GSI-191
Long-Term Core Cooling

Core Inlet Flow Blockage

February 6, 2007

Topics

- Problem Statement
- PWR Vessel Design Comparisons
  - Selection of plant to be modelled
- WCOBRA/TRAC Modelling Approach
- Preliminary Results

Problem Statement

- For a Double-Ended Guillotine Break:
  - RWST can be Depleted, and,
  - Sump Recirculation Begun Within ~ 20 Minutes
- Fibrous Debris and Particulates Can Pass Through Sump Screen
- Potential for Build-up at Core Inlet
  - Fuel assembly bottom nozzle, debris filter, grids
  - 1/8 inch of uniform matting with trapped particulates sufficient to cause high head loss

Selection of Limiting Break

Double-Ended Cold Leg

- Spilling of ECCS to containment
- Gravity head to loop level only
  - True for no single failure also
- Lower flow results in slower debris build-up

Double-Ended Hot Leg

- No spilling of ECCS
- Additional driving head from ECCS pumps
  - more for no single failure
- Higher flow results in faster build-up

Use Double-Ended Cold Leg Break With No Delay in Debris Build-up

Vessel Design Considerations (W OEM)

- Designed Upflow is Least Limiting
  - Numerous large pressure relief holes in baffle wall allow flow to bypass core inlet if blocked
- Converted Upflow is More Limiting
  - No pressure relief holes, limited flow to top of core (if any)
- Downflow is Most Limiting
  - Flow must enter core through lower core plate

Other PWR Vessel Designs

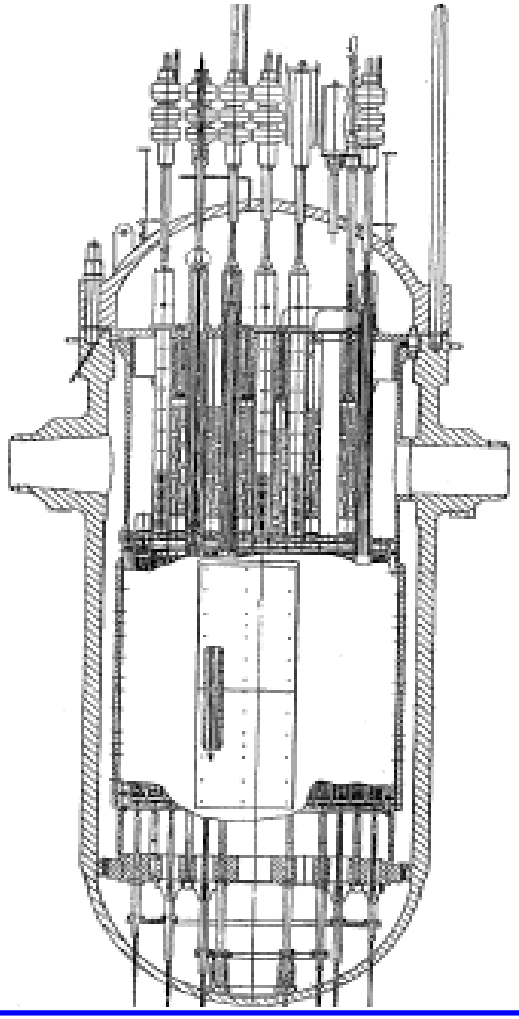
- B&W Design Similar to W Designed Upflow
  - Numerous large pressure relief holes in baffle wall allow flow to bypass core inlet if blocked
  - Barrel vent valves located above loop level
    - No impact on this issue
- CE Design Similar to W Converted Upflow No pressure relief holes, limited flow to top of core (if any)

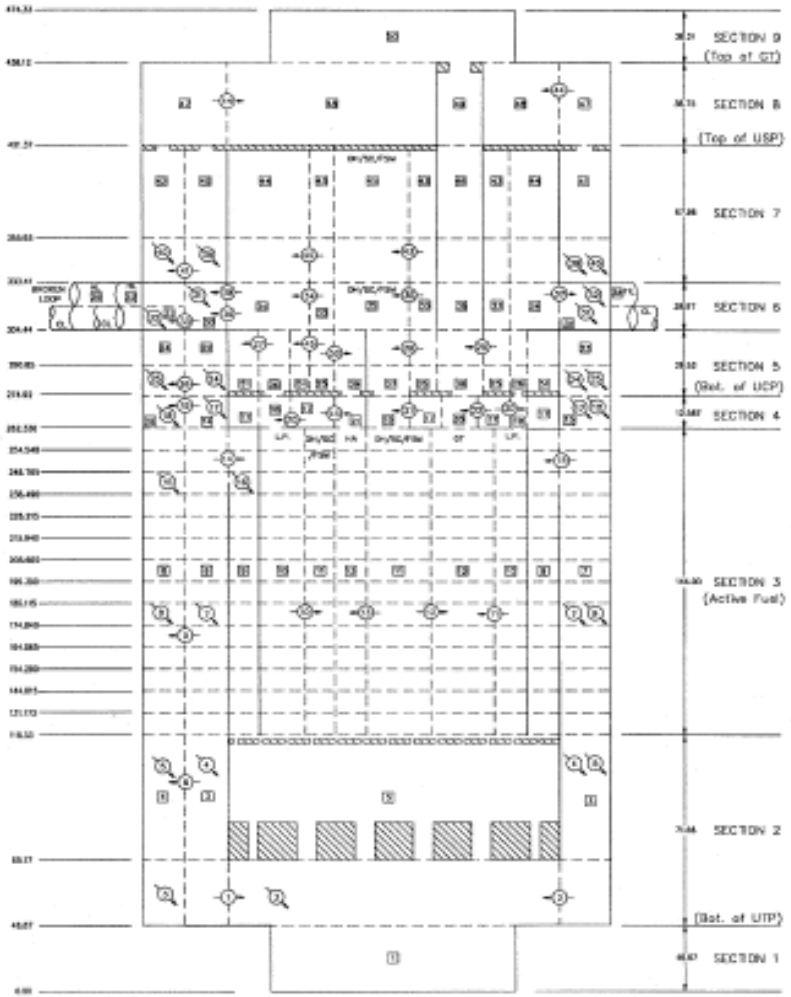
W Downflow Design is Bounding

Plant Selection

- Downflow Most Limiting Configuration
- Core Power Density Also Important for Heat Removal
  - Use available 3-loop downflow model for plant rated at 2900 MWt

Vessel Sketch and Noding Diagram

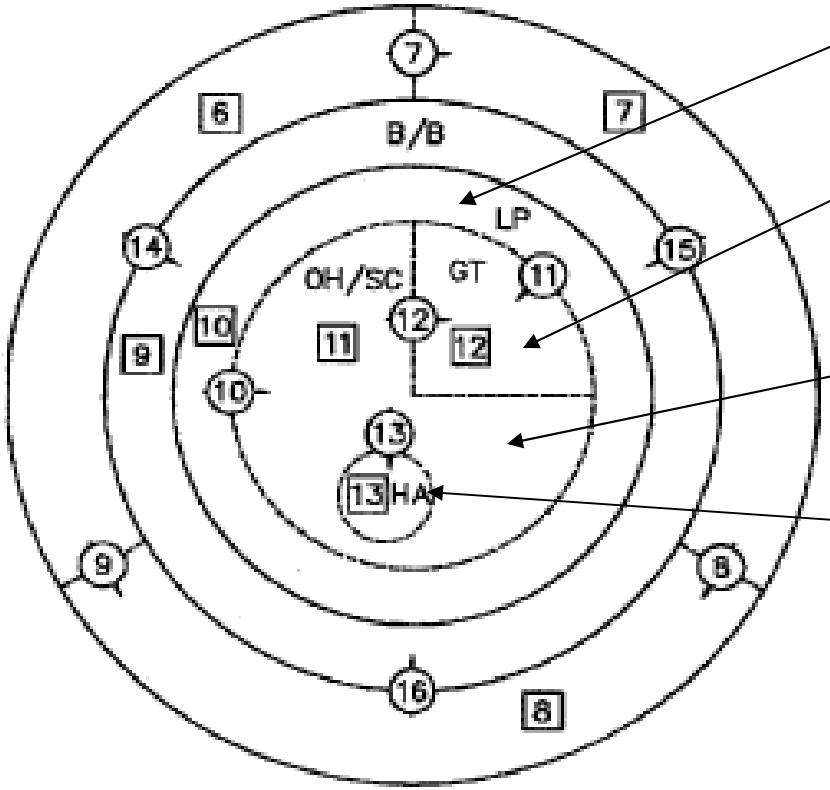




WCOBRA/TRAC Modeling Approach

- Run Problem from Break Initiation
  - Create Single Use code version which ramps in high resistance as specified by User
  - Ramp in large increase in resistance at core inlet of PWR model
  - Investigate effect of radial distribution of resistances (conceptual at this point)

Standard Core Modelling



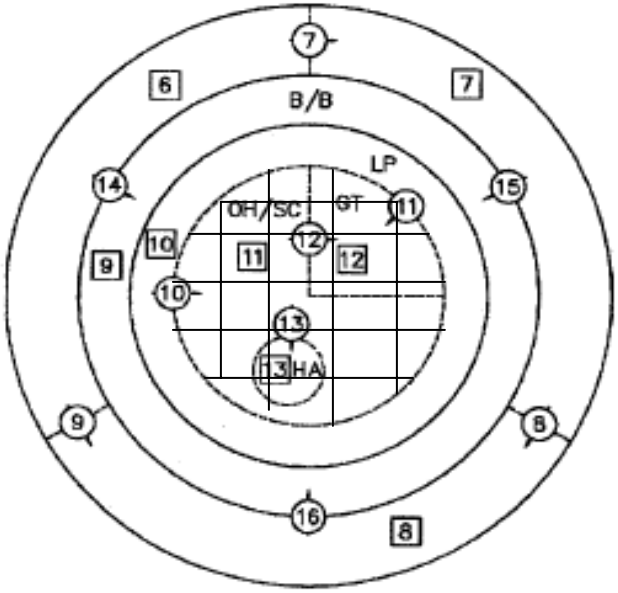
Peripheral Assemblies (28)

Interior Assemblies Under Guide Tubes (53)

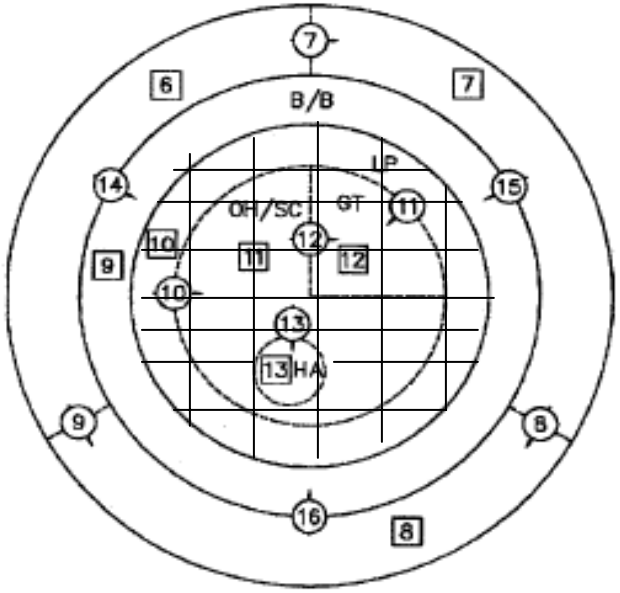
Interior Assemblies Under Other Structures (75)

Hot Assembly Under a Restricted Flow Structure (1)

Blockage Approaches (Conceptual)



Block All Except Peripheral
(82%)

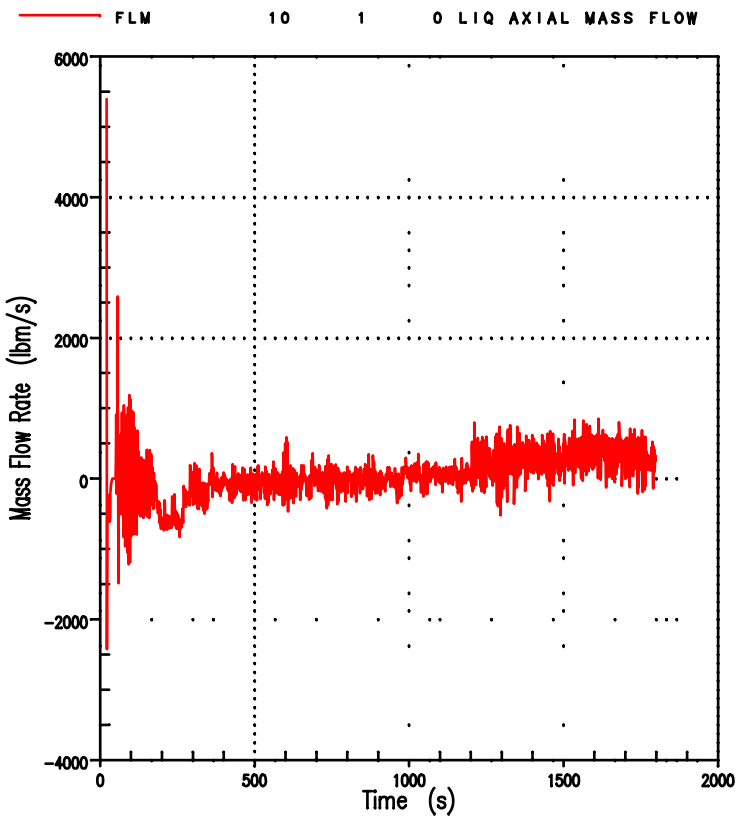


Block All Except Hot Assembly
(99.4%)

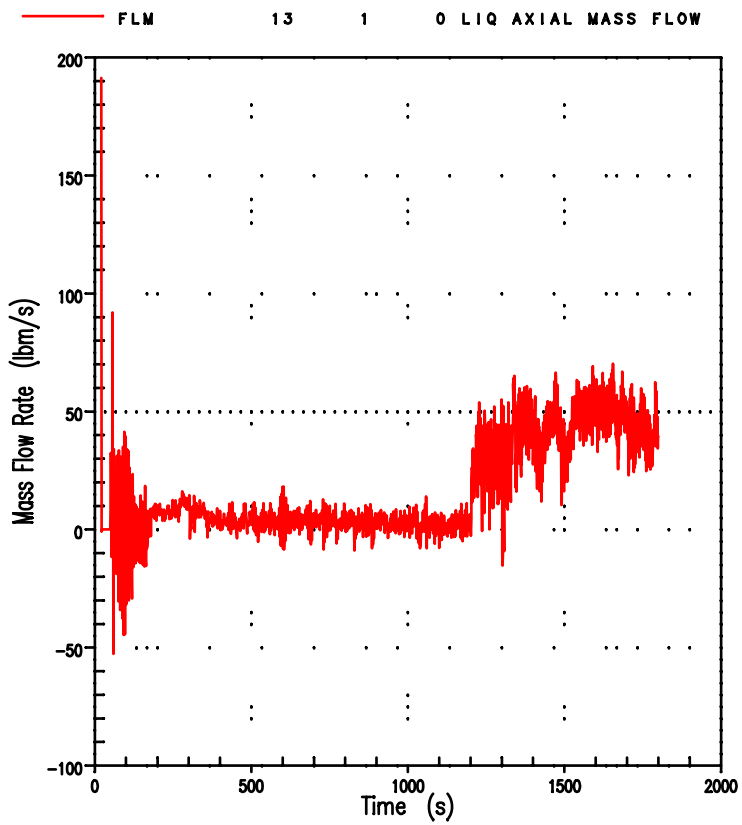
Results to Date

- Both Blockage Cases Run to 30 Minutes
  - Blockage ramped in from 20 to 20.5 minutes
    - K = 1000 used to simulate blockage
- Evaluation of Initial Results
  - Need larger K to adequately block channels
    - Case with 99.4% blockage has hot assembly flow approaching that required to replace core boil-off due to decay heat
    - Case with 82% blockage has total peripheral assembly flow well in excess of boil-off

Flow Through Unblocked Channel



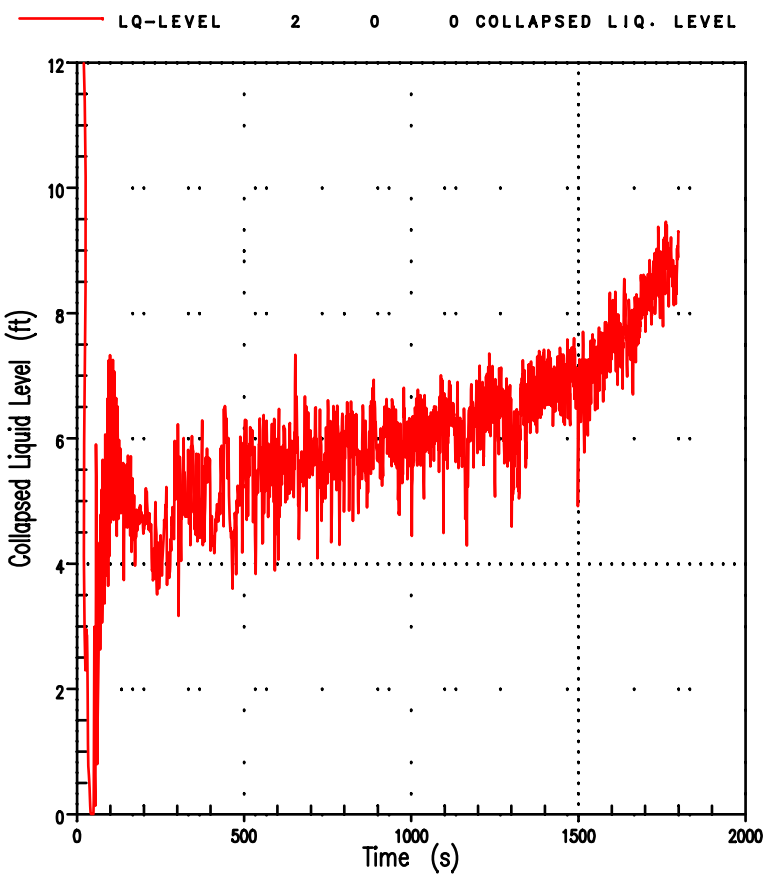
82% Blockage



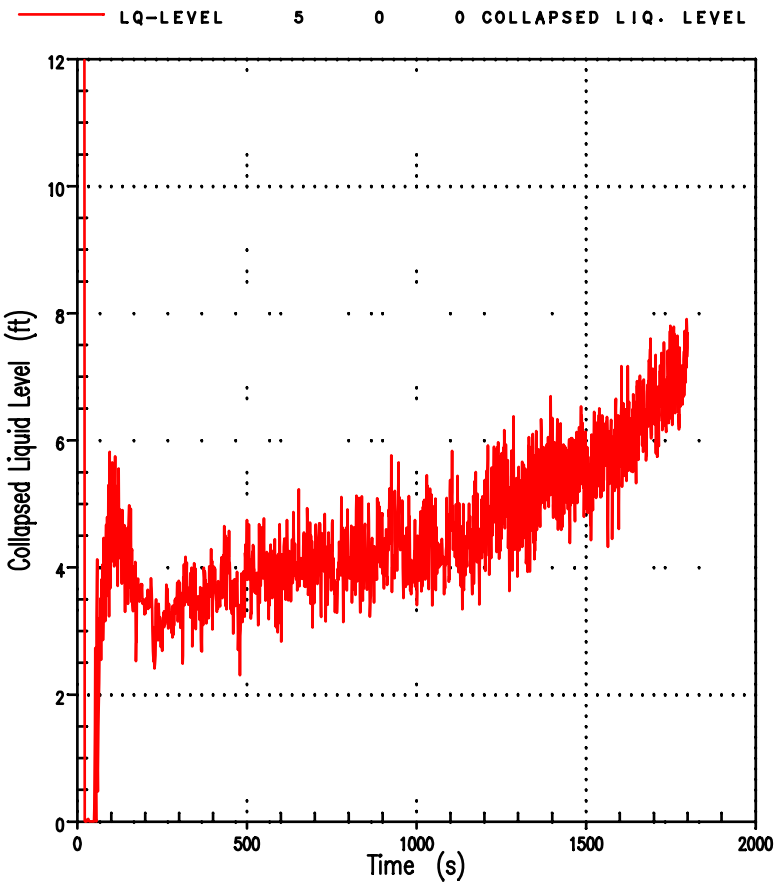
99.4% Blockage

Need < 60 lb/sec to replace boil-off at 20 min.

Collapsed Liquid Level in Core

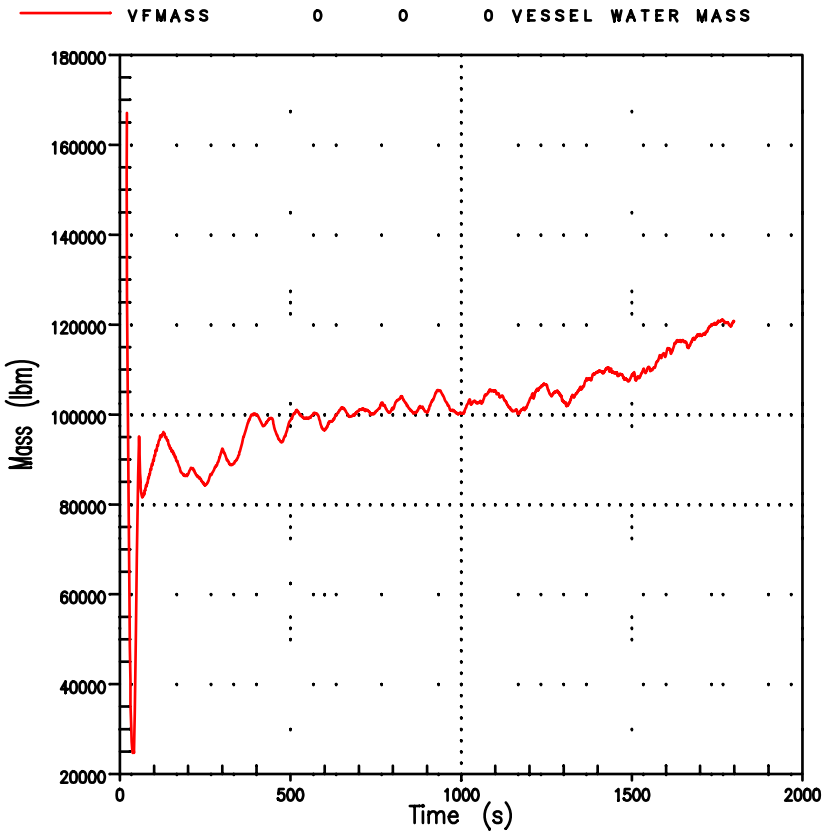


82% Blockage

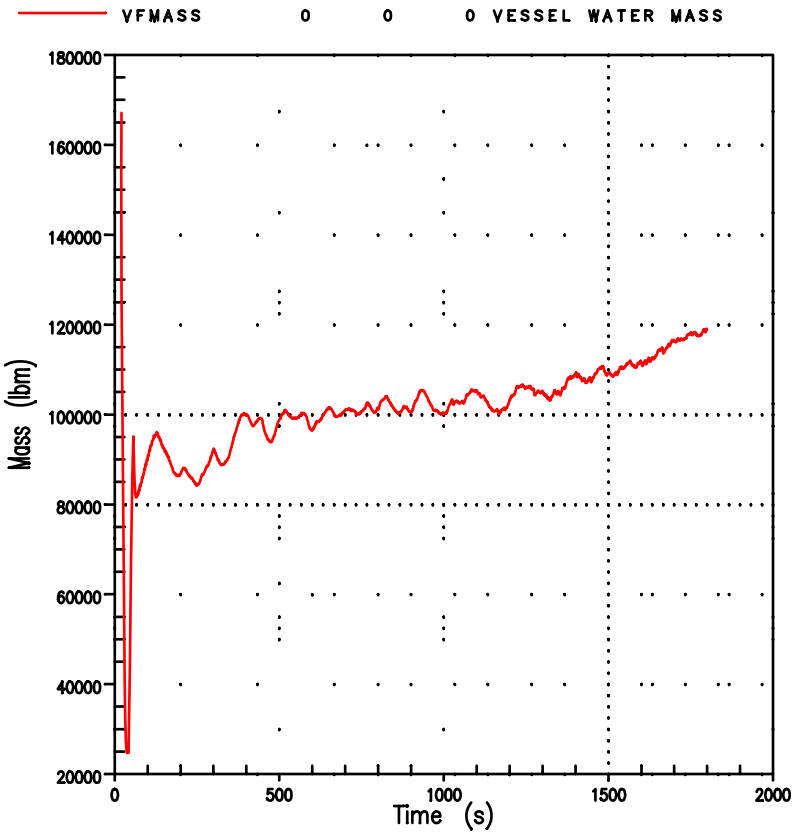


99.4% Blockage

Total Vessel Mass

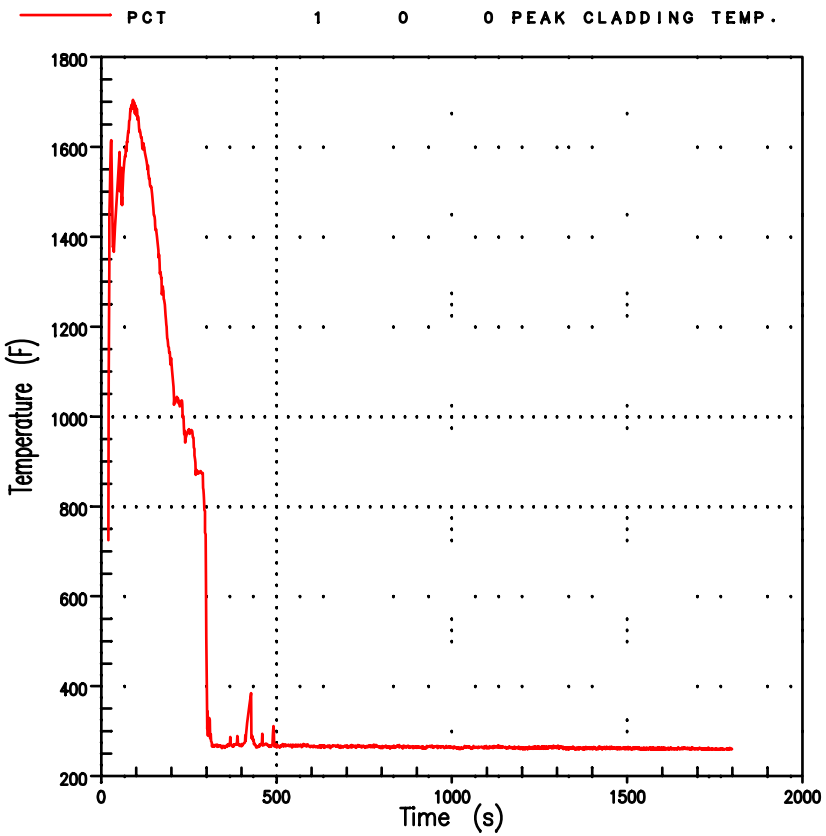


82% Blockage

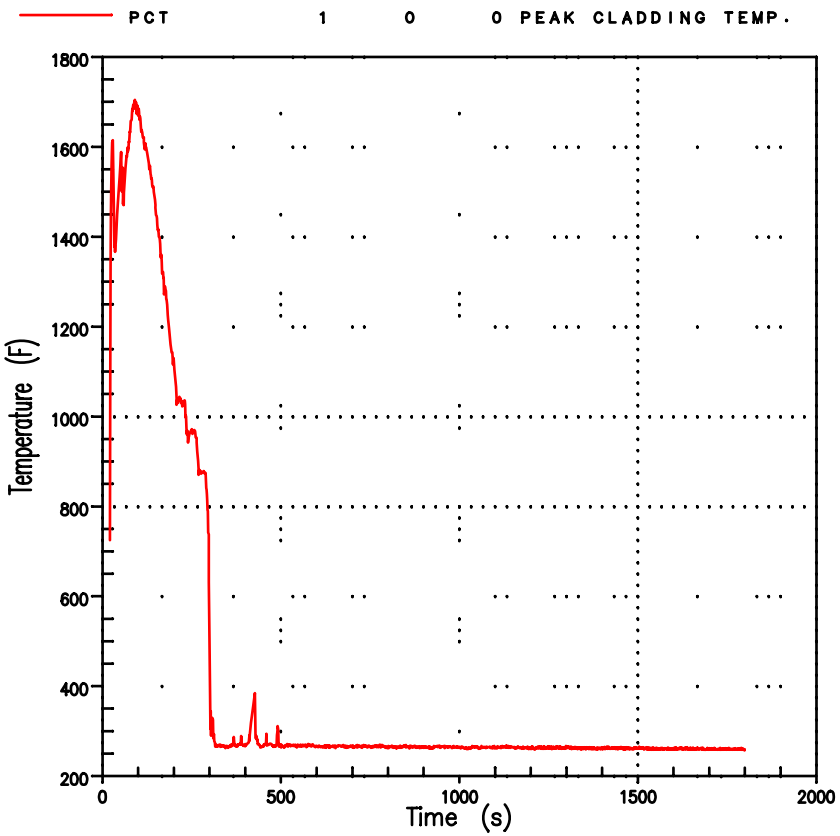


99.4% Blockage

Peak Cladding Temperature in Core



82% Blockage



99.4% Blockage

Summary

- Initial Results
  - Indicate Blockages > 90% Can Be Accommodated
  - Are consistent with NRC calculations performed as part of an audit
- Further Investigations to be Performed
  - Improved modelling of blockage
  - Longer transients
  - Further study of flow vs. blockage vs. core boil-off rates