Thermodynamics of the Lithium Loop in a Liquid Metal Divertor for Future Fusion Reactors

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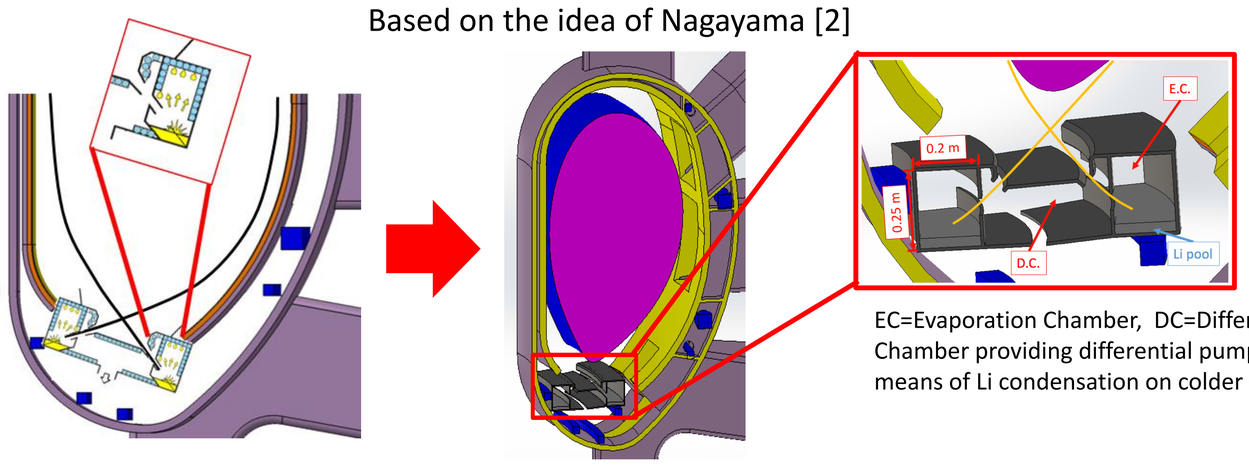
Background and aim

- Future fusion rectors like DEMO will encounter significant power exhaust issues.
- Alternative configurations are being studied to solve this issue, both numerically and experimentally,e.g. the DTT facility [1]
- One of the possible strategies foresees the usage of a LM (Liquid Metal) divertor.
- The aim here is to ***propose and develop a simplified model for a possible LM divertor for DTT.***

Preliminary CAD of a liquid metal divertor (the DTT case)

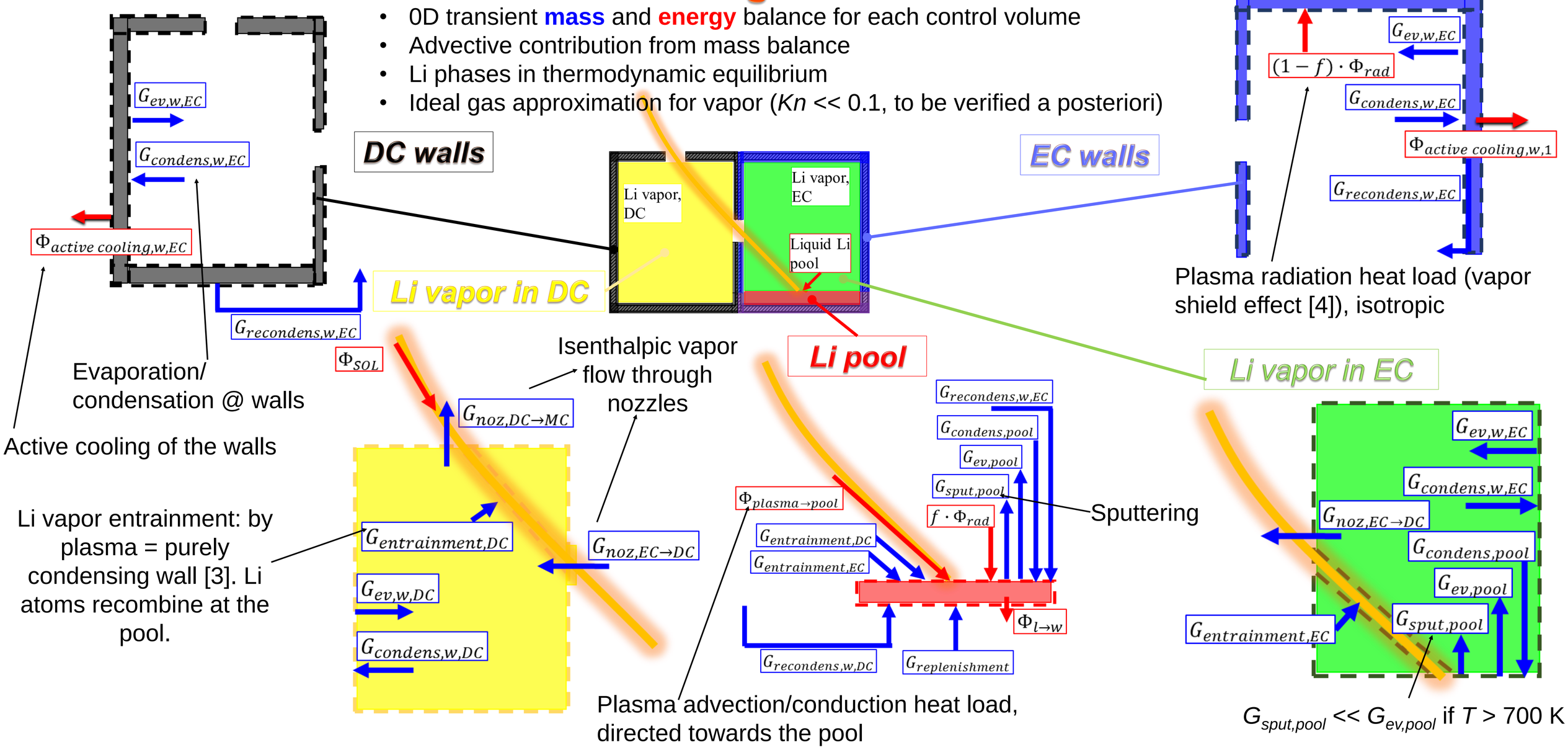
Based on the idea of Nagayama [2]



EC=Evaporation Chamber, DC=Differential Chamber providing differential pumping by means of Li condensation on colder walls

Model ingredients

- 0D transient **mass** and **energy** balance for each control volume
- Advective contribution from mass balance
- Li phases in thermodynamic equilibrium
- Ideal gas approximation for vapor (*Kn* << 0.1, to be verified a posteriori)



Evaporation/ condensation @ walls

Active cooling of the walls

Li vapor entrainment: by plasma = purely condensing wall [3]. Li atoms recombine at the pool.

Isenthalpic vapor flow through nozzles

Plasma advection/conduction heat load, directed towards the pool

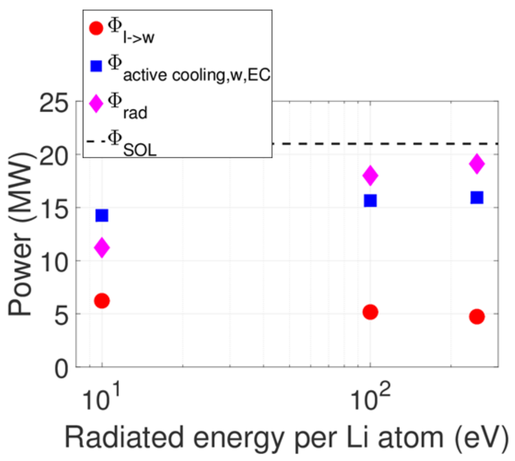
Sputtering

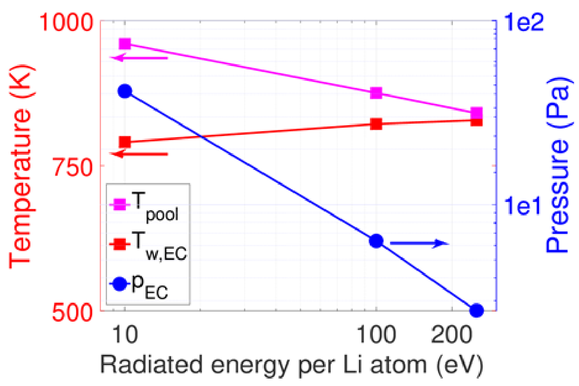
Plasma radiation heat load (vapor shield effect [4]), isotropic

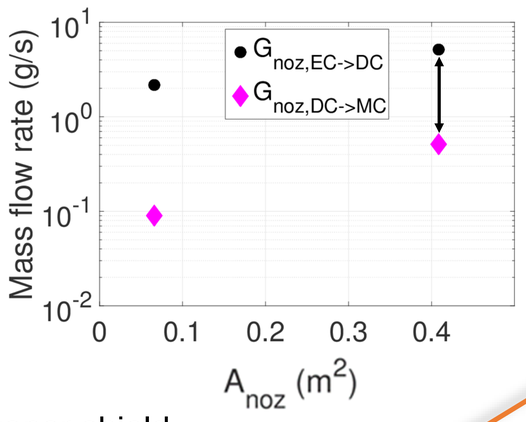
$G_{sput,pool}$ << $G_{ev,pool}$ if T > 700 K

Results

HTC between walls and coolant set to 5000 W/m^{2}K



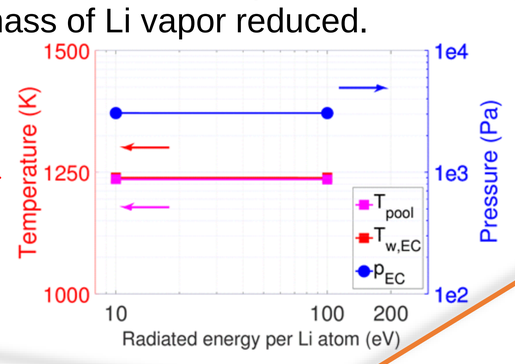




Li efflux to main chamber ~ 10^1 lower thanks to DC

- $E_{rad,pot,z}$ increased → heat load is shifted from the pool to the walls (vapor shield effect + evaporative cooling) → mass of Li vapor reduced.
- *Kn*<0.1 only in EC!

If *HTC* = 500 W/m^{2}K → *Kn*<0.1 in both chambers but unacceptable T_W



Conclusions …

- Thermodynamic model (0D mass & energy balances) for a pool type liquid Li divertor has been developed
- First application to DTT is proposed and analysed
- Combined effect of Li latent heat of evaporation and Li vapor ionization/radiation are effective in redistributing the plasma heat load
- Passive pumping due to Li vapor recondensation → reduction of Li contamination in main plasma chamber

… perspective

1) More detailed model of the plasma + Li vapor model suitable for *Kn*>0.1
2) Include CPS, Li condensate flows on EC walls, thermomechanics of wall cooling
3) Issue of D / T inventory in Li

Refs

[1] ENEA, Divertor Tokamak Test Facility Project Proposal, Frascati (2015).
[2] Nagayama Y., Fus. Eng. Des. 84 (2009).
[3] Goldston R. et al., Phys. Scr. T167 (2016).
[4] Mazzitelli G., 22nd PSI conference, Rome (2016).