Task V: Exploring Moving Liquid Metals for Plasma Stabilization

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FY 2002 Tasks:

PURPOSE

Liquid walls can enhance MHD stability and performance in tokamak reactors in two distinct and quite different ways:

1) by placing a passive conducting wall closer to the plasma, enabling much higher elongation and easing stabilization of resistive wall MHD modes by active feedback systems, or

2) by having rapid metal flow in the liquid, stabilizing resistive wall MHD modes without the need for active feedback systems.

In *neither* of these approaches is it necessary to have a *free surface* facing the plasma. The metal could be in channels just behind the first wall, and the effect on the plasma MHD would be the same. The second method is more novel, but the physics analysis of realistic cases is *much* more complex, and similarly, the engineering feasibility is *much* more challenging. "Show stopping" issues are much more likely to arise in this approach. The magnitude of the benefits for plasma stability from *either* method is quite large and roughly comparable.

It is proposed that the initial emphasis be placed on 1), since progress can be much more rapidly. Results and codes developed for this approach can then be used to tackle 2). Thus in 2002, consideration of the fast flow approach will be limited to a consideration of the flow damping of such flows due to plasma interaction effects and a finite normal magnetic field component. Work on better defining the flow requirements for plasma stability, and engineering issues for fast channel flows, will be deferred to 2003.

For passive stabilization, a solid conductor would do as well, in principle, as a liquid conductor. However, the engineering constraints of a D-T reactor may make it difficult to place a sufficiently thick solid conductor very close to the first wall. These engineering problems can be eliminated by using a breeding liquid as the conducting shell, but at the expense of introducing new issues. Resistive wall MHD modes (both vertical instabilities and kink modes) would still have to be stabilized by active feedback, as with a conventional conducting wall. Hence, we propose:

1st half 2002

1) Define feedback stabilization requirements for vertical stability. Determine this using codes at IFS, with some benchmarking with codes at PPPL (by Bob Woolley, Chuck Kessel, and Steve Jardin). This includes determining elongation limits in a model that includes a realistic hole for the divertor. (See also second item in Task V list under Common Task B.)

2) Determine kink mode stability at high elongation. This is a continuation of work primarily at IFS, with some assistance by PPPL.

3) Find a liquid shell geometry for vertical instability stabilization which gives the effect of a continuous toroidal current path, and is compatible with reliability, maintanance, and neutronic considerations. Note that a continuous conductor at the first wall, is not *required*. Conceptual solutions are being devised at the IFS, but require more analysis for engineering and physics feasibility.

4) Examine liquid metal MHD effects on the *passive* stability properties of a shell. At the IFS, preliminary examination of liquid metal MHD effects on the viability of a *passive* liquid shell indicates that it is not a serious issue. More detailed liquid metal MHD considerations in more realistic geometries are needed with assistance of the UCLA group. (See also first item in Task V list under Common Task B.)

5) Determine flow damping effects on a fast flowing shell due to normal magnetic fields arising from plasma interactions, and how (or if) they can be made acceptable.

6) Develop ways to put active feedback conductors closer to the plasma than behind the shield. This is an engineering issue that requires materials and neutronics calculations to resolve. Some collaboration/consultation with Dai Kai Sze, Steve Zinkle, Mahmoud Youssef, Mohamed Sawan, and/or others with similar expertise, will be required.

2nd half 2002

Continuation of issues above, as well as:

1) The poloidal field coil set required for this must be located outside the shield, and also outside theTF coils if at all possible. This may or may not be extremely difficult with the stand-off distances required of super-conducting coils. This is a zero-th order engineering feasibility issue.

2) Analysis to determine if disruption/halo current highly elongated plasmas are more dangerous than for conventional designs. Would require collaborations with GA and/or Ahmet Aydemir at IFS. Some contacts with GA have been made for this, but more are required.

3) Determine requirements to attain neoclassical tearing mode stability, and its consistency with poloidal field coil requirements. Expertise for this exists at FRC, the sister organization of the IFS at Texas, but contacts and possibly additional funds for this are required.