Design Issues for UCLA Liquid Surface FW and Blanket Concepts

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Liquid wall concepts under investigation at UCLA

Convective Liquid Layer

Liquid-Filled Porous Wall

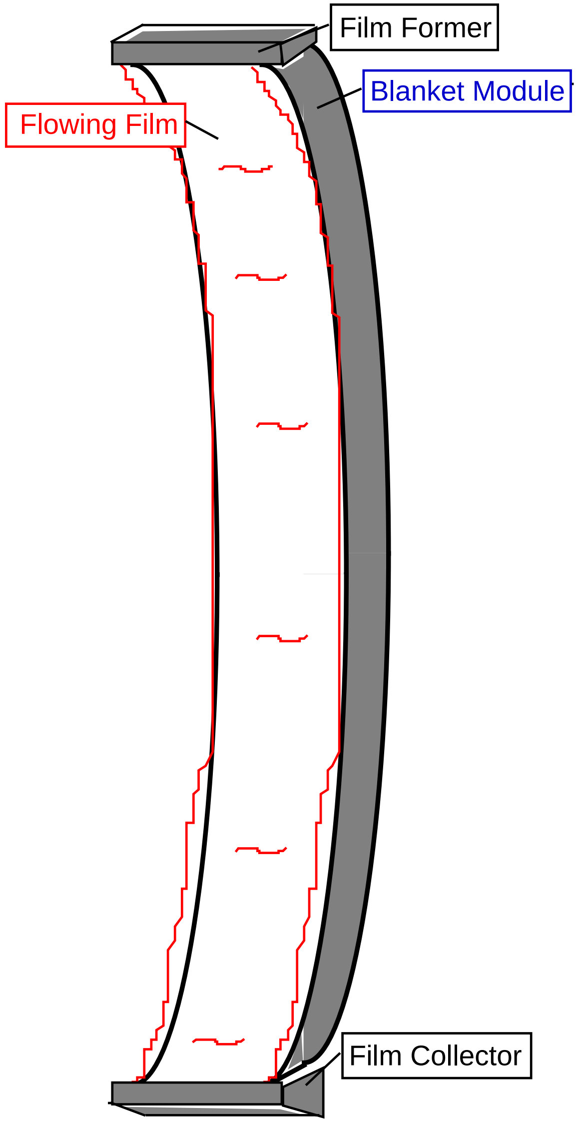
Multi-layered Thick Liquid FW and Blanket

- Concepts suitable for High Power Density extraction
- May have possibility of reduced mechanical failures and
- Increased maintainability

Convective Liquid Layer Concepts

- Use relatively thin/fast liquid layer to remove "surface" heat and peak nuclear heat in FW (and divertor) at low surface temperatures

- Pump liquid back through self-cooled blanket to:
  1. achieve bulk heating for energy conversion
  2. breed sufficient tritium
  3. attenuate neutron flux



<u>Other advantages</u>

- ➢ Renewable FW surface
- ➢ FW surface breeds tritium
- ➢ Flowing liquid pumps impurities
- ➢ Reduction of fluence to first structural walls

Series Issues for Convective Liquid Layers

- Surface Temperature & Heat Removal
  1. evaporation rate

- Hydraulics & Fluid Mechanical Stability
  1. film thickness and velocity
  2. velocity profile
  3. surface waves

- Tritium Breeding Characteristics
  1. optimum enrichment

- Mechanical Design Issues
  1. nozzles and collectors (diffusers)
  2. integrated divertor
  3. return pumping up through blanket module
  4. insulator coating
  5. ducts and antennae

Surface Temperature

Analysis

- Liquid layer velocity (Morley)
- Heat sources (Youssef)
  1. "Surface" heat composition
  2. Nuclear heating rates
- Design: choice of liquid and desired thicknesses (Ying, Youssef)
  1. Turbulent or laminar MHD
  2. Penetration of energetic photons
- Heat transfer calculations using all above data (Ying)

Preliminary Conclusions

- 20 m/s Lithium layer appears to be effective due to photon penetration and high thermal conductivity
- 20 m/s Flibe layer appears to be effective due to turbulent mixing
- However, limits on temperature or evaporation rates must be established

Hydraulics and Fluid Mechanical Stability

Analysis

- 1D hydraulics, behavior of bulk liquid flow (Morley)
  1. Development of the flow, thickening (slowing) or thinning (accelerating)
  2. Adhesion to backing surface

- Stability, behavior of surface (Morley, Konkachbaev)
  1. Velocity profiles
  2. Dripping
  3. Heat transfer at surface

Preliminary Results

- 20 m/s, 2 cm lithium film remains constant depth and centrifugally adhered along flow length

- 20 m/s, 6 cm flibe film grows slightly in depth and remains adhered along flow length. Will be unstable to surface waves which may grow rapidly in this geometry.

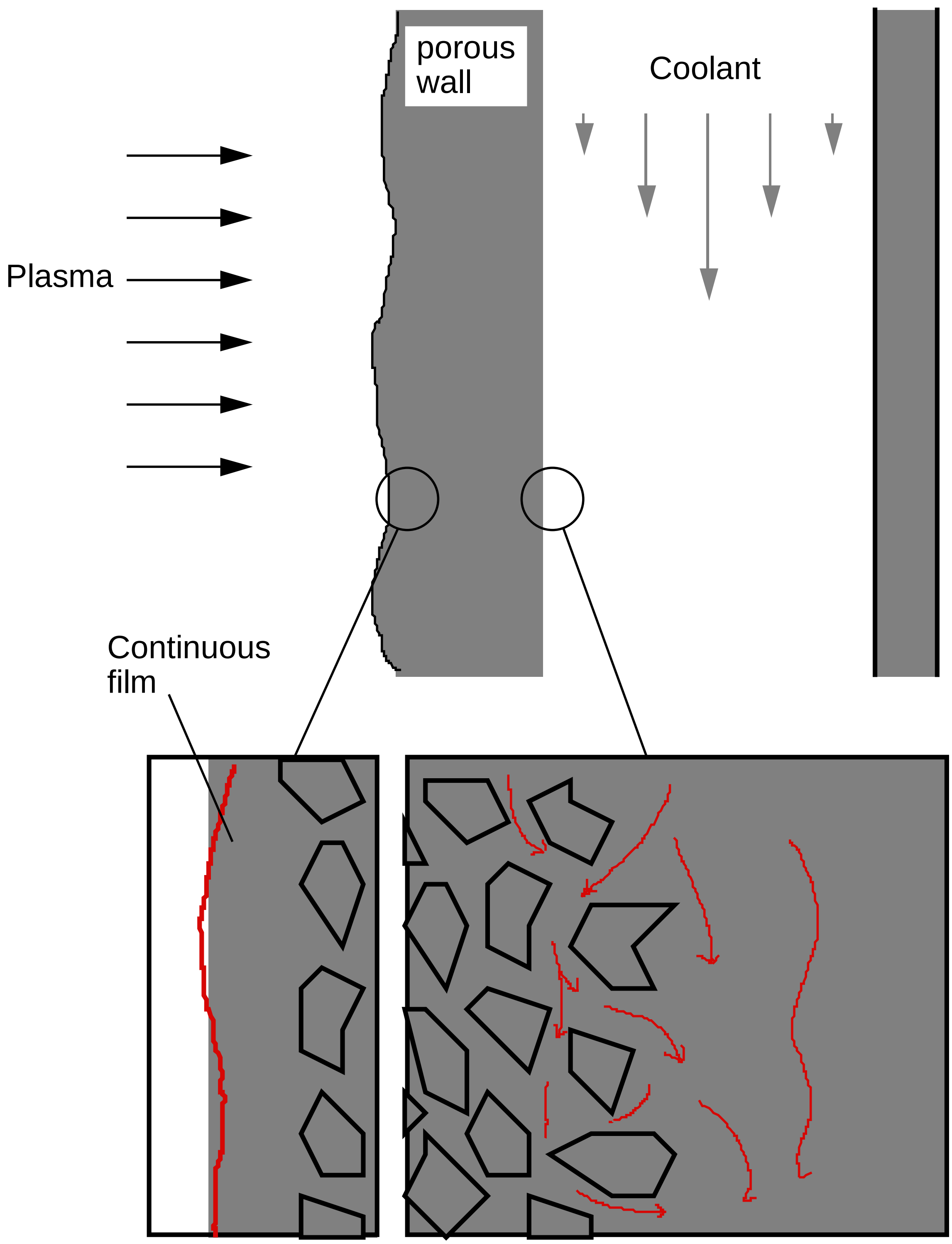
Liquid-Filled Porous Wall Concepts

- Liquid from cooling channel flows through porous wall to the plasma-facing surface
- Surface heat removed by combination of conduction to main coolant channels, convection along wall, and/or heat of vaporization

Advantages

- Renewable FW surface
- Reduced elastic modulus of porous material FW
- High thermal conductivity (even under irradiation) and thermal inertial due to filling porous FW with liquid
- Reduced coolant-side film drop and thermal contact resistance by direct liquid contact to bulk coolant and mixing

Liquid Film/Porous FW



Serious Issues for Liquid-Filled Porous Walls

- Structural properties and thermomechanics of porous FW materials
  1. FW overly weakened by porosity?
  2. Gain in thermomechanical performance?

- Hydraulics and fluid mechanical stability of free surface/porous wall liquid flows
  1. Thickness/velocity issue important for heat transfer to main coolant

- Allowable surface temperature due to excessive evaporation

- Compatible material choices and preliminary design

  1. Module size

  2. Liquid film removal in high heat flux area

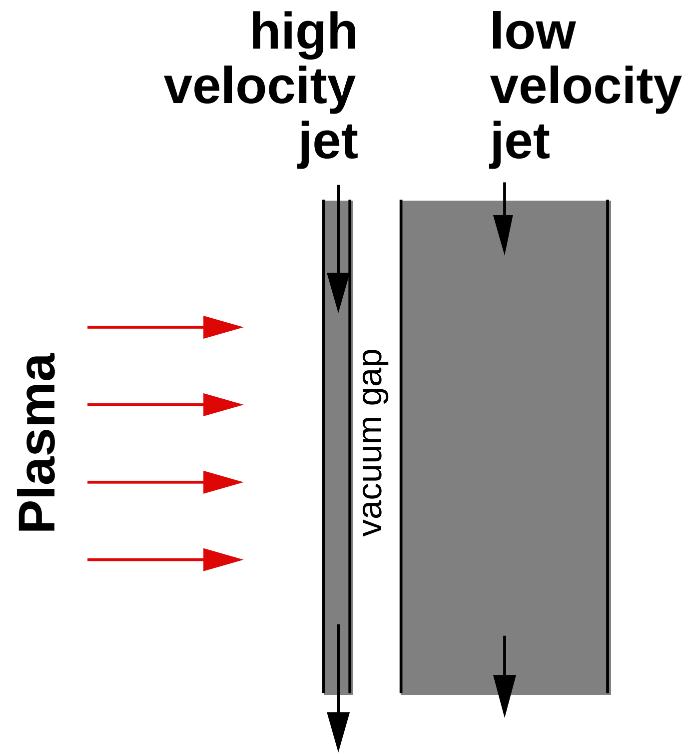
Structural Properties and Thermomechanical Performance of Porous Walls

(ElAzab)

- Effective Young's modulus, E
- Effective thermal conductivity, k
- Primary and secondary stress limits
- Failure mechanisms for porous materials (different from 100% dense?)
- Preliminary temperature and thermal stress calculations

Multi-Layered Thick Liquid FW and Blanket

- Fast front layer removes surface heat
- Recirculated to back layer which captures bulk heating, shields, and breeds



<u>Other advantages</u>

- ➢ Easy access when flow is off
- ➢ Lower activation and radiation damage of structures
- ➢ High tritium breeding ration