Management of Severe Accident Phenomena in the ESBWR Design

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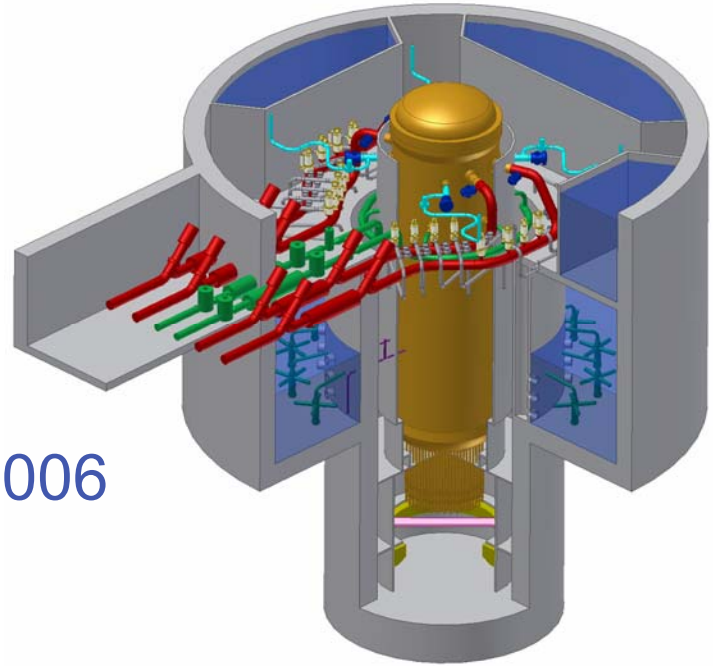

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imagination at work

Treatment of Severe Accidents

Severe Accidents in ESBWR are Remote and Speculative

- > Core Damage Frequency □ 10^{-8} per year
- > Could be treated as Residual Risk

GE Designs for Defense-In-Depth

- > Assessed full complement of severe accident threats
- > Determined and Enhanced ESBWR capabilities

Result:
ESBWR Containment Failure is Physically Unreasonable

Severe Accident Threats and Failure Modes Resolved in ESBWR Design

Direct Containment Heating (DCH)

- No energetic failure of upper drywell
- No liner failure in upper drywell
- Fission products contained during potential local failures of lower drywell liner

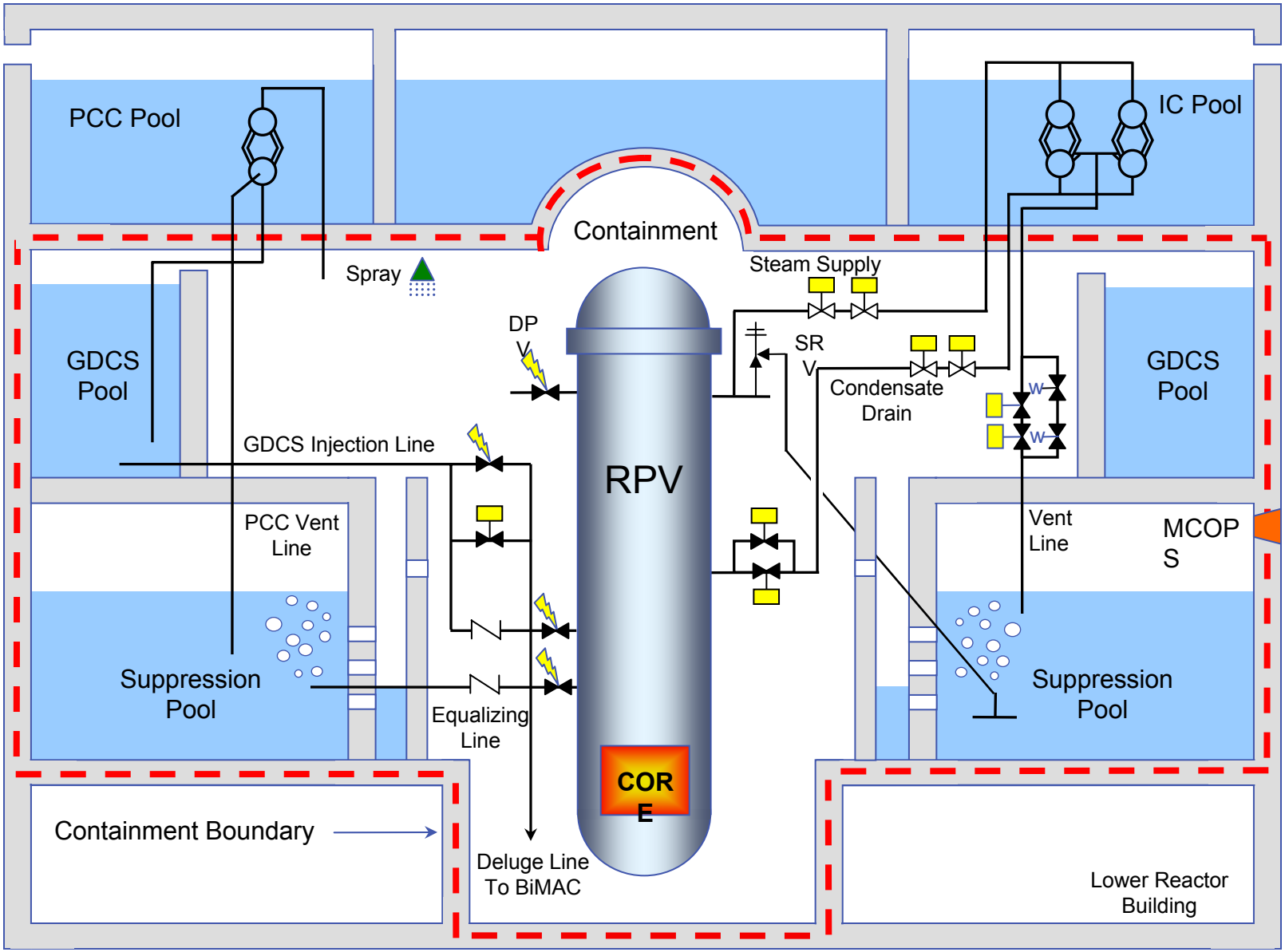
Ex-Vessel Explosions (EVE)

- Pedestal or BiMAC failure can occur only with deep subcooled pools of water in lower drywell
- ESBWR design resists formation of deep pools (~1% of CDF)

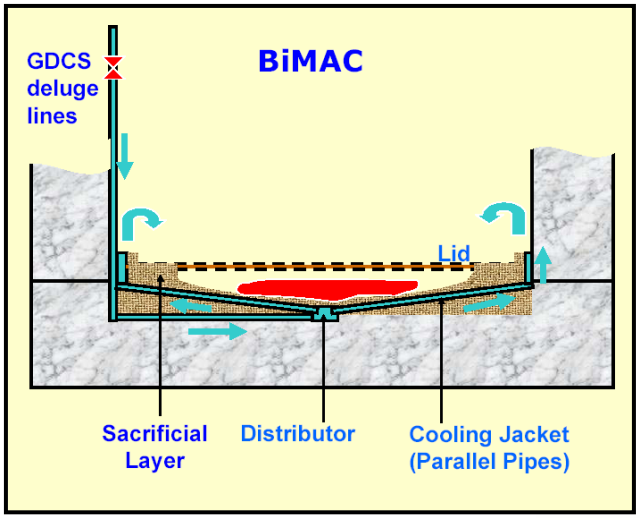
Basemat Melt Penetration (BMP)

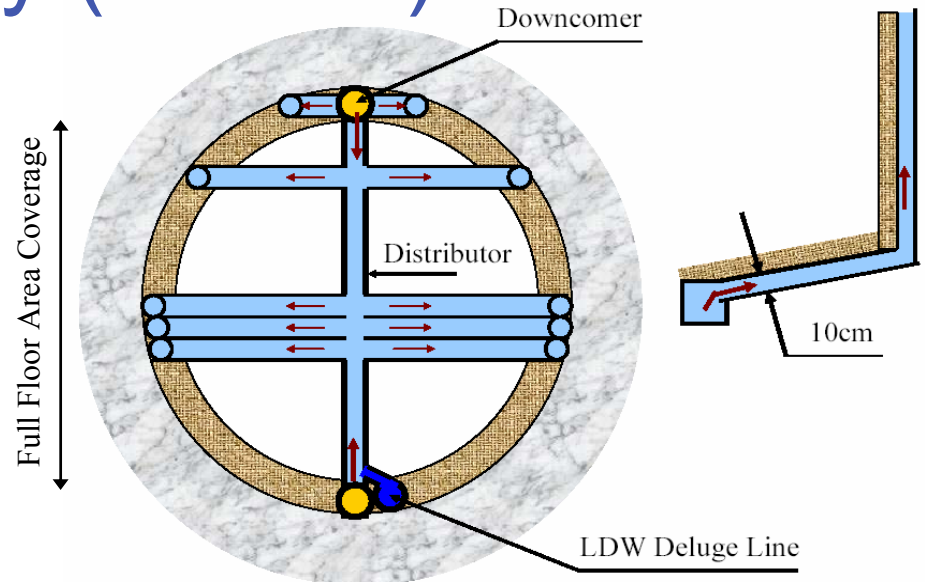
- BiMAC thermal failure due to burnout, dryout, or penetration is physically unreasonable

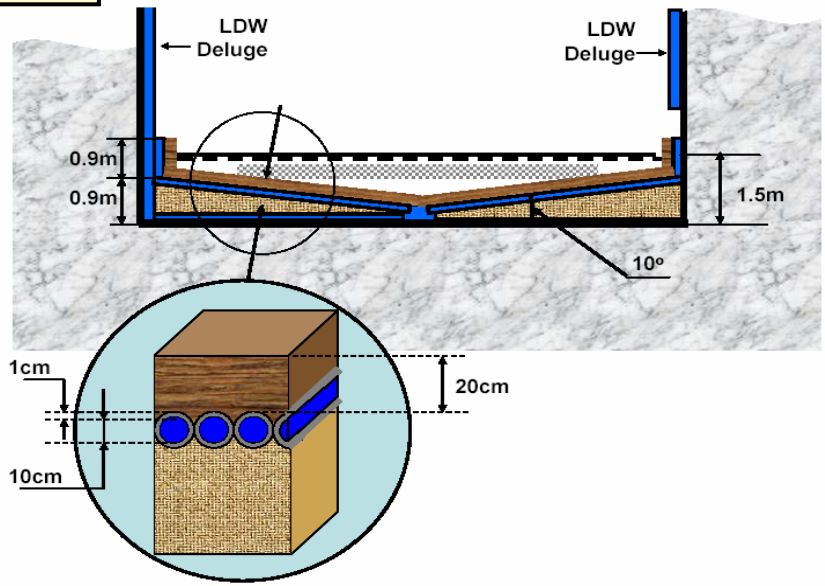
ESBWR Containment Highlights



GE Introduces the Basemat internal Melt Arrest and Coolability (BiMAC) Device







Basemat Melt Penetration (BMP)

Assessment of BiMAC Thermal Failure due to Burnout or Dryout

Key Bounding Ingredients:

- Average thermal loads from full-core pools at bounding decay power levels
- Bounding local peaking of loads from verified CFD calculations
- Lower bounds of CHF from ULPU pool boiling experiments
- No flow-stability, or boil-off issues, found using a two-phase flow model that was verified using inclined-channel data from the SULTAN experiments
- Full floor area coverage—the melt has no other place to go but inside the BiMAC.
- Confirmatory full scale BiMAC tests during COL stage

BiMAC Thermal Failure is Physically Unreasonable

Average Thermal Loads and Peaking Factors

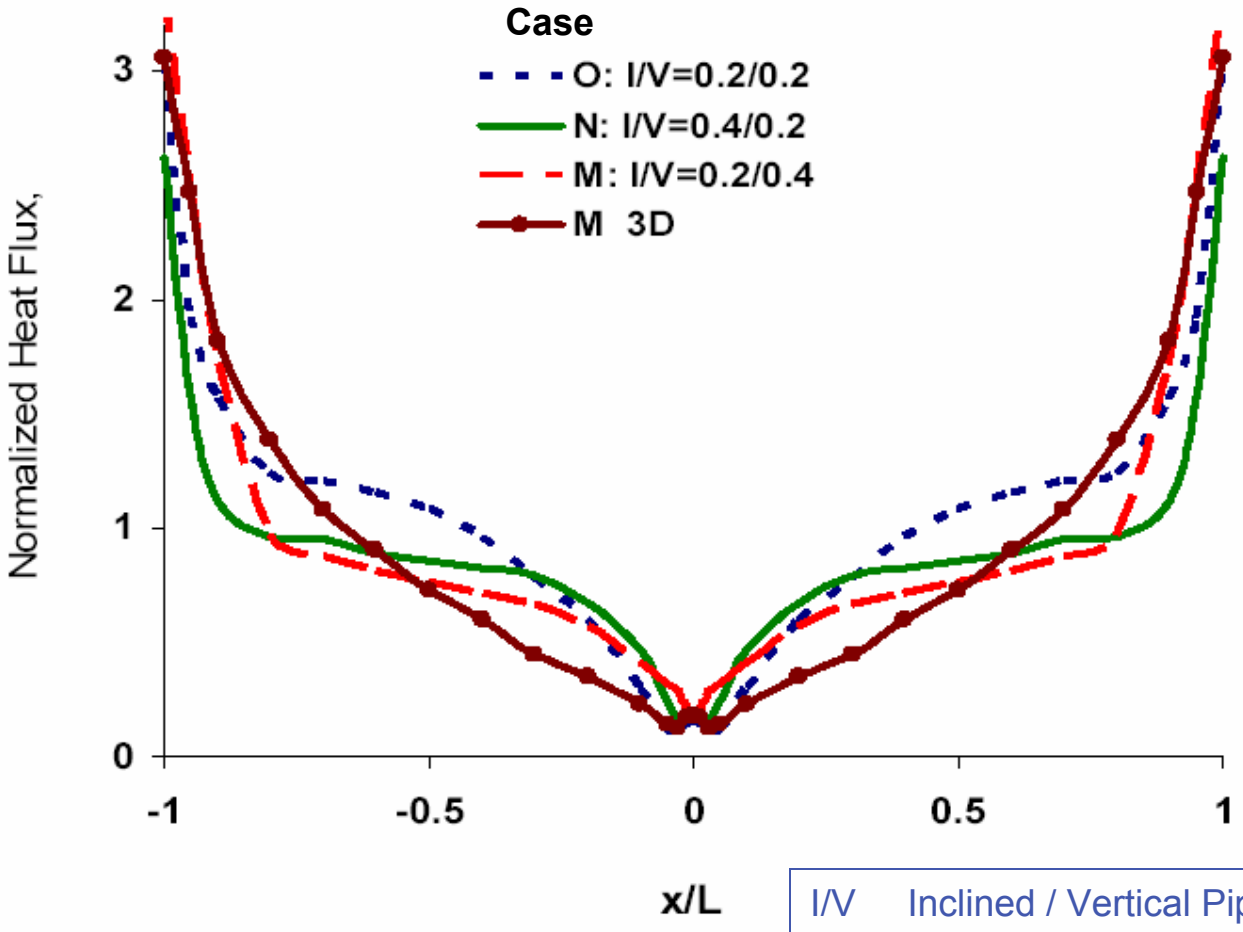
BiMAC Thermal Capacity a Function of Melt Pool Height and Resulting Average Heat Fluxes

- 100% core decay power at ~6 hr into the accident
- Bounding scenarios
  - ≤ 100 kW/m2 downward heat flux
  - ≤ 350 kW/m2 sideward heat flux

Power Split and Peaking Factors from Direct Numerical Simulations

- Downward peaking: 3.0
- Sideward Peaking: 1.4

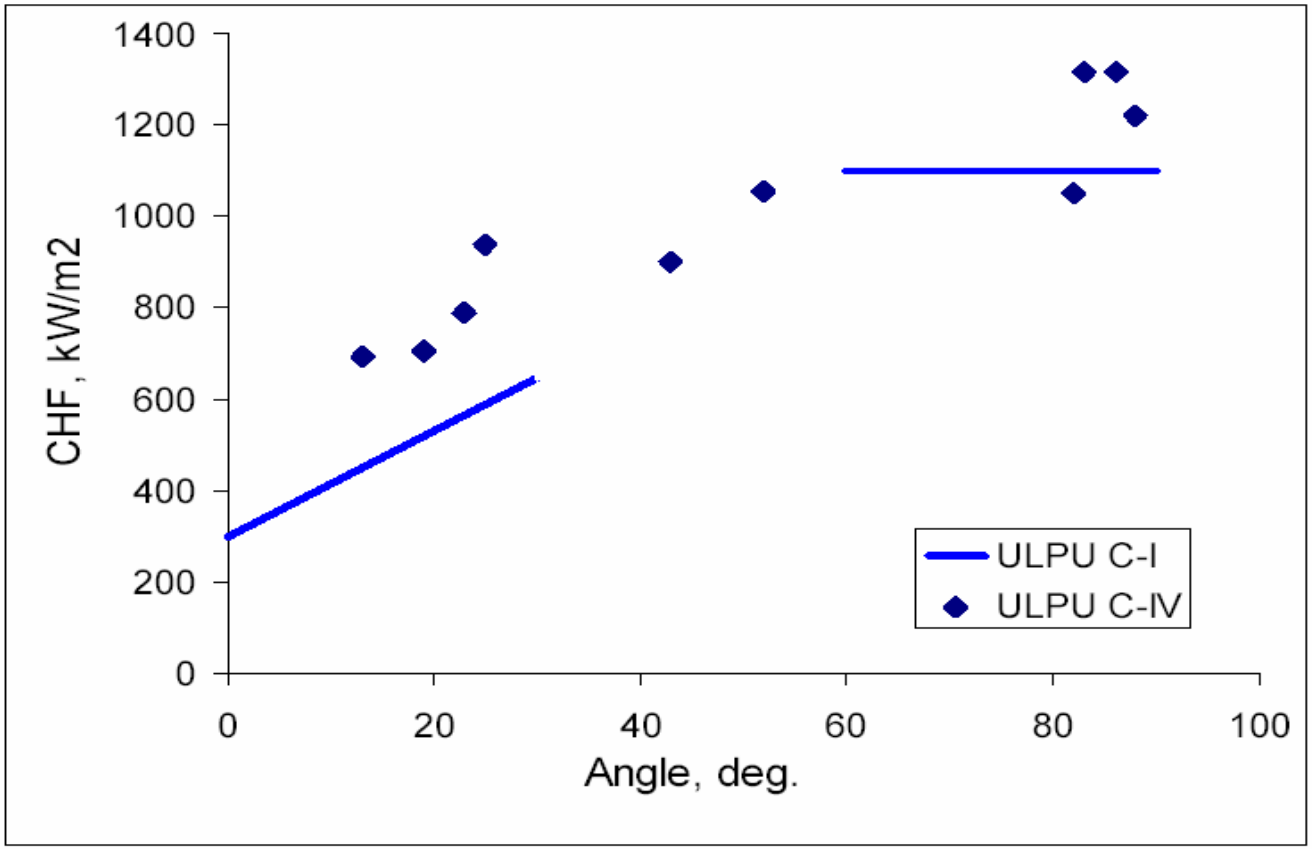
The Peaking at the Edge of Near-Edge Channels is the most Limiting



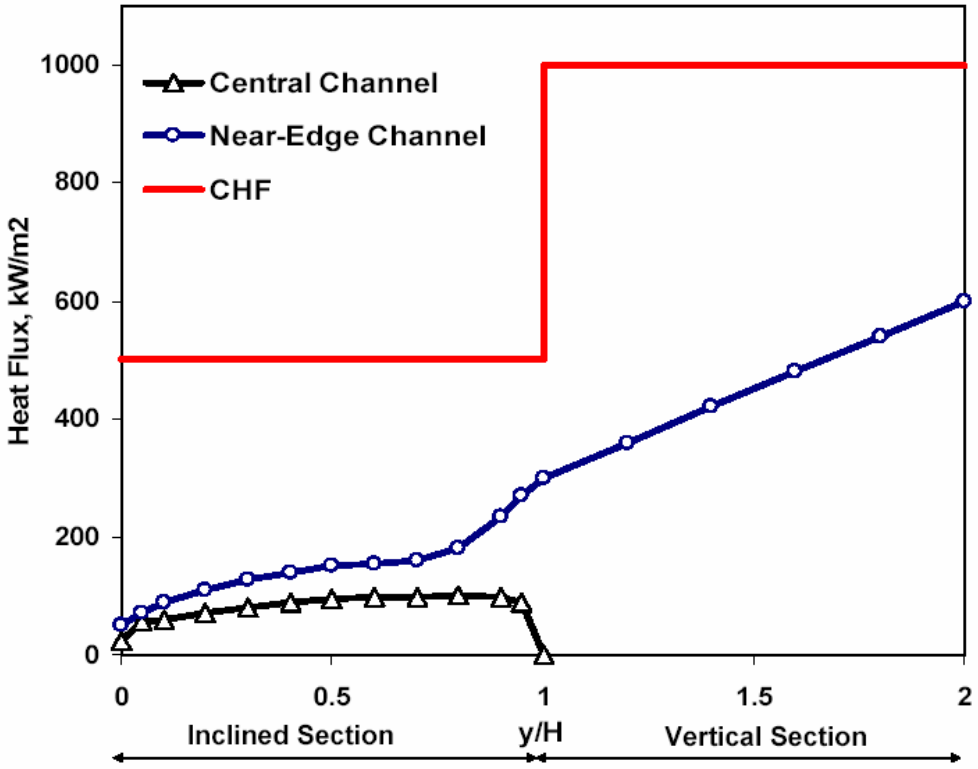
I/V	Inclined / Vertical Pipe Length Ratio
3D	Simulation

Coolability Limits for BiMAC

Applicability based on similarity of geometries and flow/heating regimes



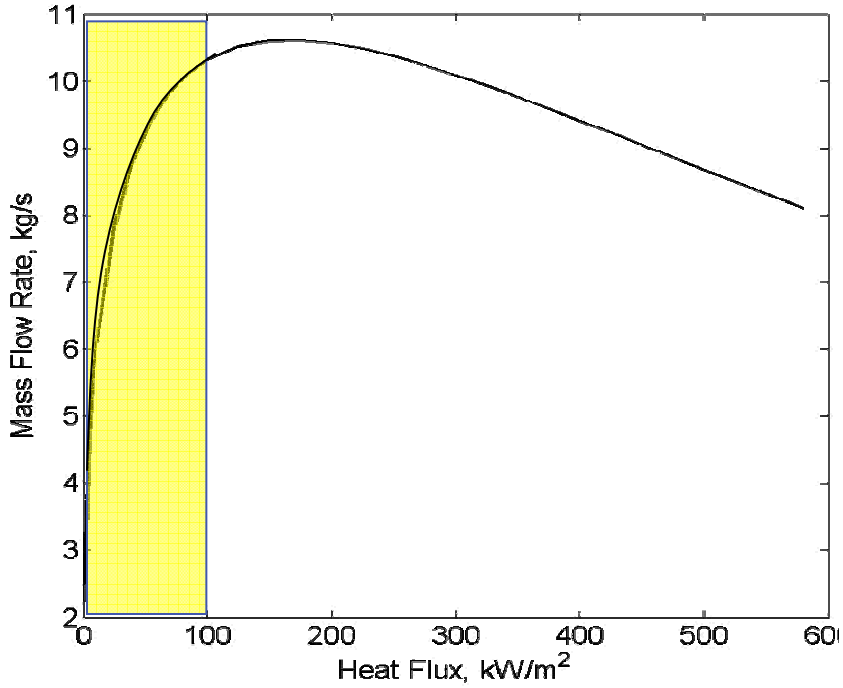
Thermal Loads vs Coolability Limits in BiMAC Channels



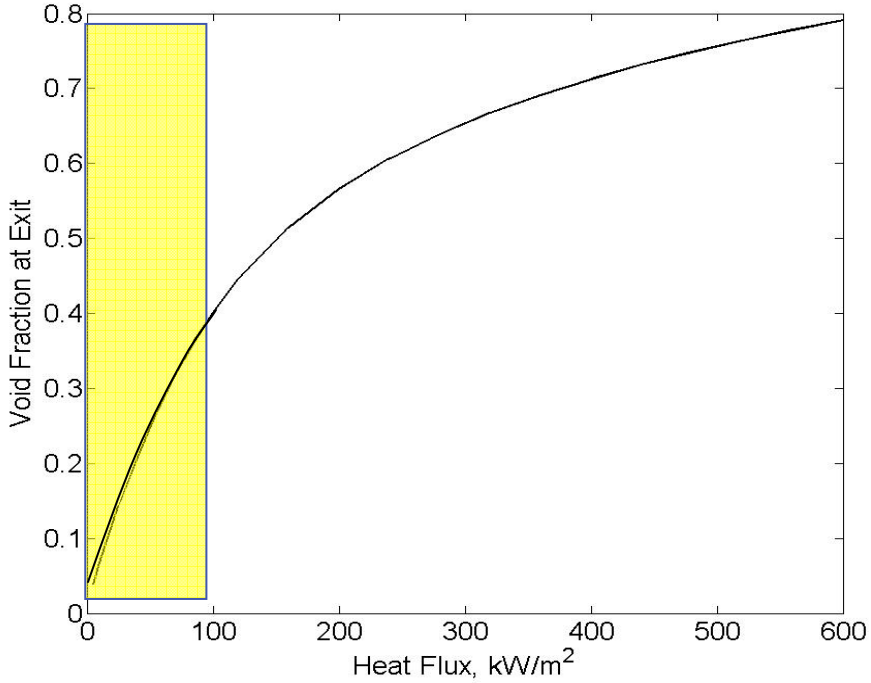
- Based on ULPU data
- Margins to be verified by new experiments at full scale

BiMAC Operating Range

Natural Convection in BiMAC



Thermal Margins for BiMAC



No Flow Instability

No Danger of Dryout

- Operating range to be optimized through new experiments at full scale

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GE Designs for Defense-In-Depth

- > Assessed full complement of severe accident threats
- > Determined and Enhanced ESBWR capabilities
- > Verified by a full ROAAM treatment

NEDO-33201 Section 21 Contains Complete Details of these Analyses