Liquid Metal PFC Discussion

- Why use liquid metals for PFC’s?
  - Solids may not work!
    - Run-away electrons
    - Disruption damage
    - Neutron damage
    - Thermal fatigue
    - Erosion / Fuzz / Melting
- Why not use liquid metals for PFC’s?
  - MHD forces causing ejection
    - Can balance with surface tension
    - Could be used to create flow
  - Temperature limits (FESAC report)
    - Can be controlled through flow and design
    - Does not necessarily limit power plant efficiency

From Dennis Whyte

1. How do we reconcile a blanket heat sink at >500 C (for plant thermal efficiency) with a lithium surface receiving plasma/radiative heating that has to be below 350 C to control lithium evaporation?

2. If the lithium is pumping large amounts of tritium, what is the result for the required inventory of tritium in a 2GW fusion power plant?
Plasma power exhaust: 400 MW
Average incident ion energy: 100 eV (low-recycling, Te~20 eV)
Tritons/deuterons per second on wall: 0.5* 400e6 / (e 100) ~ 1e25 tritons/s
Tritium pumped per day: (1e25 tritons/s)*5e-27 kg/T * 0.8e5 s /day ~ 4000 kg

(this is not a new calculation, I remember Ali Mahdavi did something like this). I would argue the liquid Li advocates propose a valid scheme to recycle tritium fast enough to lower the plant inventory to 10 kg, which by this estimate means a 200 second turnaround time.

From Dick Majeski

First of all, I strongly favor developing a self-cooled lithium wall - a 1 cm fast flowing wall moving fast enough to remove the heat with the fluid. That's 10 - 20 m/sec, so an axisymmetric flow would be needed to eliminate hartmann layers, and the fluid would be glued to the wall by JxB forces. So if you give me that (which is quite a gift):

1. Interposing this system between a burning plasma and a hot radiating blanket at 600C or so means that the plasma would heat the exposed surface of the fluid, while the lithium layer next to the guide wall would remove the radiative heating of the guidewall by the blanket. In other words the plasma heats the top of the lithium while the blanket radiatively heats the bottom. The radiative load from the blanket, though, is peanuts compared to the heat load from the plasma. I'm assuming the guide wall is supported by something like SiC/SiC which doesn't have wonderful thermal conductivity, so the guide wall heating is primarily radiative.

The key point here is that if the upper layer of lithium can remove the plasma heat, then the bottom of the flowing layer can remove the heat deposited in the guide wall from the blanket.

You do get lower thermal conversion efficiency from the alpha power, which ends up in the wall. Assuming a reduction in conversion efficiency from 60 to 30% (pretty severe), you'd lose about 6% electricity output compared to a system where the wall and blanket were both at 600C. You'd have to see whether the gains with lithium (confinement, beta limits) were worth it.

Dick Majeski (continued)

2. That's an impressive number. Seems to imply a burnup fraction around 6 x 10^-5. Note that the system you describe requires burning around 250 g of tritium a day. How much tritium you have to pump through the tokamak to burn this 250 g, for the 2 GW fusion output, is a function of confinement time and the fueling technique.

I usually consider smaller unit size reactors (generally around 400 MW fusion), but I tend to target a "research reactor". Then very efficient fueling with neutral beams is possible, and even with a 10% burnup fraction I'd "only" end up handling 500 g/day. I think it is possible to use simple distillation in this case to remove the tritium from the lithium.

For your larger system, with fueling by high field side pellets, and a 10% burnup fraction you would have to handle something more than 2.5 kg/day - maybe 5 kg/day, depending on the fueling efficiency.

The bottom line here is that the efficiency with which you are burning tritium looks really pessimistic to me. Another way to look at it is if I had a 400 m^3 plasma with an average triton density of 1e21, then the triton inventory is 4e23. Your 1e25 triton/sec exhaust means that the particle confinement time is 40 msec for this machine. If that's the best we can do for an ITER scale machine, then we should all pack up and go home.