases

  status: model formulated, coding underway.

- Design review for Flibe Hydrodynamics Simulation Facility (*Fli-Hy*)

  status: design and sourcing largely complete.

  Awaiting review and construction phase.

task II milestone report, March

Task II Milestones covered elsewhere…

- Complete lithium wall simulations (for tangent walls) with UEDGE (LLNL). Compare with kinetic impurity model in MCI code
- Initial results on stabilizing effects of liquid walls in simplified (straight) geometry
- Design review for toroidal MHD flow facility

Effect of Solid Conducting Shell at the First Wall on TBR

- Removing the liquid convective layer itself (2m thick) can drop TBR by ~4% (SiC structure) if no front beryllium multiplying zone is deployed. On the other hand, this removal leads to ~3% increase in TBR if a beryllium multiplying zone is implemented in the system.

- Placing W as a conducting shell at the FW in front of the beryllium multiplying zone gives the largest adverse impact on TBR (up to ~-30% for 2 cm shell). The least impact is with V and Al conductors (~-12% for 2 cm shell).

The % change in TBR upon including a conducting shell of thickness, d

Material of Conducting shell	d= 1 cm	d=2 cm
Cu	-12.6%	-20.3%
Al	-6.5%	-11.8%
Ferritic Steel	-8.8%	-15.3%
W	-25.2%	-30%
V	-6.9%	-11.9%

(Flibe with natural Li/SiC structure-

with 10 cm front Be multiplying zone)

other task II talks...

LM-MHD MODEL DEVELOPMENT: FREE SURFACE FLOW WITH FIELD GRADIENTS AND APPLIED CURRENTS

Morley (7.5 min.)

CURRENT STATUS OF APEX HEAT TRANSFER MODELING USING "K-EPSILON" MODEL OF MHD TURBULENCE

Smolentsev (7 min.)

PROGRESS ON FLIBE HYDRODYNAMICS SIMULATION FACILITY, and HEAT TRANSFER ENHANCEMENT TECHNIQUES EVALUATION

Gulec (10 min.)

STRATEGIES TO MINIMIZE SURFACE VAPORIZATION, and PROGRESS ON LWs WITH ALTERNATIVE CONFINEMENT SCHEMES

Moir (3 min.)

APEX FY2000 Task II

LM-MHD model development:

Free surface flow with field gradients and applied currents

Presented by:
Neil Morley

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MHD modeling for FREE SURFACE flows in variable fields

Issues

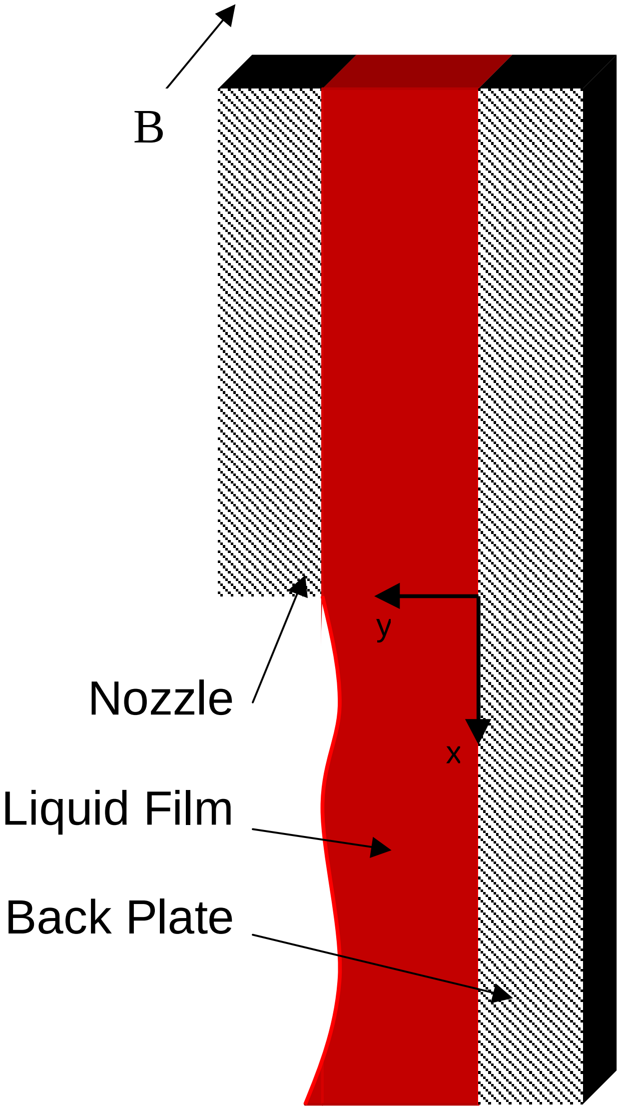
- Sensitivity of LM flows to spatial field gradients
- Sensitivity of LM flows to temporal field gradients
- Effect of applied electric currents on LM flow with and without field gradients

LW Applications

- Flow on first wall in 1/R toroidal field
- Flow in NSTX 1/R pulsed toroidal field
- Electromagnetic Restraint and Magnetic Propulsion
- Jet Breakup into Droplet (cylinders) – internal velocity profiles for heat transfer

Code Description

- Infinitely wide film in z (toroidal) direction
- Magnetic field in z-direction with spatial and temporal variations in the xy-plane
- Electric currents applied at boundaries
- VOF interface tracking methodology



Code Development and Benchmarking

Status

- Applied to closed channels with Ha > 1000, N > 500 –
- Agreement with Walker solutions for ΔP_{3D} due to strong gradients
- Free surface benchmark tests w/o field begun, more still needed

Near term improvements

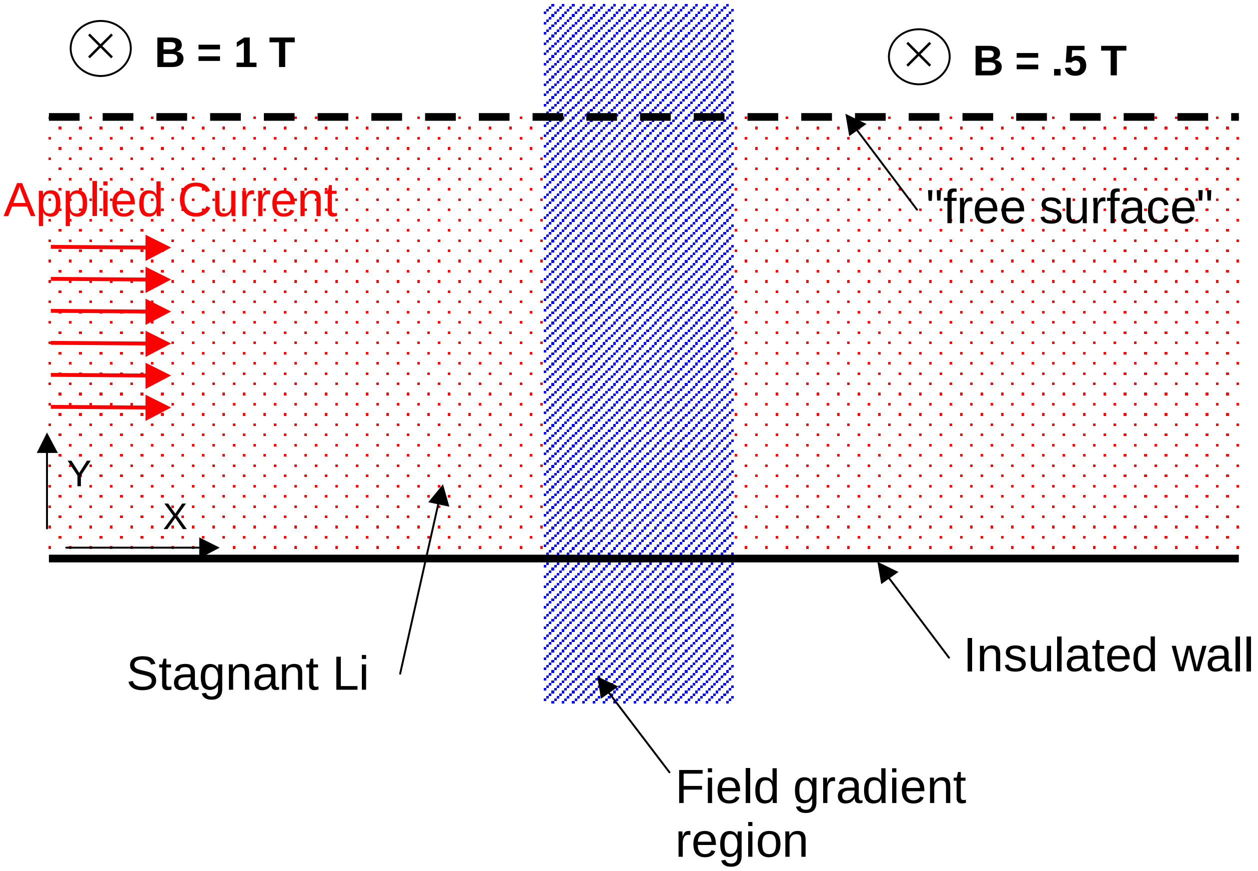
- Obstacles
- Thin conducting walls
- Alternate geometries
- Better handling of non-linear terms for flow instabilities

Long term improvements

- Multiple field components
- 3D Hydrodynamics
- Heat Transfer

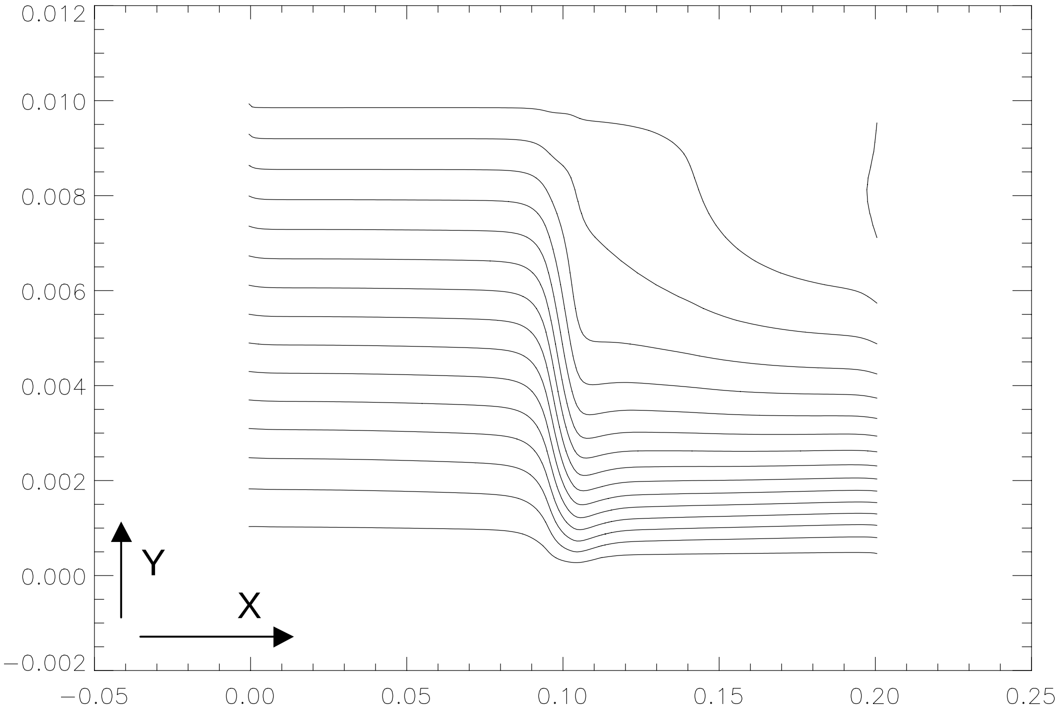
Example Case:

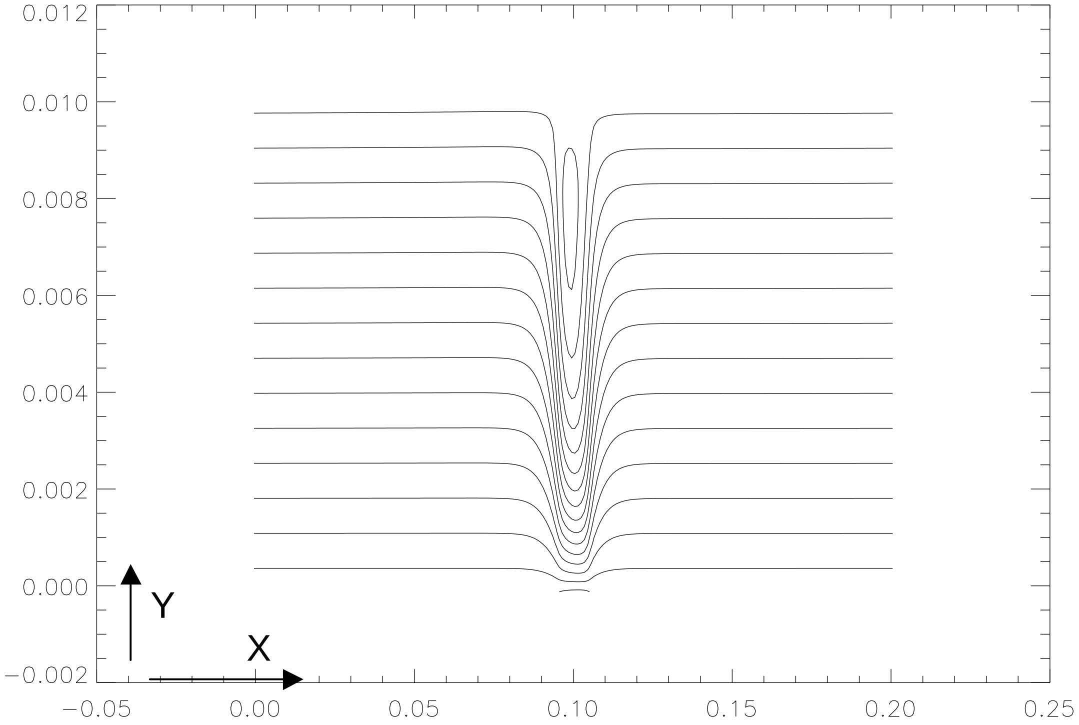
Acceleration of initially stagnant liquid with a pseudo-free surface by Zakharov's Magnetic Propulsion effect



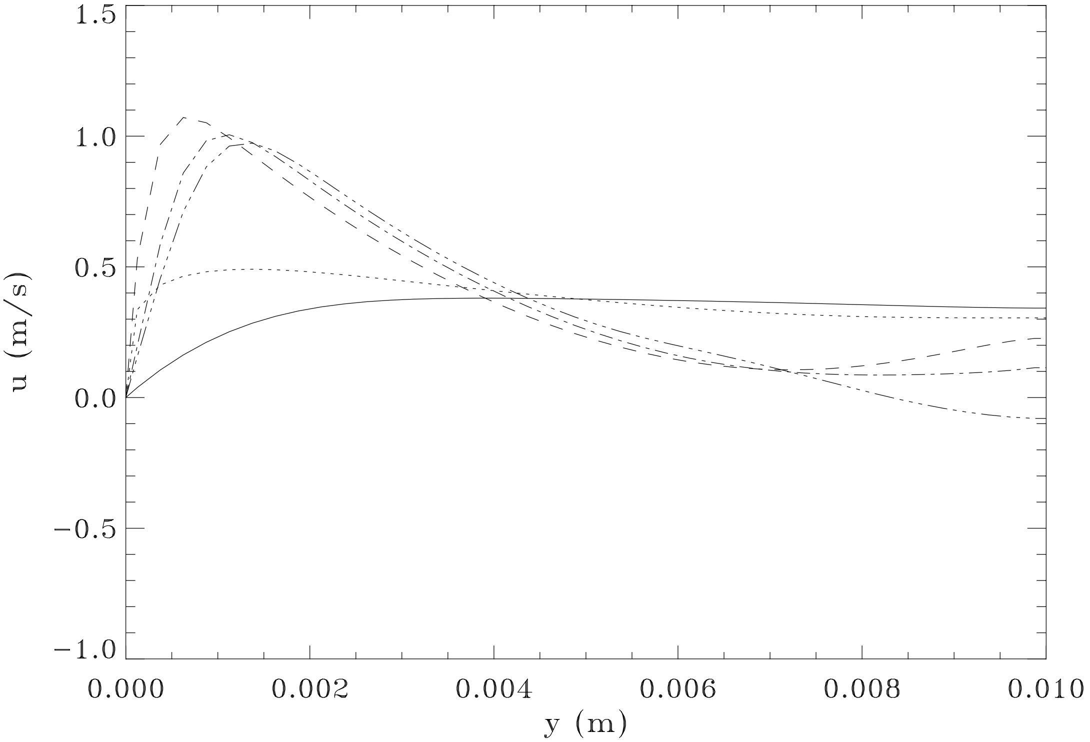
- Free inflow/outflow velocity and pressure BCs
- Applied current density = 10^5 A/m^2
- Channel size = 1 x 20 cm, Gradient region size = 1 cm
- Free surface approximated by fixed, free slip wall at P=0

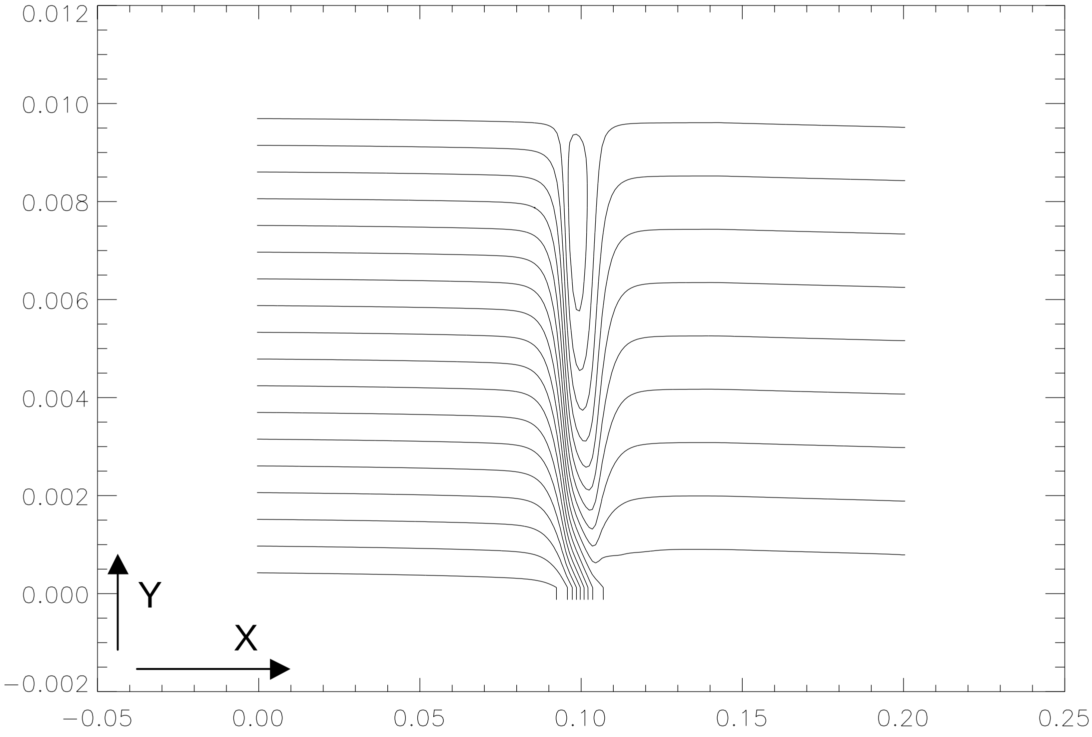
Fully developed results for MP simulation– velocity and current streamlines in the xy plane





x-velocity profiles in y-crosssection and pressure streamlines in the xy plane





Important points gleaned from

MP test case

- MP is effective in accelerating and sustaining LM flow in the presence of field gradient and viscous drag

- Velocity profile produced by MP effect has region of slow flow near surface - not attractive for surface heat removal

- Actual free surface model is required to validate these conclusion