Self cooled lithium walls

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Reactor design

- Present tungsten wall concepts for reactors are very large and complex
- High leverage advances in reactor design would be:
  - Increased confinement
  - Increased beta
    - » Reduced/no disruptivity
  - Decreased complexity
    - » Fewer/no interlocking coils
    - » Reduced feedback requirements
  - Higher wall power handling
  - Reduced in-vessel maintenance
- What innovation would best advanced these goals?

Self-cooled lithium walls (1)

- Potential confinement increases
  - Experimental evidence for confinement increases from TFTR, CDX-U, NSTX
  - Theoretical analyses have been performed by Zakharov, Krasheninnikov
    - » Z&K: very hot edge removes instability ∇T_e drive
    - » Catto and Hazeltine have explored the extremes of tokamak confinement with no ∇T_e drive, minor modifications to distribution function
      - Would be characterized by *electron* neoclassical confinement
- Potential beta increases
  - Theoretical analyses: Zakharov for tokamaks (again), Hegna for Forest's rotating wall experiment
  - Experimental evidence: MHD stabilization of a Z-pinch by rotating (solid) walls was successfully demonstrated (Forest)
    - » Liquid metal flow pattern would be better – counterflowing walls inhibit mode locking

Self-cooled lithium walls (2)

- Potential simplifications
  - Rely on the wall for stabilization. Could relax plasma shaping requirements ➪ no need for closely coupled PF coils? No interlocking coils? ➪ relaxed feedback requirements on PF?
  - Flowing lithium wall carries the plasma heat. No helium cooling system; no separate in vessel wall cooling system at all.
  - No divertor? Lithium provides fuel particle pumping. Divertor H-mode with full lithium walls is an oxymoron. Fast flowing walls have good heat removal capability. Only remaining function for a divertor is helium pumping – can we produce sufficient helium pumping without a divertor (or without much of a divertor)?
- Power handling
  - Could eliminate the need to concentrate power outflow at a divertor. Distributed power at the wall is a few MW/m^2.
- Reduced in-vessel maintenance
  - Could be a much smaller overall system with many fewer components

So what are we doing?

- Confinement explorations. Not much else.
- Lithium coated copper walls on LTX may inform beta limits
  - Provides a conductor within 0.5 cm (average) of the plasma LCFS
  - But no flow
- Some work on thermal transfer in liquid metals, in a high(ish) magnetic field
  - Has modest impact. Recall that we want fast flow for MHD stabilization, so enhanced thermal transfer primarily impacts wall power density limit, which is already adequate in the conduction limit.
- Some work on fast LM flows in a magnetic field
  - MTOR, results were encouraging, but relatively narrow channels. Fully axisymmetric flow not tested.

Common objections

- What about a hot blanket for high thermal efficiency?
  - For a fast flowing wall, heated (active) depth facing the plasma is thin compared to depth of flow (conduction limit)
  - A hot (600C) blanket radiatively heats flow from the guide wall side
  - This heat load is small compared to the plasma
  - Reduced thermal efficiency for the alpha power (⇨wall) would reduce *net* electricity by ~5%
- Tritium inventory:
  - Broad temperature profile, need for efficient fueling, very good particle confinement all imply a high tritium burnup fraction
  - Small demonstration reactor (say 0.5 GW fusion) and a high burnup fraction imply tritium handling requirements can be ~1 kg/day
  - 10 kg site inventory limit implies a 10 day turnaround for tritium removal from the lithium

Other common objections

- It’s crazy.
  - Answer: need to demonstrate wall adhered LM flows
    - » Demonstration in liquid lithium requires a significant toroidal test stand