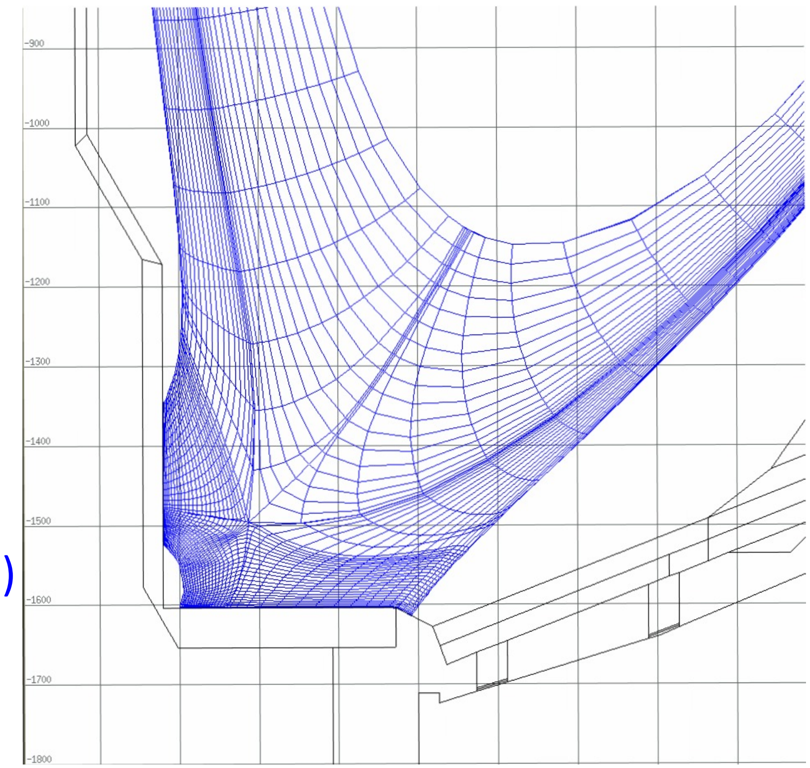
REDEP/WBC analysis - J. Brooks
for boronization discussion 2/28/2011 [1]

J. Brooks email 2/2/8/2011

- Analysis not yet complete
- REDEP/WBC erosion/redeposition analysis of NSTX inner divertor with:
  - a) pure Mo tile surface, and
  - b) pure carbon surface. (did not yet implement the apparent nstx plan for dual zone Mo, and C on inner divertor, but that is not a major issue for this discussion)
- Plasma scrape-off layer 2-D plasma parameters and poloidal grid inputs from J. Canik SOLPS high-D-recycle plasma solution.
- For Mo case, I used 1% Li/D and 1% C/D content.
- For carbon case, am using pure D plasma (for now).
- Did not analyze BC3 or any boron-containing case for NSTX, but from past experience, boron carbide etc. sputtering and transport is fairly similar to pure carbon.



NSTX Inner Divertor Plasma Solution (J. Canik SOLPS B2-EIRENE code 2D fluid plasma + MC neutrals used to model NSTX data). High recycling solution.
Near inner separatrix peak N_e~ $1x10^{20}$ m^{-3}, T_e~ 60 eV

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- For the inner divertor carbon case, my codes predict a peak gross erosion rate of carbon of order 20 nm/s and a net erosion rate (erosion minus redeposition) of order 2 nm/s.
- This rate varies over the divertor and is negative in spots, meaning net deposition.
- Using variations in the strike point of plasma discharges, it looks like a net erosion rate of ~2 nm/s of carbon over most of the surface is feasible,with D-only discharges.
- Per comment above, I would expect similar rate for BC3 or other low-Z, boron-containing surface.
- From previous work, an effective way of increasing C (or B) erosion rate is to add ~1% neon to the discharges. Neon (or Ar) does not ballistically scatter from carbon (impossible with a pure binary collision). Instead, neon would desorb thermally and tend to recycle numerous time in the near-surface region, for the high density plasma regime modeled, thus effectively amplifying the 1% Ne/D core flux to maybe 10X as much at the divertor. After picking up high sheath energy, the neon etc. ions would likely be very effective at sputtering BC3.

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- I have not traced the fate of C (or B) entering the core plasma. Per comment above, the core-entering C current is about 10% of the sputtered current. Presumably, for boron, this would flow to various other surfaces (including some redeposition on the inner divertor iteself, but still a net loss of material from the inner divertor, as desired to clean up the boron). However, PPPL needs to think about the fate of B sputtered into the core plasma, i.e. where is it removed.
- One major caution-Charles alerted me to, post-exposure D-retention data of Wampler et al. (W.R. Wampler, C.H. Skinner, H.W. Kugel, A.L. Roquemore, J. Nuc. Materials 390-391(2009)1009), which, together with my present analysis, seems to point to a substantial additional source of carbon to the plasma, and inner divertor, of order 1-2% of the D flux. (A candidate source of this carbon is the center stack).
- If such high carbon content were to be present during "cleaning discharges" it could interfere with B removal, possibly burying the B under layers of carbon. (This comment also relates to my previous comment to Charles, that a "pure Mo" inner-divertor surface could get covered by carbon sputtered from other places.)
- Regarding the LLD, Jean Paul and I analyzed a Li surface only, and with a corresponding *low-recycle* regime (with very high Te, low Ne). However, I would guess that a high-recycle regime at the LLD, with Boron/Carbon surface, would have ballpark erosion rates same as inner divertor.

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Summary:

<u>Question from Henry:</u>

- How many discharges to erode 20nm of BC3 from the Mo tiles and LLD ?

<u>Answer by Jeff:</u>

- Subject to numerous qualifications, per above, and others,
- a *rough number for you to use in your discussion this week, is the 2 nm/s net erosion rate, thus order of 10 one second discharges to remove a 20 nm thick BC3 coating, and maybe much fewer discharges with added neon, argon.*