<u>Session III:</u>

Preliminary Examples of High Power Density Concepts

Moir, Morley, Sze, Wong, Wooley, Ying, others?

Advanced Power Extraction (APEX) Meeting

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Presentation Points

- How does the concept handle high power density (e.g. uses coolant latent heat to carry heat load)
- Can the concept be applied to large heat transfer areas
- What are the projected loads (P_{NW} and $P_{SURFACE}$) the concept can handle
- What other attractiveness features does the concept exhibit (e.g. renewable plasma facing surface, easy maintainability)?
- What are the anticipated problems associated with this concept (e.g. negative impact on TBR)?
- Required next steps to flesh out the concept

Free Liquid Surface FW and Blanket Concepts for High Power Density Reactors

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Liquid-Filled Porous First Wall

Description

Plasma facing surface is porous

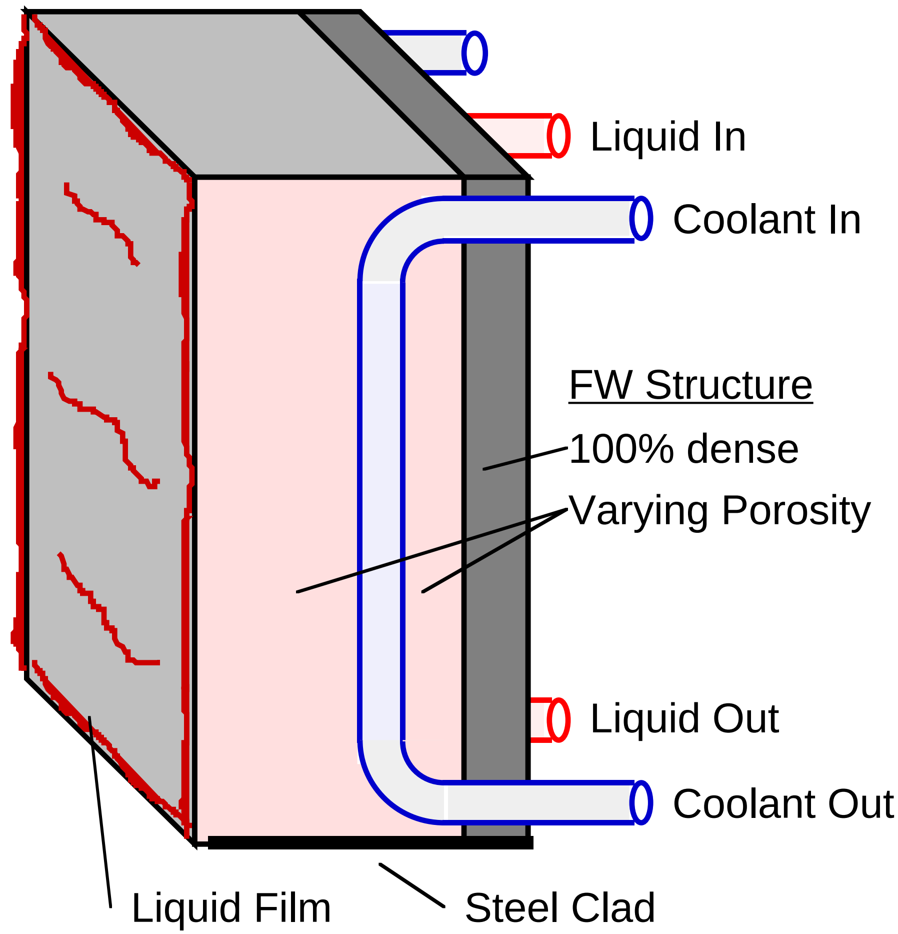
High k liquid fills gaps in porous wall

Thin metal (V, Ferritic) tubes contain pressurized coolant, or leaky tubes for self-cooled approach

Concept

Liquid in bulk provides compliant conduction path to coolant

Liquid film protects surface from damage by the plasma



HPD Rational for Liquid-Filled Porous FW Concept

Reduces stress in FW structure by:

- decreasing effective elastic modulus
- increasing effective thermal conductivity (especially for LMs/Ceramic combinations)
- increased contact conductance between coolant tube and FW structure
- decreases required FW armor thickness

Power Density Limits

- Difficult to estimate, but above factors should increase the heat removal capability compared to 100% dense walls

Other Attractive Features of Liquid/Porous Wall Concept

- Liquid layer at surface protects underlying structure from charge exchange neutrals, off-normal plasma events (renewable armor)

- Reduced degradation of the FW thermal conductivity due to neutron irradiation

- Use of breeding (Li, LiPb, Flibe) or neutron multiplying (Pb) liquid possible

- Possible extension of FW concept to entire “weeping block” blanket module

  1. High P_{nw} capabilities
  2. Passive refueling possibilities (DT diffusion out of LiPb)

Required R&D

Potential Issues

- Evaporation from liquid surface (plasma contamination)
- Additional liquid feed and collection systems required
- Impact on FW strength

Near Term Tasks

- Assessment of thermomechanical characteristics of porous metals and ceramic composites. Identification of suitable materials
- Quantitative calculation of FW stress/temperature behavior
- Determine liquid surface temperature limits

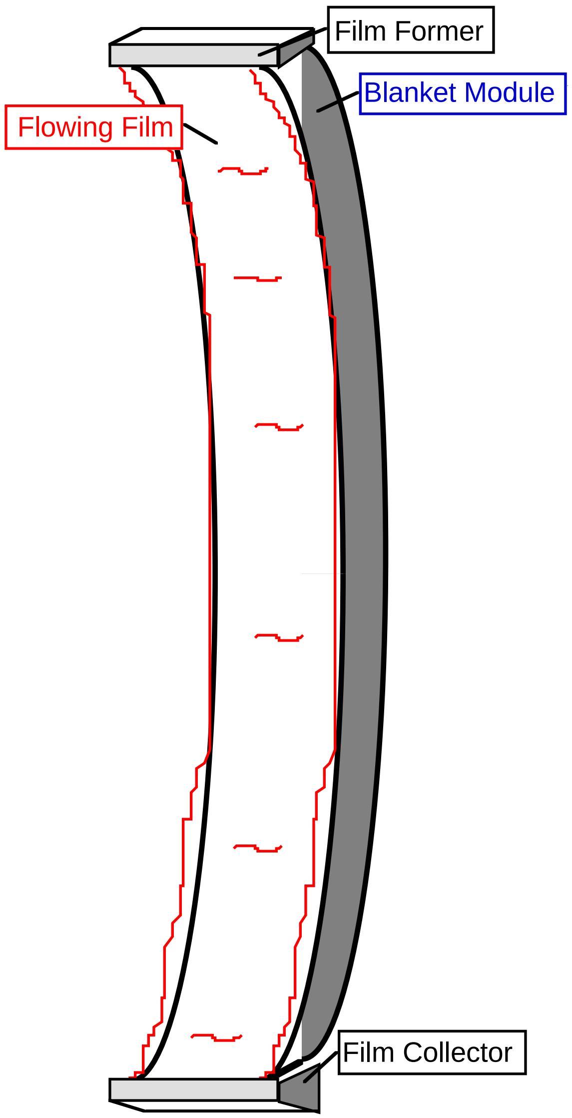
Rapidly Flowing Liquid Film FW

Description

- Flowing film is injected along wall
- Film flows poloidally along module surface
- Film is collected and removed from the plasma chamber

Concept

- Liquid film convects heat away from first structural wall
- Liquid protects surface from damage



HPD Rational for Fast Liquid Film Concept

Elimination of structural wall in contact with the plasma

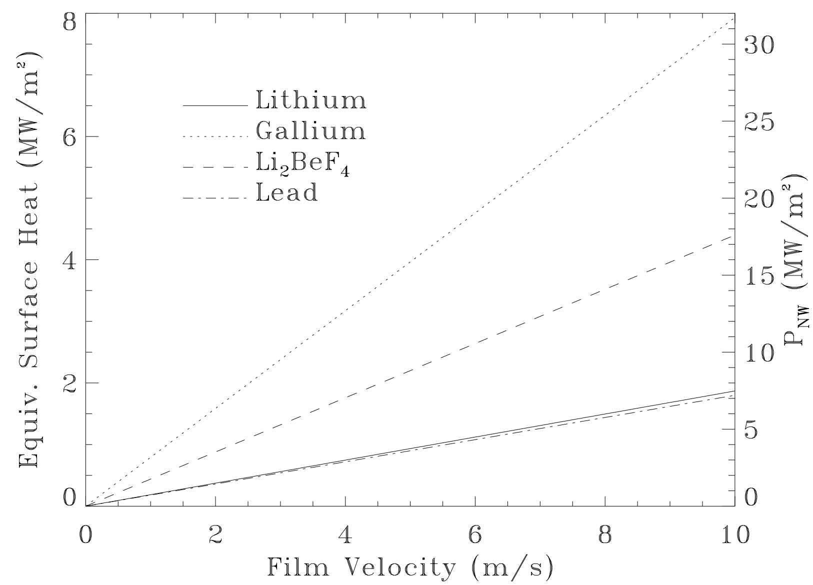
- eliminates thermal stress problems in FW
- allows heat deposition directly into coolant

Power Density Limits

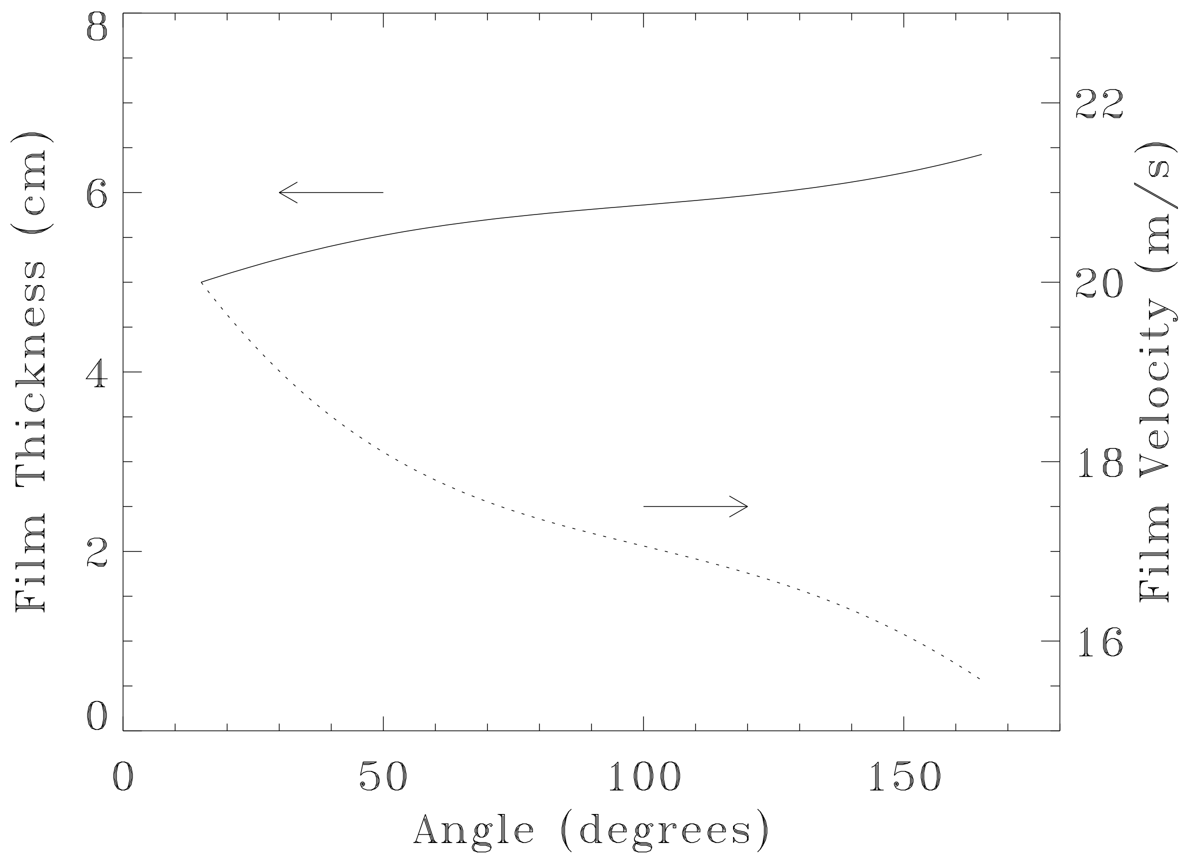
$$q'' + q'''t = (vt / L)(\rho c_p \Delta T)$$

t = 5 mm
L = 10 m
$\Delta T \equiv (T_{10\text{-}5\ Torr} - T_{melt})$

(except Flibe, $\Delta T = 200^{\circ}C$)

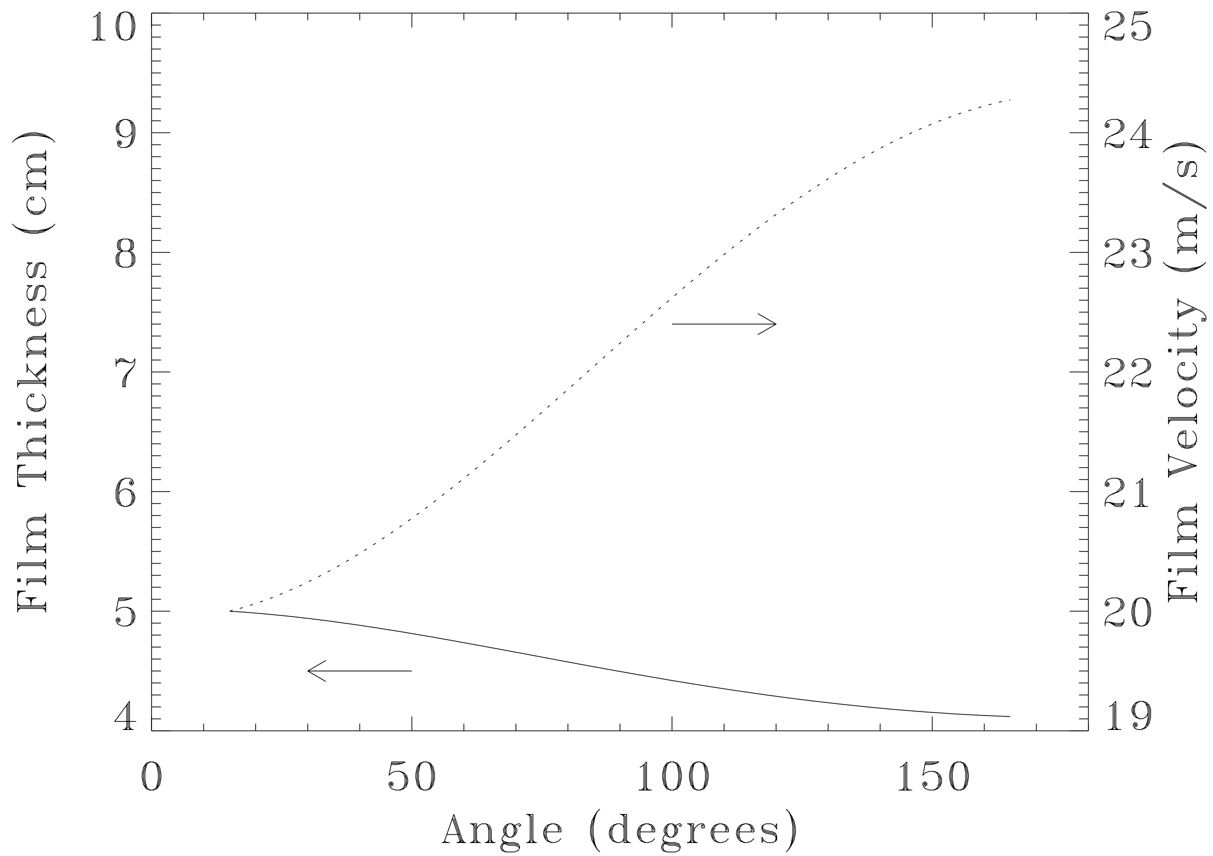


Turbulent Liquid Film Depth and Velocity Profile



Adhered Flibe film over 150˚ arc (13 m length)

Laminar Liquid Film Depth and Velocity Profile



Adhered Lithium film over 150˚ arc (13 m length)

Other Benefits of Fast Liquid Film Concept

- Liquid layer at surface protects underlying structure from charge exchange neutrals, off-normal plasma events (renewable armor)
- Use of breeding (Li, LiPb, Flibe) or neutron multiplying (Pb) liquid possible
- No degradation of the FW thermal conductivity due to neutron irradiation
- Possibility of integrated limiter or divertor (ALPS)

Required R&D

Potential Issues

- Evaporation from liquid surface (plasma contamination)
- Additional liquid feed and collection systems
- Liquid flow control during normal and off-normal plasma operation (pressure drop, stability, MHD, etc.)
- Corrosion

Near Term Tasks

- Consistent heat transfer/hydrodynamics calculations
- Assessment of need for insulator coatings (LMs only)
- Liquid temperature limits assuming plasma contact