PWROG Fuel Nozzle Testing Under Post-LOCA Conditions

PWR Owners Group Presentation

Public Meeting on the Resolution of Generic Safety Issue (GSI)-191

January 15, 2009

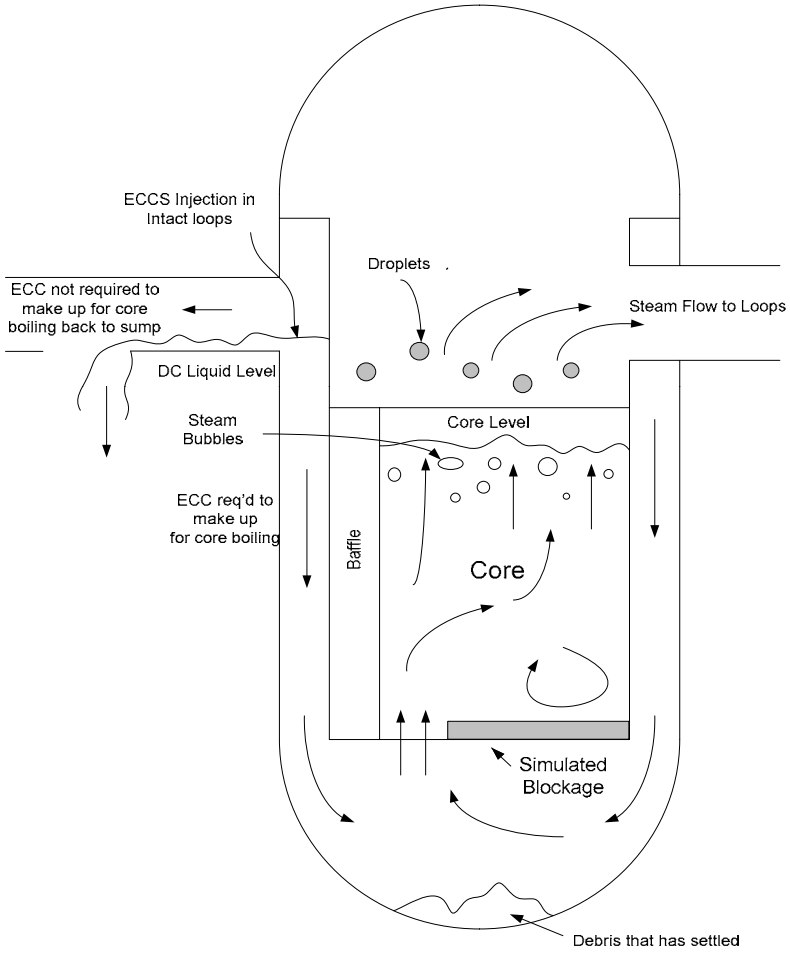
PWROG Fuel Nozzle Testing Under Post-LOCA Conditions

- Head loss test protocol developed to support WCAP-16793-NP
- Testing investigates:
  - Combinations of debris materials (fibrous, particulate, chemical, etc.)
  - Thin bed debris loading
- Output of test program will be an acceptance criteria:
  - Define maximum debris masses which, if passed through the reactor containment building sump screen, will result in an acceptable pressure drop at the core inlet
  - As part of GSI-191 closure with respect to fuel, each plant may demonstrate acceptable long term core cooling by showing that plant-specific sump screen bypass masses are bounded by the limits of the acceptance criteria

Cold Leg Break Scenario

Considerations

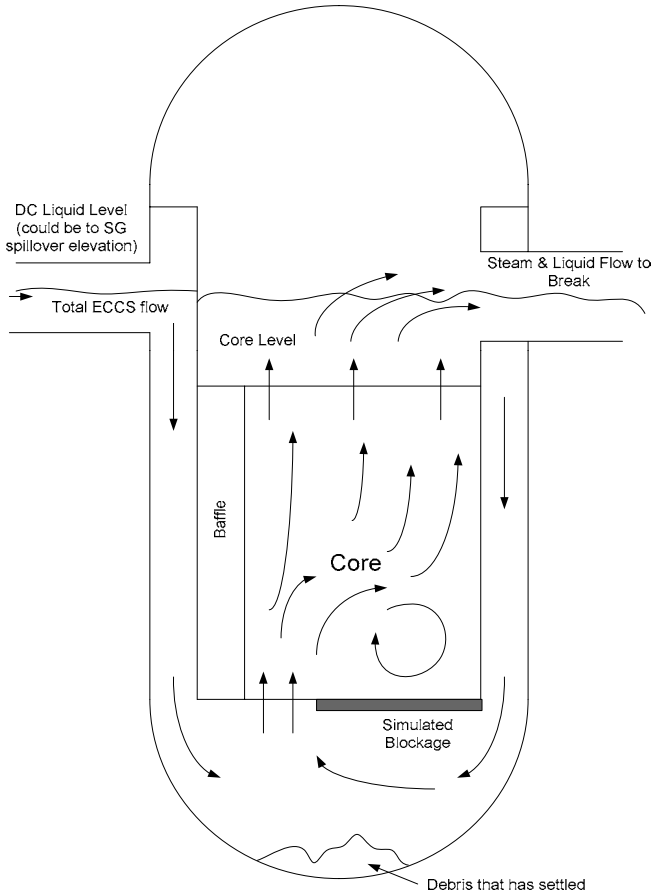
- Earliest time for blockage formation is at switchover from injection to recirculation
  - ~20 minutes for large break LOCA
- Flow rate is determined by boil-off and density difference between downcomer and core inventory
  - Decay heat is low, decreases with increasing time
  - Flows are low
- No flow through alternate paths
- Flow in excess of boil-off
  - “Spills” out the break
  - Is “recycled” through sump screen without passing through core



Hot Leg Break Scenario

Considerations

- Earliest time for blockage formation is at switchover from injection to recirculation
  - ~20 minutes for large break LOCA
- Flow rate is determined by ECCS pump capability
  - Flow exceeds that needed for decay heat removal
  - Limited / no boiling in core
- No flow through alternate paths



PWROG Fuel Nozzle Testing Under Post-LOCA Conditions

- Key Features of Test Protocol
  - Goal of Testing
    - Identify maximum debris loads while achieving acceptable ΔP
  - Test Method Defined
  - Appropriate Test Configuration Defined
  - Debris Preparation Defined
  - Data Collection Defined
  - Test Termination Criteria Defined

PWROG Fuel Nozzle Testing Under Post-LOCA Conditions

Debris Characteristics

Fiber Sizes		
Fiber Length	Target	Range
< 500 µm	77%	67% - 87%
500 µm < 1000 µm	18%	8% - 28%
≥ 1000 µm	5%	0% - 15%

- Fiber size is consistent with that of representative plant data.

- Particulates: Silicon carbide
  - Represents debris that can be characterized as particulate. (Including, not limited to, coatings, latent debris, dirt, etc.)
  - 10µm ± 2 µm
  - Small size provides for maximum transport to and penetration into fiber bed

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Debris Characteristics

- Chemical Surrogate: Aluminum Oxy-hydroxide (AlOOH)
  - Shown by Argonne National Laboratory to produce the highest pressure drop among all of the chemical precipitates
  - Ensure AlOOH surrogate meets settling criteria of WCAP-16530-NP-A and its modification in the associated SER

- Calcium silicate
  - Used in tests designed for plants with calcium silicate.

- Microporous
  - Microtherm is used to represent all microporous material including Min-K.
  - Used in tests designed for plants with microporous material.

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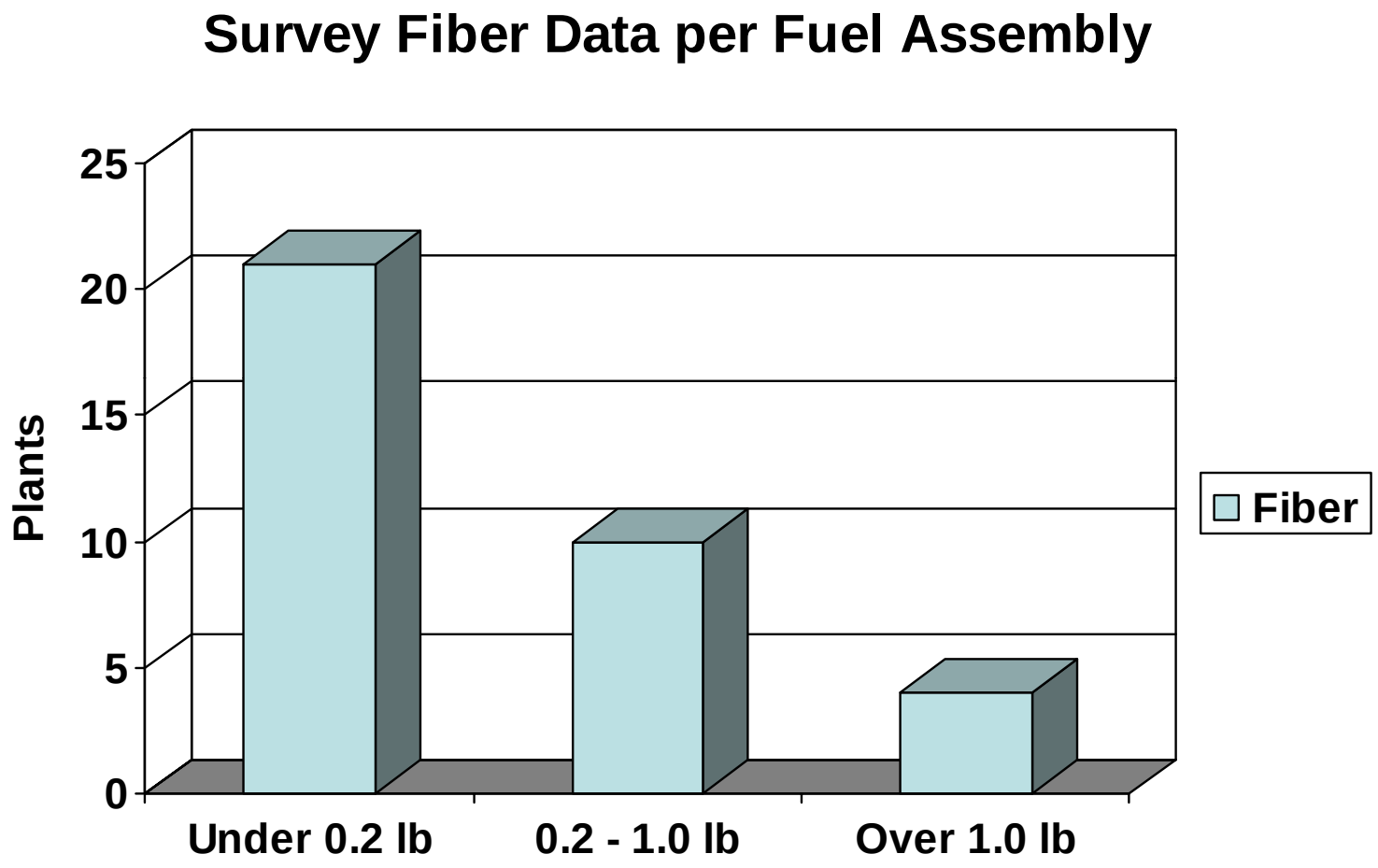
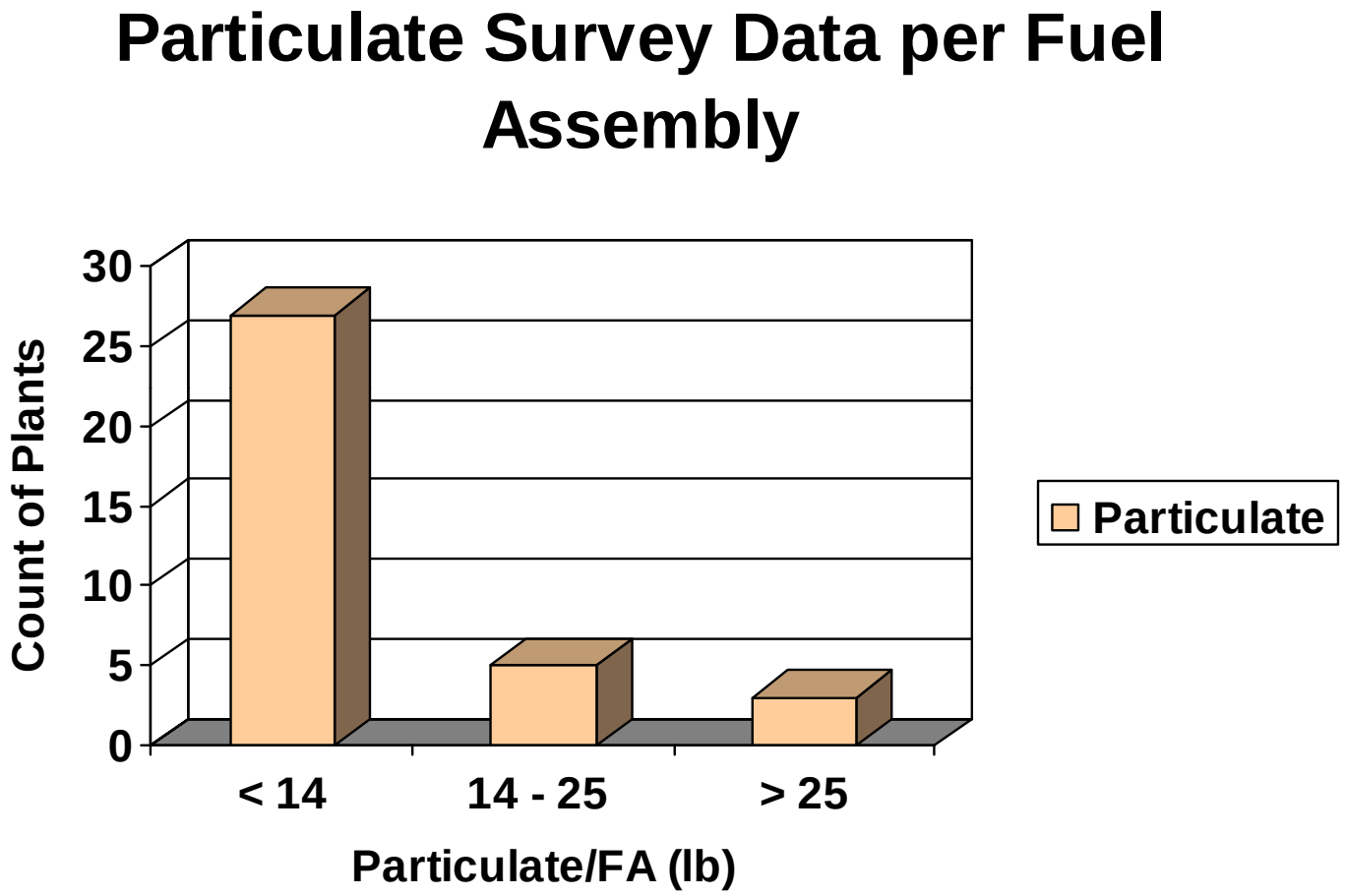
- Fuel Assembly Debris Capture Tests
  - Vendor bottom nozzle configurations (AREVA/CE/Westinghouse)
    - Testing performed with limiting nozzle design
  - Hot-leg break flow rates
  - Representative debris loads
    - Set by sump screen bypass data provided by licensees
  - NRC Involvement:
    - Test Protocol shared with NRC, comments received and addressed
    - NRC visited and observed both W and AREVA test

Fiber Survey Data



Particulate Survey Data

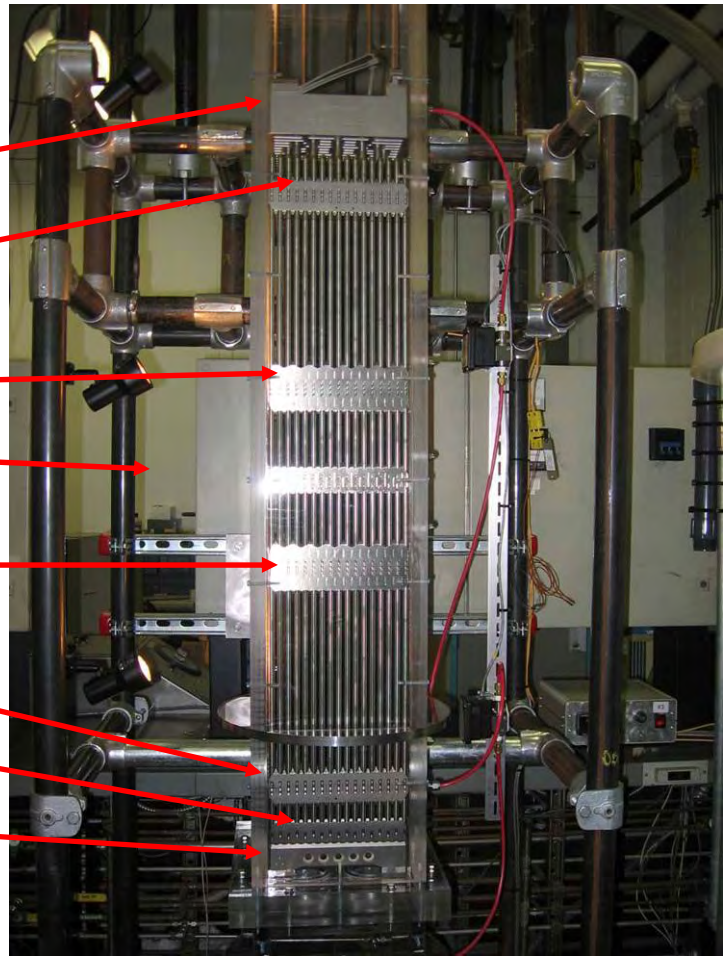


PWROG Fuel Nozzle Testing Under Post-LOCA Conditions

- Test Rig – Westinghouse F/A (Representative)
  - Assembly Height: 4 ft

Top Nozzle
Inconel top grid
Intermediate grid
Intermediate Flow Mixing (IFM) grid
Intermediate grid
Inconel bottom grid
Standard p-grid

Debris Filtering Bottom Nozzle



PWROG Fuel Nozzle Testing Under Post-LOCA Conditions

- Westinghouse Test Plan
  - Three bottom nozzle designs
    - Alternate P-grid was not tested since it had previously been determined that the standard P-grid was limiting in comparison
    - Initial tests run with same debris loading to determine limiting nozzle design
  - Upper Plenum Injection test to be performed

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Westinghouse Tests Performed			
Test No.	Plant Design	Bottom Nozzle	Debris
1	W/B&W	P-Grid	Part/Fiber/Chem
2	W/B&W	P-Grid	Part/Fiber/Chem
3	W/B&W	P-Grid	Part/Fiber/Chem
4	CE	Guardian	Part/Fiber/Chem
5	W/B&W	P-Grid	Part/Fiber/Chem/CalSil
6	W/B&W	P-Grid	Part/Fiber/Chem/Microtherm/ Cal Sil

PWROG Fuel Nozzle Testing Under Post-LOCA Conditions

- AREVA Test Plan
  - B&W & W Designed Plants
    - Three bottom nozzle designs
      - Initial tests run with same debris loading to determine limiting nozzle design
  - CE Designed Plants
    - FUELGUARD fuel filter

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AREVA Test Plan			
Test No.	Plant Design	Bottom Nozzle	Debris
1	W/B&W	TRAPPER Fine Mesh	Part/Fiber/Chem
2	W/B&W	FUELGUARD	Part/Fiber/Chem
3	W/B&W	TRAPPER Coarse Mesh	Part/Fiber/Chem
4	W/B&W	Limiting	Max Part/Fiber/Chem/CalSil
5	W/B&W	Limiting	Max Part/Fiber/Chem/Microtherm
6	CE	FUELGUARD	Max Part/Fiber/Chem

PWROG Fuel Nozzle Testing Under Post-LOCA Conditions

- Data Under Review
- Conclusions/Observations to Date
  - "Thin bed" behavior not observed in tests
  - Particulates only a minor impact on head loss
  - Fiber:
    - Provides collection sites for debris
    - **Is the driver for head loss**
  - Chemical precipitates:
    - Are another source of particulates
    - Results show chemical precipitates only a minor impact on head loss
  - Cal Sil and Microporous insulation
    - Are another source of particulates
    - Again, results show only a minor impact on head loss
  - Some debris observed to collect at grids along the height of the bundle

Fuel Nozzle Testing Under Post-LOCA Conditions

- F/A Test Parameters
  - Hot-leg flow rates
  - Scaled on per assembly basis
  - Sequenced addition of debris
    - Particulates
    - Fiber
    - Chemical
    - Microporous and Calcium Silicate debris added with particulate and after chemical addition

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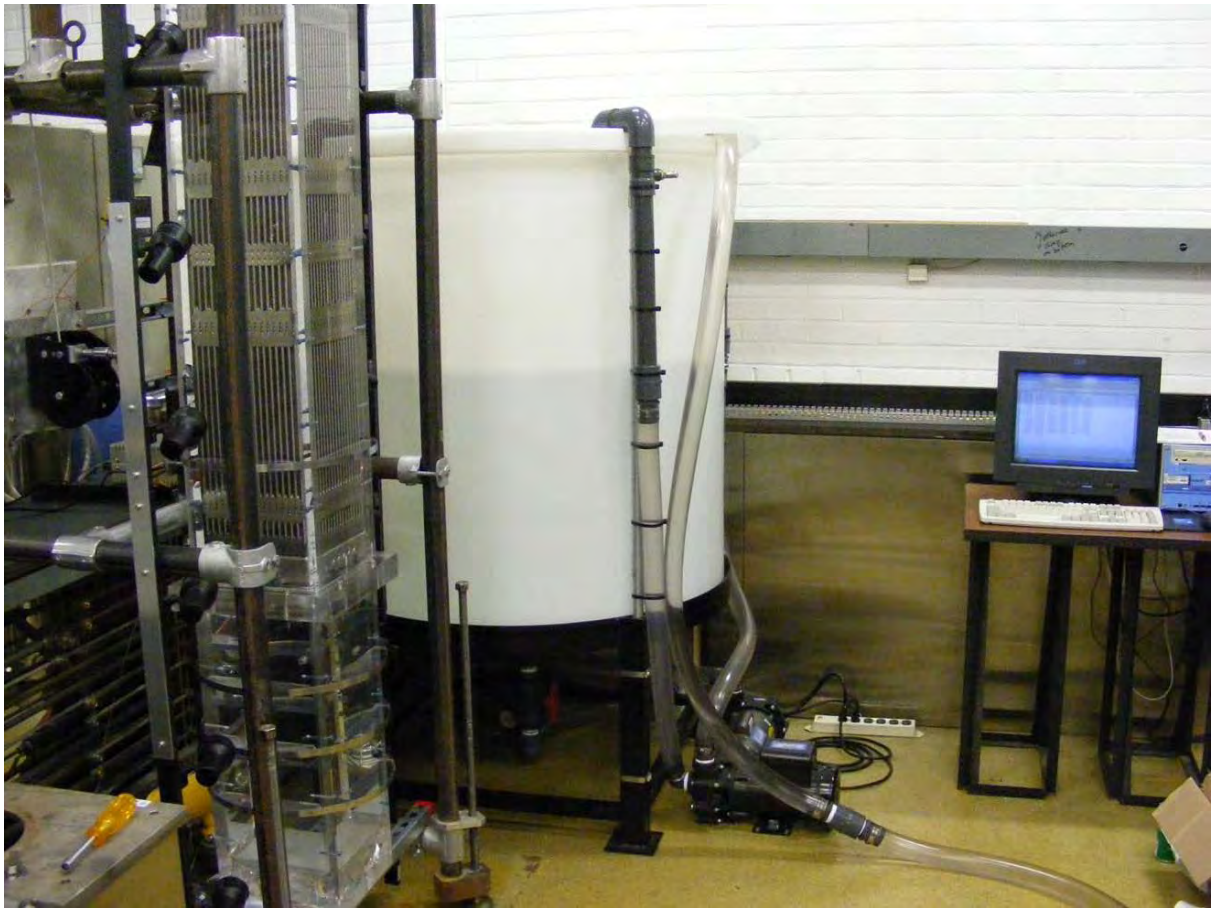
Sample Test Set Up (Representative of Both AREVA and Westinghouse)



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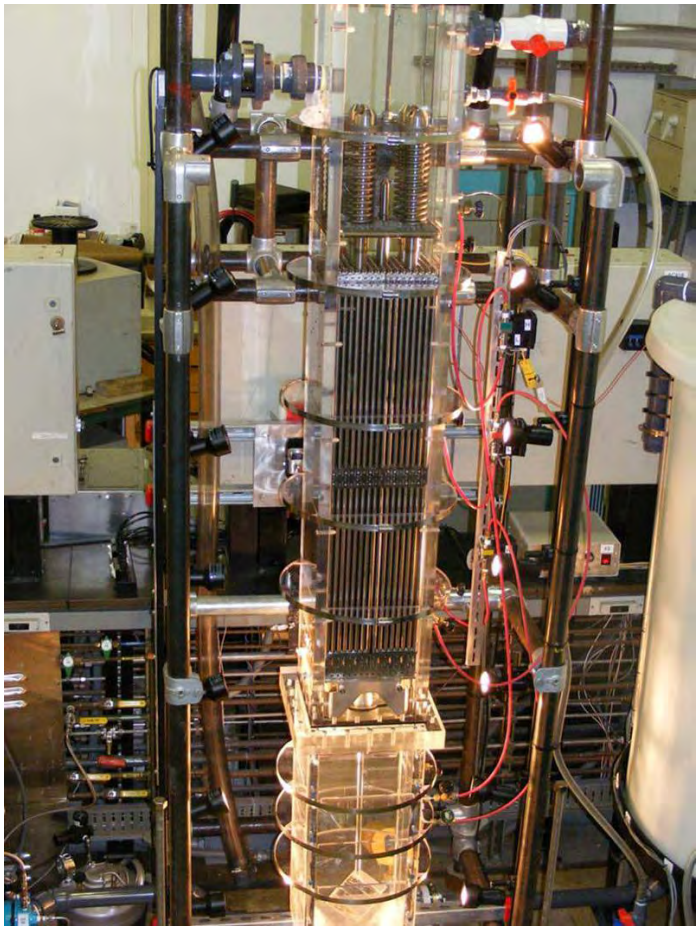
Westinghouse Fuel Assembly (Representative of AREVA's Set Up)



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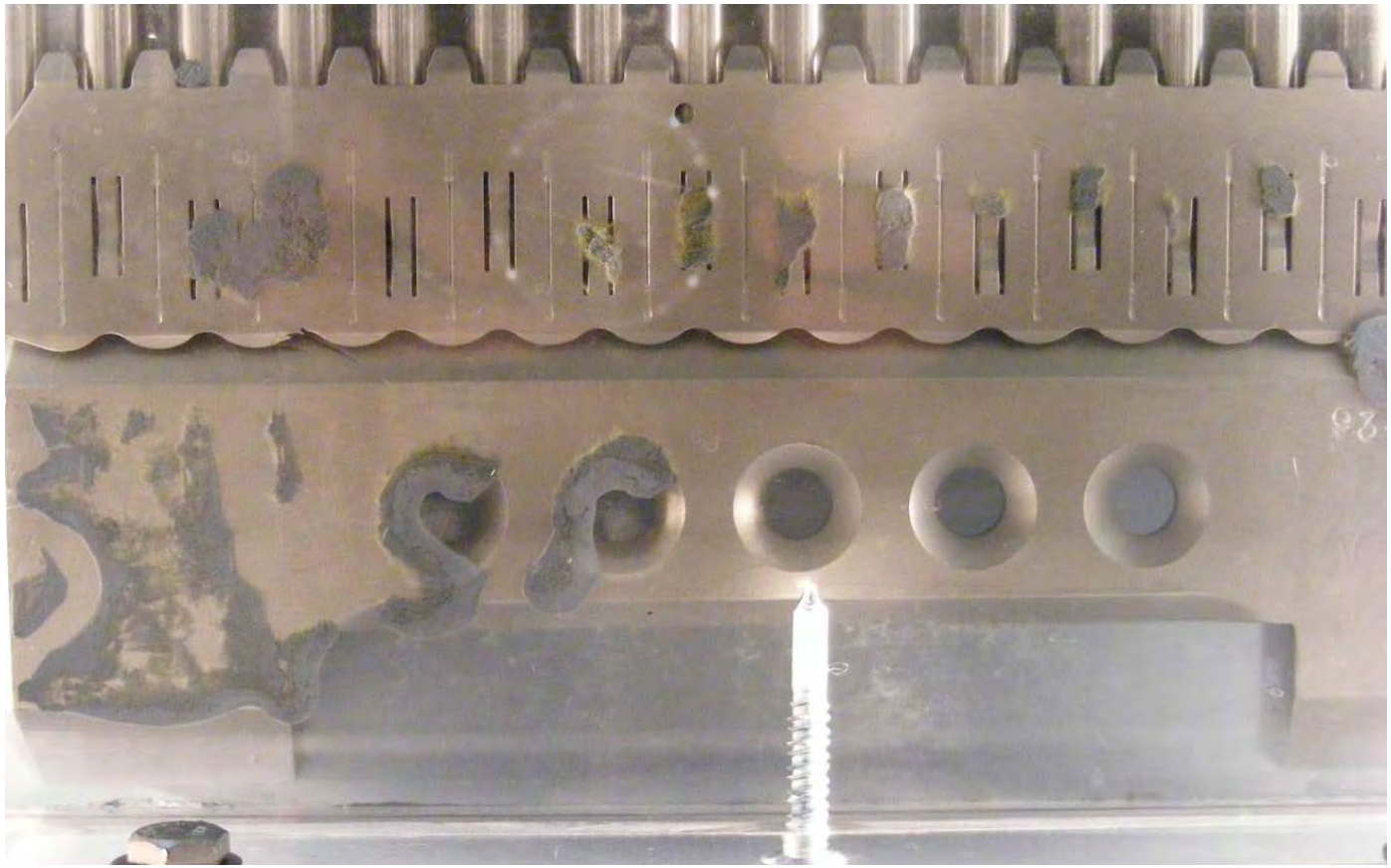
Sample of Debris Collection at Grid

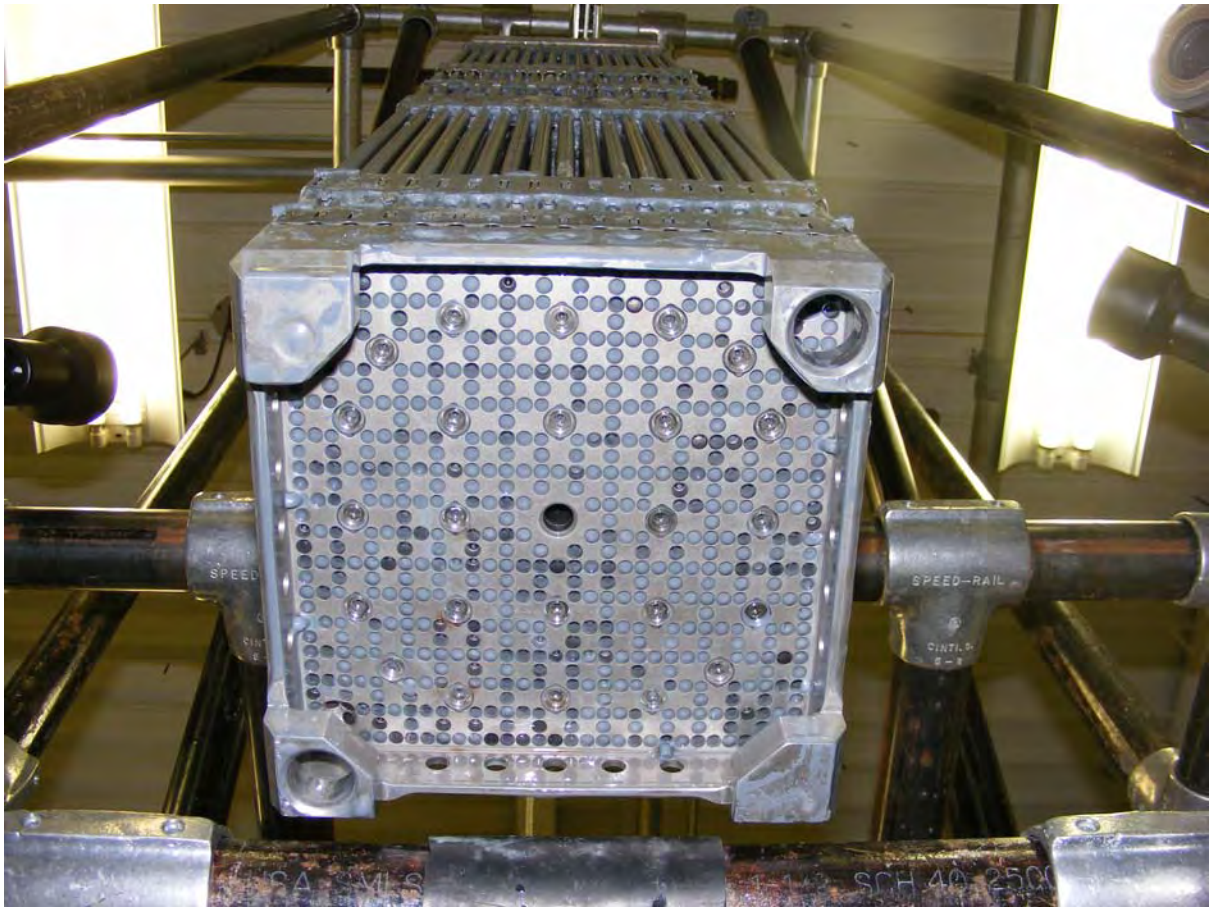
PWROG Fuel Nozzle Testing Under Post-LOCA Conditions

Sample of Debris Collection on Bottom Nozzle – Side View



PWROG Fuel Nozzle Testing Under Post-LOCA Conditions

Sample of Debris Collection on Bottom of Bottom Nozzle



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Sample of Debris Collection on Grids

Looking Ahead

- Week of January 19, 2009
  - Phone Calls to discuss RAIs and Cold Leg Break
- Week of February 23, 2009
  - Submit RAI Responses
- Week of March 16, 2009
  - Submit Proprietary Fuel Assembly Test Data Report (data only, no conclusions)
  - Non-proprietary version also submitted (title and index)
- Week of April 13, 2009
  - Based on NRC head-nod on RAI responses, submit Revision 1 of WCAP-16793