Summary of Session III: Task I and Task B

Summary of Task B Activities (R. Kaita)

The work is a continuation of Advanced Power Extraction (APEX) activities that proceeded during FY00 in this task area. In support of Task I, the characterization of NSTX operating conditions will be provide for high power auxiliary heating as required by the Fusion Science and Technology at UCLA and other members of the APEX effort for their design of liquid walls for NSTX. For the MTORR liquid metal experimental facility set up and initial exploratory experiments, there will be participation in the experimental planning and provide engineering support for facility operation and upgrades. Help will also be provided to identify key issues and develop an R&D plan for implementing liquid walls in NSTX.

Under Task II, the evaluation of the conditions under which flowing lithium will have an effect on the resistive wall mode will continue. Information from simulations of CDX-U liquid lithium experiments and other computational efforts to develop a model for a spherical torus plasma in contact with a very low recycling surface, including recommendations for further experimental tests, will be provided. Progress on the comparison between methods of propulsion (e. g., electromagnetic propulsion vs. pumping) will be reported, including results of tests in dedicated experimental devices.

As part of Task III, the feasibility of developing a systematic staged approach for introducing flowing liquid lithium walls into tokamaks will be investigated, including what we are to learn from each step, and what are the technological and physical barriers and milestones. Refinements to the DEGAS 2 neutral transport code as they pertain to liquid-bulk plasma interactions will also continue.

Plasma Stabilization by Intense Liquid Lithium Streams (L. Zakharov)

Magnetic propulsion has been proposed as a means of driving lithium streams in tokamaks. They can be used to improve the stability of free boundary modes in such devices, and are a potential means of stabilizing configurations that are unstable in the presence of passive conducting walls. One stabilizing effect is due to the fact that a lithium stream permits a conducting shell to be located at the plasma boundary. This can be treated with the theory developed for resistive wall modes in solid conductors, and the analysis has been addressed extensively in the literature.

A second possibility is that the axisymmetric m = 1, n = 0 pattern of the fast metal flow itself affects explicitly the resistive wall mode (RWM). A simple rotating metal shell is not effective in stabilizing these modes, because the RWM can be locked into the rotation. In contrast, a magnetic propulsion scheme that introduces metal on the high field side of the tokamak and removes it from the low field side creates a two stream pattern. The mode can only lock into one of the streams, and this makes the other equivalent to a perfectly conducting shell. The theoretical formalism for calculating the eddy currents in the streams has been developed, and it can be used with existing numerical codes to evaluate the growth rates and stability conditions for RWM's in the presence of such lithium flows.

Task I: Plasma Surface Interactions and Impurity Control in NSTX (R. Kaita)

Several wall conditioning techniques have been employed on NSTX. These include center stack resistive bakeout to 300^{o}C, passive plate bakeout to 160^{o}C, helium glow discharge cleaning (HeGDC) to remove impurities and deuterium, and boronization with deuterated trimethyl boron (TMB). The TMB gas is bled in during HeGDC, followed by 2 hours of pure HeGDC to remove the deuterium in the boron film. Inter-shot HeGDC of 5 minutes was performed as required during NBI operations for reproducibility and deuterium removal. Helium discharges were also run for further depletion of wall deuterium to achieve the lowest deuterium recycling cases.

The HeGDC lowers edge recycling and impurity content, allowing slower ℓ_i evolution and longer time before q_0 drops below unity. It is also most useful if there are plasma burn-through problems. Furthermore, HeGDC could be affecting the characteristics of MHD events, leading to 10% higher plasma currents or longer flat-tops in certain cases. This suggests that wall contact and/or impurities played a role in controlling the MHD. Some MHD events near the flattop may be related to an increase in central radiation and changes in the current profile.

Boundary physics research on NSTX in FY01 will focus on the effect of wall conditioning on plasma reproducibility, τ_E, and edge density, temperature, and pressure gradients. Initial heat flux scaling experiments will also be performed with new IRTV cameras.

Axisymmetric Liquid Flow Experiments at UI (D. Ruzic)

A toroidal test facility to investigate J X B effects relevant to several first wall, limiter and divertor plate applications of liquid metal walls has been constructed. The Liquid Metal Illinois Toroidal Test Facility (LIMIT) is an outgrowth of earlier work which showed the existence of severe surface oscillations at high magnetic field (900 Gauss) and current (40 A) conditions in an open liquid gallium channel. A possible cause of those oscillations was the side walls, which would be absent in a toroidal device.

LIMIT has a major radius of 8 cm and a minor radius of 6 cm. There are up to 65 toroidal windings carrying 200 A, which produces a 200 Gauss field at the surface of the central "post." Liquid gallium can flow down the center post or can just sit in the bottom of the torus. Currents up to 200 A can be driven radially or toroidally through the liquid metal. Other configurations are also possible. A number of experiments have been performed with stationary liquid gallium, and the "bowl" containing it can be rotated to investigate the behavior of a flowing liquid metal and its response to currents in a toroidal magnetic geometry.

Highlights of Lithium Experiments on TFTR (L. Zakharov)

Lithium pellet injection improved plasma performance on TFTR. The confinement time (τ_E) exceeded expectations from ITER-89P scaling by a factor of three. More pellets resulted in better performance, and the highest Lawson product ($n_H \tau_E T_i = 8.5 \text{ x}10^{20}$ m^{-3} s keV) was achieved with the injection of four lithium pellets. The highest value of Q (•0.27) was also obtained with lithium pellet injection.

Another technique for introducing lithium into TFTR plasmas was DOLLOP (Deposition of Lithium by Laser Outside of Plasma). DOLLOP deposits lithium preferentially into the scrape-off layer, by using a laser to form an aerosol as it strikes a lithium target inside the vacuum vessel. The lithium then migrates to the plasma contact points. Evidence of transport barrier formation was observed, as a robust edge structure appeared in the poloidal rotation velocity in both the Ohmic and beam-heated phases of high-performance discharges. The highest values of Q_{DD} and the lowest values of Z_{eff} in TFTR were obtained with DOLLOP.