PWR Owners Group

Path Forward for Addressing Boric Acid Precipitation to Support GSI-191 Closure

NRC Meeting, March 7, 2012

Agenda

- Issue Statement
- Proposed PWROG Path Forward
  - Steps of Path Forward
  - Lower Plenum (LP) Fluid Conditions
    - Use of CFD
  - Test Facility Concept
    - Basis for Concept
  - Run Tests
- Schedule
- Summary

Issue Statement

- NRC has identified a concern that debris associated with GSI-191 concerns may affect the potential precipitation of boric acid due to one or more of the following phenomena;
  - Reducing mass transport (i.e. mixing) between the core and the lower plenum (should debris accumulate at the core inlet),
  - Reduced lower plenum volume (should debris settle in the lower plenum), and,
  - Increased potential for boric acid precipitation in the core (should debris accumulate in suspension in the core)
- NRC has identified that boric acid precipitation must be addressed to increase the fiber limit of 15 g/FA.

Proposed PWROG Path Forward

- Objective:
  - Show the 3 phenomena of concern (core inlet blockage, lower plenum settling, and debris concentration in the core) will not increase the potential for boric acid precipitation in the core and thus compromise core cooling.
- Method:
  - Perform small heated bundle tests using;
    - Debris,
    - Buffered water, and,
    - Heated core.
- Success Criteria
  - Demonstrate that, with reasonable assurance, long-term core cooling is maintained over a range of debris loads and allow removing excessive conservatisms to get to > 15 g/FA.

Steps of Path Forward

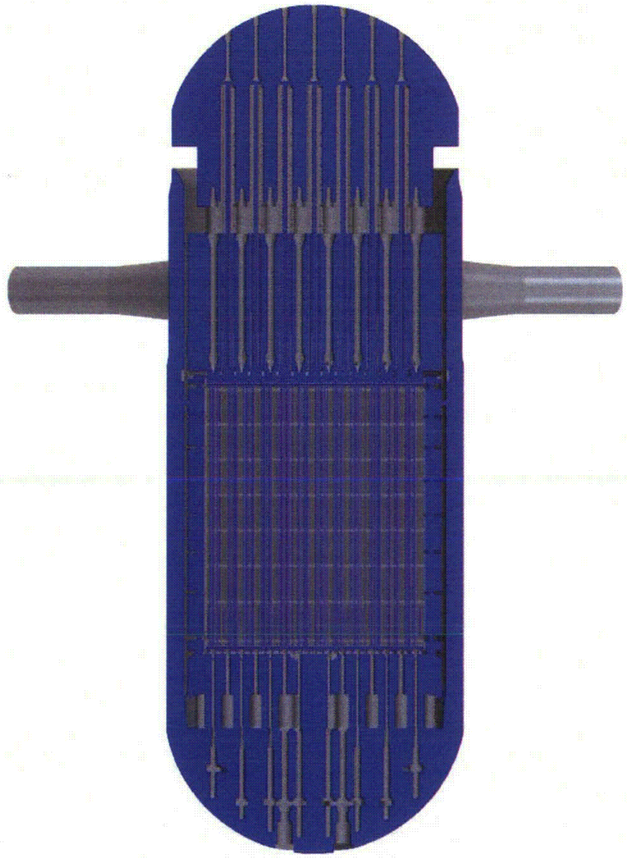
- The approach consists of several tasks;
  1) Establish Lower Plenum (LP) fluid conditions
  2) Build test facility
  3) Run tests
  4) Evaluate data
  5) Generate technical report (WCAP)
- Explanation of tasks follows.

Lower Plenum (LP) Fluid Conditions

- LP flow rates for cold leg break are low
  - < 0.7 in/sec at time of start of recirculation
  - Flow conditions are laminar or near-laminar but not uniform across the core inlet
    - Use a CFD model to demonstrate this
    - Plant model – use existing CFD model
- Use CFD to support design of test loop
  - Approximate plant mixing characteristics (order-of-magnitude)
  - If plant "mixing" > test "mixing" consider adding;
    - Obstacles in lower plenum
    - Mechanical mixing in lower plenum
    - Other methods of increasing mixing
  - If plant "mixing" < test "mixing" consider;
    - Reducing lower plenum volume
    - Other methods of decreasing mixing
  - Confirm test loop design with CFD calculations

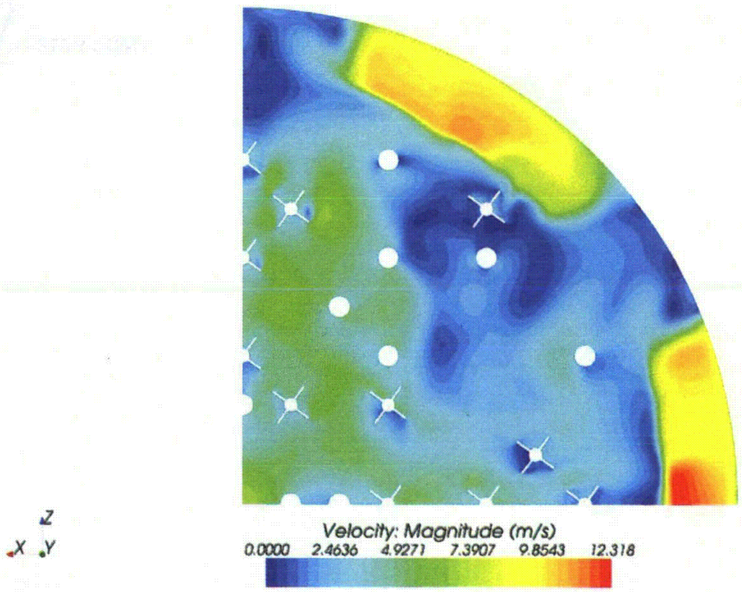
Existing Plant CFD Model

- CFD model currently exists for a Westinghouse 4 loop PWR Vessel
- CFD model is part of the DOE funded CASL project.
- Model includes the following;
  - ¼ of reactor pressure vessel
  - Hot and cold leg
  - Fuel rods and spacer grids
  - Top and bottom nozzles
  - Control rods,
  - All other reactor internals.
- Figure shows schematic of model

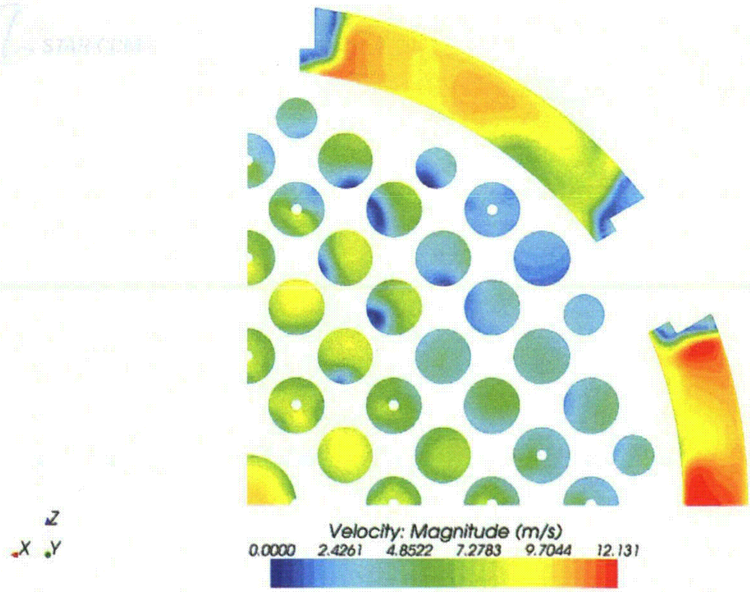


Example of CFD Results with RCP's Running (Power Operations)

Flow in Lower Plenum about Support Columns



Flow in Lower Plenum through Support Plate



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Test Facility Concept

1) Evaluate mixing in plant lower plenum vs. test
   - Use a CFD model to characterize mixing
     - Plant model – use an existing model
     - Test rig – construct a model
     - Run same boundary conditions, compare "mixing" characteristics
   - Consider design of test loop to approximate plant "mixing"
     - Approximate order-of-magnitude mixing is sufficient to demonstrate LTCC
2) Plan to build on current 3x3 heated rod experience
   - Use 3x3 configuration as a base
     - Use full-height heated rods
     - Increase number of 3x3 bundles; i.e., 2 bundles by 2 bundles
   - Simulate lower plenum volume
   - Provide for blocking 1, 2 or 3 of the 3x3 assemblies

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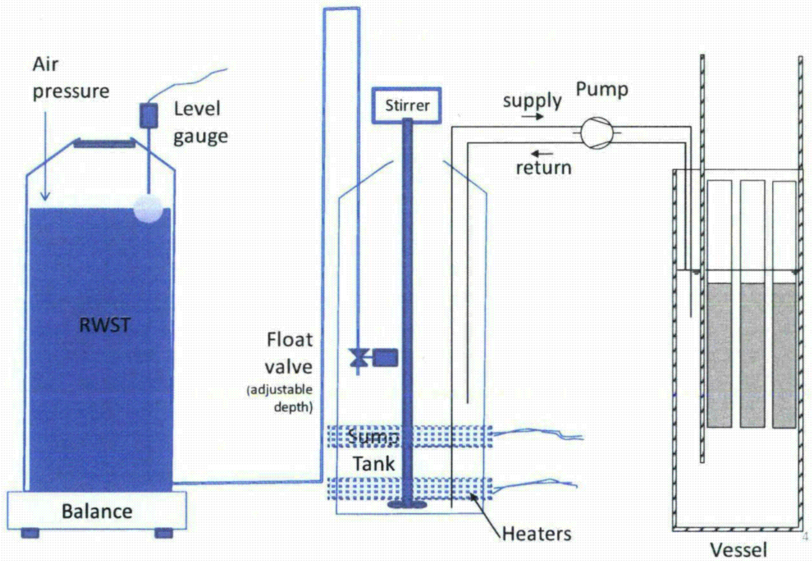
Basis for Test Loop Concept

Existing 3x3 Assembly

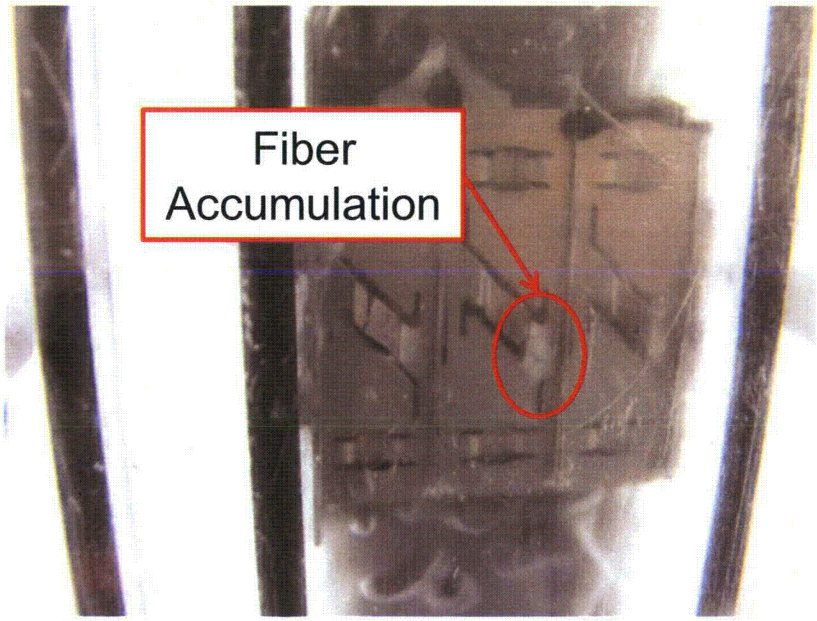
- Objectives of Previous Testing
  - Understand boric acid mixing and concentration distribution in a rod bundle array.
  - Develop heat transfer data for debris-laden borated and buffered water.
  - Compare with observations made during the VEERA and BACCHUS tests.



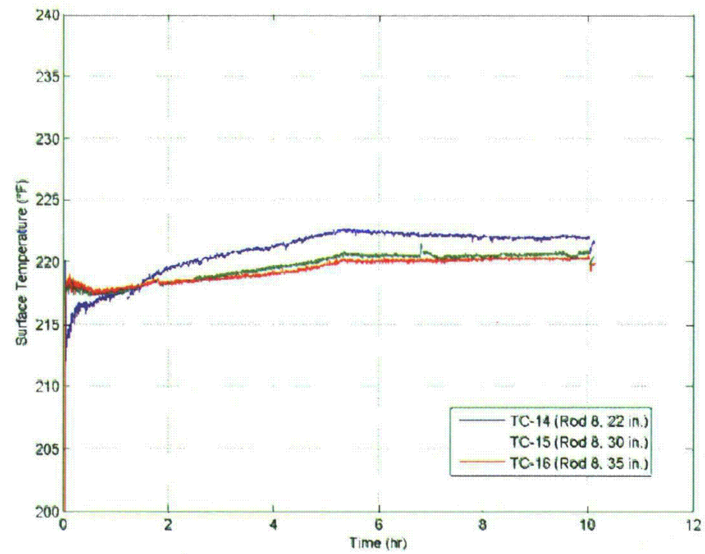
Schematic of 3x3 Test Loop

Preliminary 3x3 Assembly Test Data; LTCC Maintained

Fiber Accumulation Observed Only on Outer Edge of a Spacer Grid after 10 hour Test



Rod Temperature History: No Temperature Excursion



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Preliminary 3x3 Assembly Test Data; LTCC Maintained

- With uninterrupted coolant supply, unbuffered and buffered boric acid solutions provided adequate cooling at post-LOCA decay heat levels over the range of solute concentrations expected prior to active core dilution.
- For debris loadings used, no debris beds or major flow blockages were observed anywhere in the test section including at the fuel inlet and spacer grids; no debris was observed to stick to any cladding surfaces.
- Addition of debris to the coolant in the form of fiber, particulate and chemical components showed no adverse effects on the boiling heat transfer characteristics for the debris loadings and solution compositions tested.
- Precipitation was not observed during any of the runs conducted using buffered boric acid which indicates that the solubility limit of a buffered boric acid solution is higher compared to unbuffered boric acid solutions for the range of conditions tested.
- **These results provide confidence that the objective of the proposed PWR Owners Group Path Forward will be successful.**

Test Conditions

- Decay heat
  - Use ANS 1971 + 20% at 20 minutes following accident initiation
  - Follow decay curve
- Flow rate driven by gravity head (match boil-off with downcomer simulation)
- Initial boron concentration at time of recirculation
- Debris
  - Particulate (specific gravity ≈ 1.6)
  - Fiber (prepared as for replacement sump strainer testing)
  - Suggested P:F ratio = 1, 45, and 60
- Run time = ~10 hours (max time until hot leg injection)
- **"Success"** is no temperature excursion of the heated rods.

Schedule

- Preliminary schedule for this project is estimated to be approximately 12 months after approval to proceed.
- Activities include;
  - CFD Activities
    - Build model of test loop
    - Performing CFD calculations
  - Design test facility
  - Procure test facility components
  - Fabricate and assemble test facility
  - Perform testing
  - Prepare a Technical Report (WCAP)

Summary

- A path forward for addressing boric acid precipitation to support GSI-191 closure has been proposed.
- The approach considers the use of;
  - CFD analyses:
    - Allows for comparison of mixing in plant lower plenum and test lower plenum, and,
    - Will support validity of lower plenum/core inlet observations from testing.
  - Testing:
    - Builds on previous successful small scale testing.
    - Utilizes a facility with;
      - A larger heated bundle, and,
      - Lower plenum for mixing.

Summary (continued)

- Program provides reasonable assurance that;
  - Long-term core cooling will be maintained with debris and boron solutes in coolant.
  - Development of long-term boric acid precipitation evaluation methodology (EM) will not affect GSI-191 debris limits.
  - GSI-191 fuel assembly test data may be credited independent of boric acid precipitation concerns.

Questions?