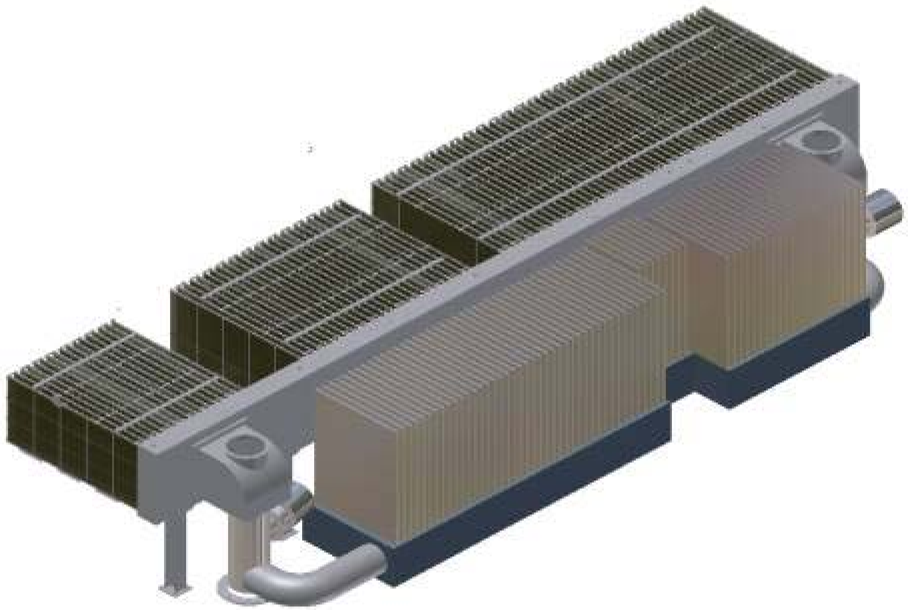
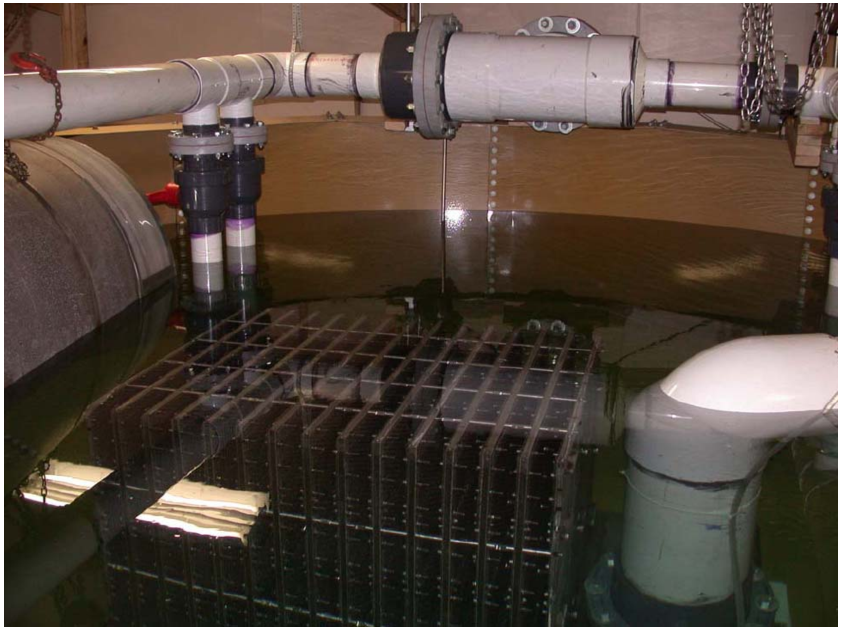
GE Hitachi Nuclear Energy Americas
Diablo Canyon Power Plant

Head Loss and Chemical Effects Testing Program





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Overview

- Chemical effects testing conducted for Diablo Canyon Power Plant (DCPP)
- Plenum style strainer with ~3300 ft^2 of perforated area allows open area for chemical effect bypass
- Sector and module testing with WCAP-16530-NP chemical precipitant surrogates

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History – Chemical Effects

- Diablo Canyon installed new 700 square foot screens in the year 2000
- 9 tests in 8/05 without chemical effects:
  - > Failed large break debris (12%)
  - > Passed alternate break debris (175%)
- 6 tests in 7/06 with chemical effects:
  - > Clean Screen passed 100% of chemicals
  - > Very thin fiber bed (significantly less than 1/8") failed with first batch addition (10%) of chemicals

History – Chemical Effects

- Observations
  > Chemicals pass through clean screen area

  > Prevent a fibrous thin bed from covering the entire screen
    - Larger screen area
    - Ensure some “clean screen” area
    - Reduce fibrous debris source term

Erosion Testing

- Fire stop material in cable trays
  - > Kaowool
    - – Horizontal – 5% erosion with metal tray cover
    - – Horizontal - 13% erosion without tray cover
    - – Vertical – 37% erosion
  - > Marinite board - 0% erosion
- Piping insulation
  - > Temp-Mat - 1% erosion, unjacketed
  - > Cerablanket – 3% erosion, unjacketed

Debris Transport and Settling

- Determine incipient, bulk and settling velocities of:
  - > Various cable insulation
  - > Lamicoid labels
  - > Reflective tape
  - > Cable ties
  - > Light bulb fragments
- Testing allowed the use of specific values to reduce the transport of debris

Steam Jet Testing

- Purpose: Determine Zone of Influence (ZOI)
- Pressurizer heater cables (5D)
- Control and power cable (5D)
- Cable Tray with 18 gauge stainless steel cover over pressurizer heater cable (2D)
- Encapsulated Temp Mat insulation (3.7D)
- Double jacketed calcium silicate insulation (3D)
- Single jacketed cal-sil with banding at 3" centers (3D)
- Steam Generator support fibrous insulation with jet deflector (20D)

Jet Test – Cables 5D

Pre-Test

Post Test

- Pressurizer heater cable: #4 copper, fiberglass and mica insulated
- Power cable: 4conductor #10 AWG copper, cross-linked polyethylene (XLPE) with a cross-linked polyethylene jacket
- Instrumentation cable: 2-#16, silicone rubber with a silicone rubber jacket

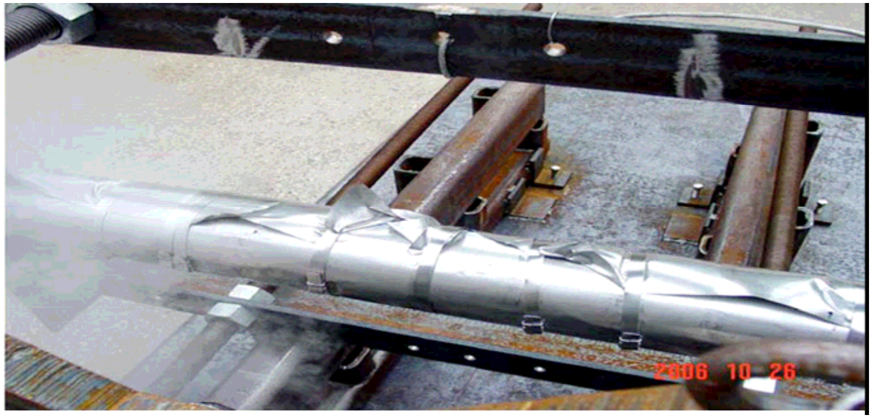
Jet Tests - Piping Insulation

Post Test

Hog Tied Temp Mat with wire mesh – 3.7D ZOI

Post Test

Calcium silicate with single jacket and bands on 3 inch centers – 3D ZOI



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Interceptor Testing

- Initial testing with a 18" high vertical perforated plate failed when holes became plugged with debris
- 18" high inverted "L" with 10" horizontal plate was successful even with holes plugged
  - very effective in capturing sliding or tumbling debris and for entrained debris in the lower 12"
- Interceptor not credited for the capture of fines (Calcium silicate or fiber)

Plant Modifications

- Remove / Jacket Temp-Mat Insulation Inside Crane Wall – 500 lb.
- Remove 71 Fire Stops Inside Crane Wall
- Install Bands on 3” Centers, Cal-Sil Insulated Pipe Inside the Crane Wall - 1200 linear feet
- Install Covers on Cable Trays Under Pressurizer
- Add Debris Interceptors at all three doors in the Crane Wall
- Modify Reactor Cavity Door to allow more debris capture in the inactive sump
- Install tested configuration of Temp Mat insulation on Pressurizer Relief Valves

DCPP Summary Observations

- Even a very thin fiber bed will fail with chemicals
- Chemicals pass through clean screen area
- Benefits from erosion testing – reduce erosion from the 100% assigned in NEI 04-07
- Significant ZOI and debris reductions through encapsulation of Temp Mat and double jacketing or multi-banding of Calcium silicate insulation

DCPP/GE Testing Overview

- Chemical precipitants were included in all head loss tests.
- 11 design basis sector tests
  - > Seven sector tests initially planned, but changes in debris source term and aging of chemical effects required additional tests.
- 3 module tests, including a back-flush feasibility test
- 4 fiber bypass sector tests
- 4 bottom fuel nozzle and fuel grid head loss tests
- 2 supplementary back-flushing sector tests

DCPP Sump Chemistry Inputs

- NaOH Buffered
- No calcium silicate
- Precipitants:
  - > Aluminum Oxyhydroxide
  - > Sodium Aluminum Silicate
- 20% margin added to aluminum inventory for allow for future construction.
- pH conservatively assumed as 9.5 for the duration of the LOCA.
- Aluminum release controls all chemical precipitate formation.

DCPP Head Loss Testing

- Head loss tests were performed in fully agitated closed loop pools.
- Settling was prevented by using mechanical agitators.
- Testing duration was at least 50 pool turnovers; tests were terminated after measuring less than or equal to a 1% or 0.1 inch of water increase in head loss over a 30 minute period or 5 turnover times, whichever was longer.

DCPP Head Loss Testing

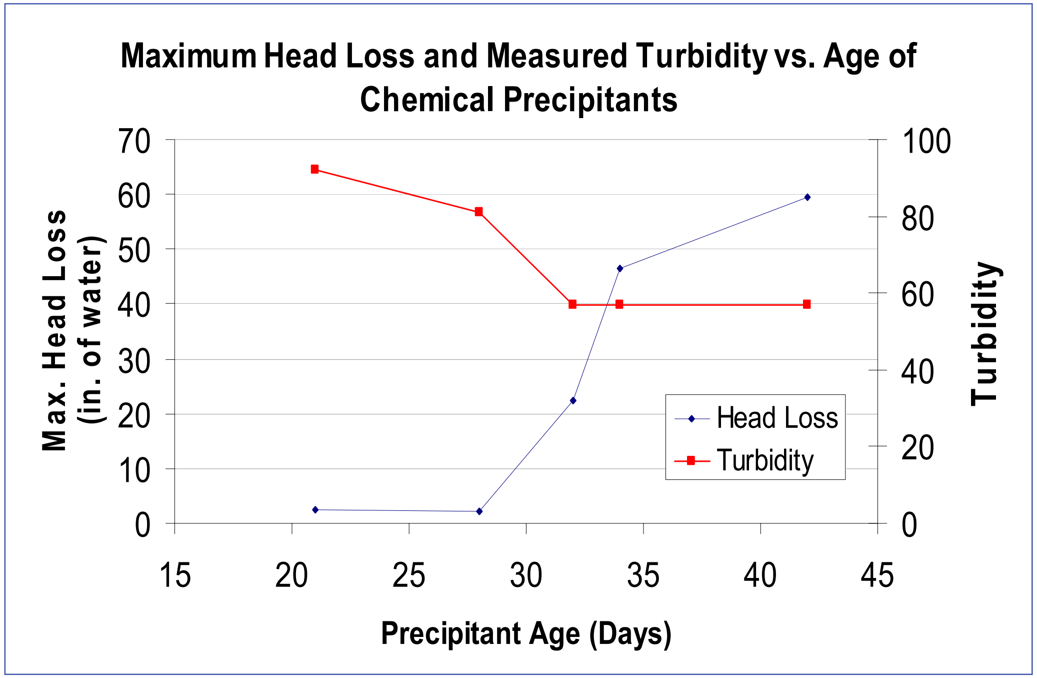
- Chemical precipitates were introduced after particulate and fiber to be representative of the expected debris sequence.
- An investigatory test was performed with chemical precipitates introduced before particulate and fiber. The resulting head loss was bounded by subsequent tests using the expected debris sequence.

DCPP Head Loss Testing Chemical Effects

- Sodium aluminum silicate prepared prior to testing per Westinghouse document TP-117172-1, via mixing aluminum nitrate with 40% sodium silicate solution.
- Aluminum Oxyhydroxide prepared prior to testing per Westinghouse document TP-117172-1, via mixing aluminum nitrate with sodium hydroxide.
- pH was monitored but not controlled during testing. The pH for design basis tests was generally around 7.2-7.6.
- Temperature was maintained between 85° and 98°F.

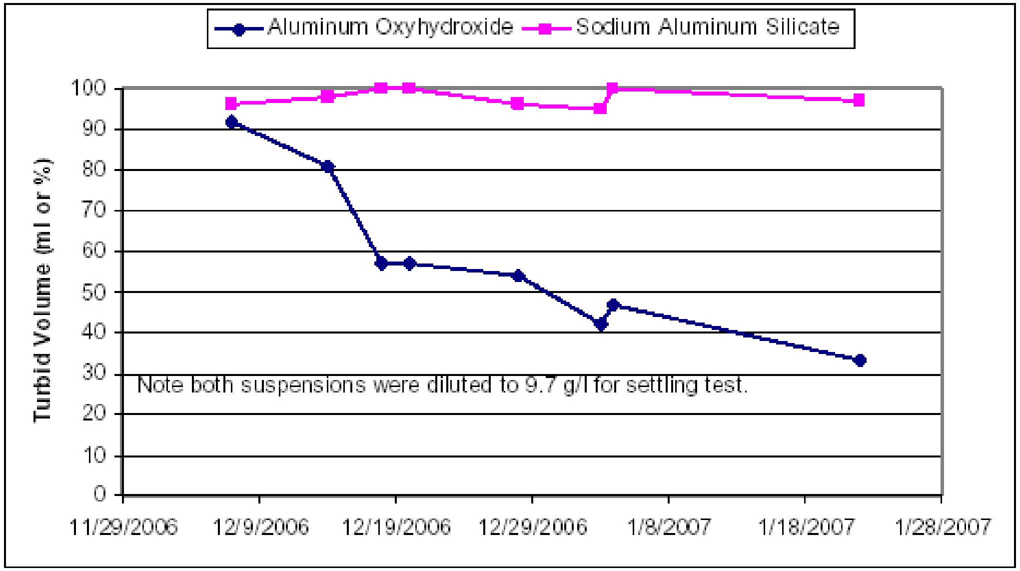
DCPP Chemical Precipitant Instability

- Over a series of repeatability tests, head loss was observed to increase over time. The debris load and test conditions were unchanged.
- Inspection of test article indicated a trend of decreasing open area over several tests, and some holes were plugged only with chemical precipitants.



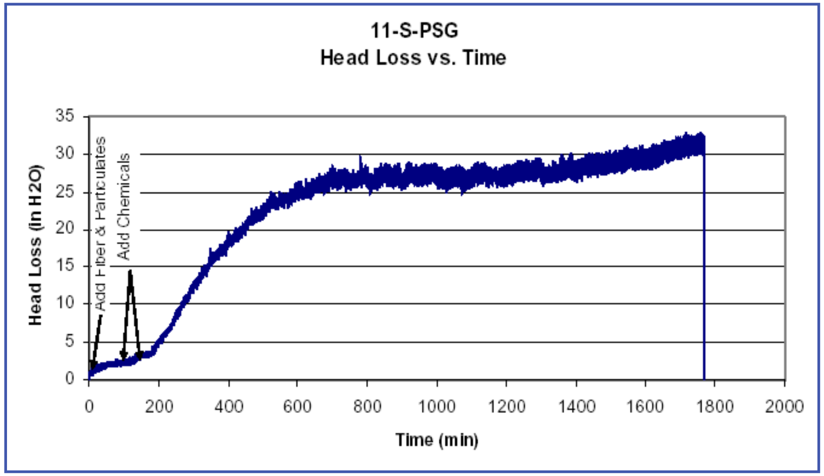
DCPP Chemical Precipitant Instability

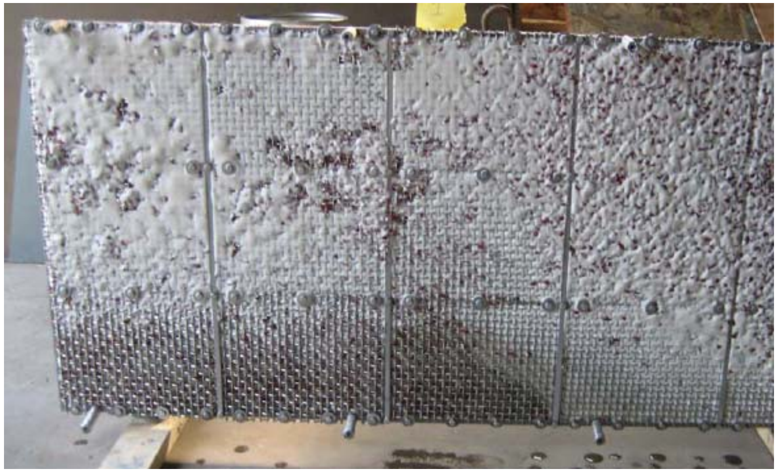
- Additional tests were performed on the chemical precipitants. Based on the results of microscopic analysis, gravity head loss tests, and turbidity tests, it was concluded that the physical properties of the aluminum oxyhydroxide changed with time and affected the test results.

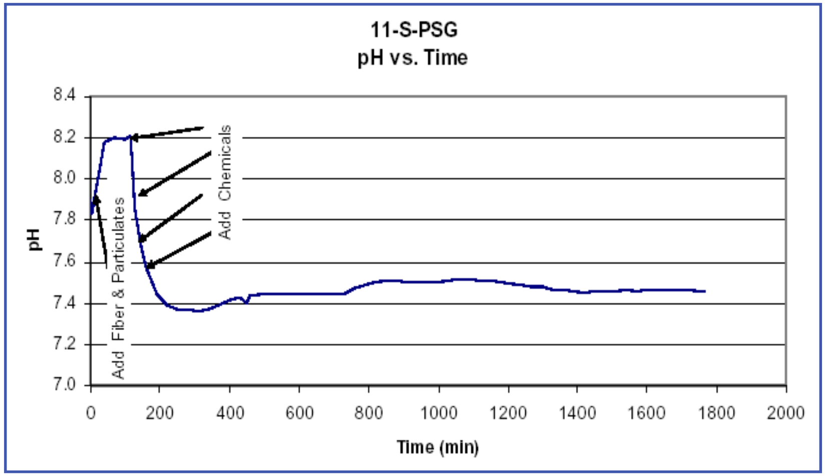


DCPP Chemical Effects Sector Testing Results

- Design basis sector test result
- Fully agitated
- Evidence of channeling, therefore test head loss is not scaled by kinematic viscosity ratio for plant head loss
- Test run for 270 turnovers.







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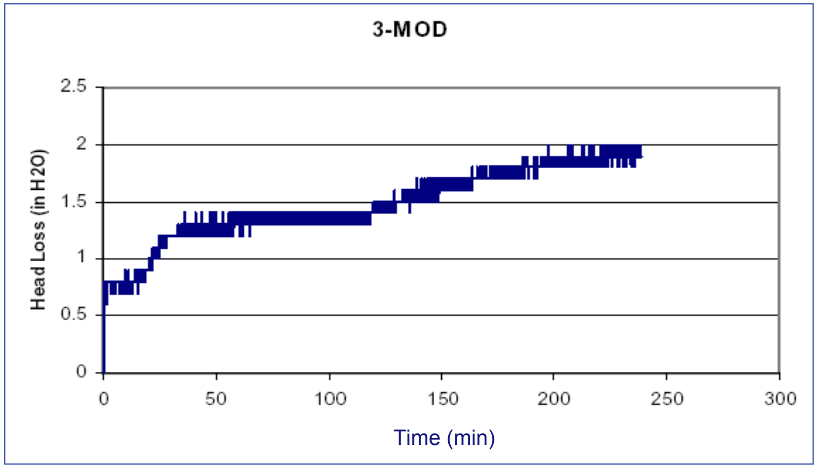
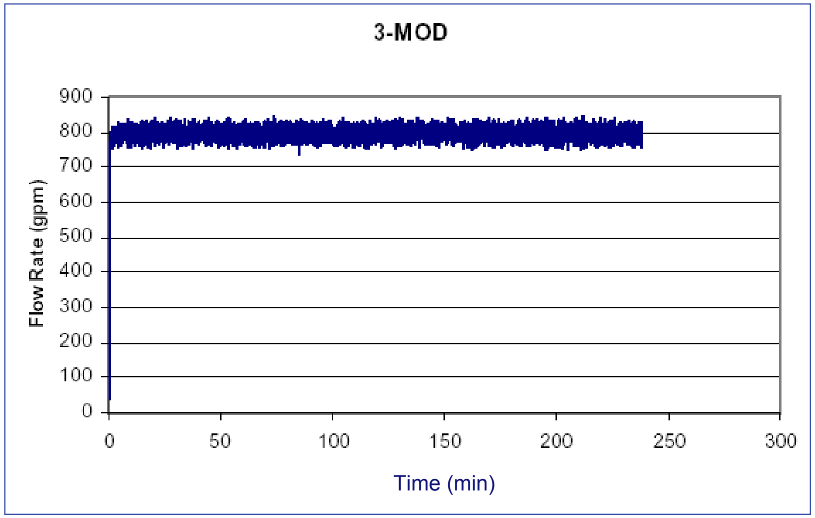
DCPP Module Testing Results

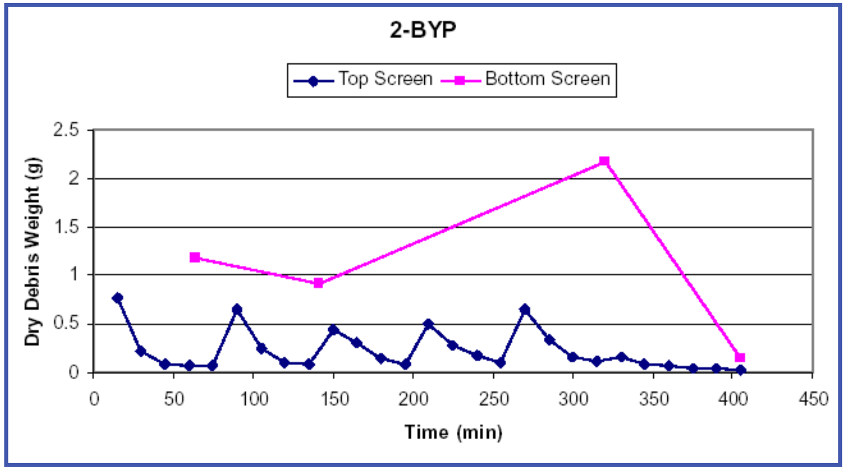
- Module test result not used as design basis - bounded by design basis sector test
- Fully agitated
- Rear strainer module
- Test run until <0.1 inch of head loss increase for 5 turnovers.

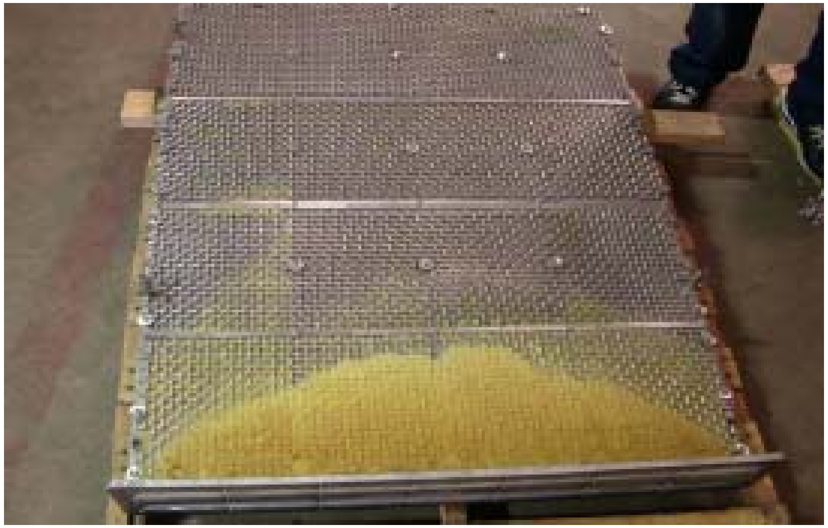




DCPP Fiber Bypass Testing Results

- Test sector with greatest open area used for conservatism
- Fiber added stepwise
- Four tests were run, highest measured bypass was scaled to plant strainer.
- Total fiber bypass for plant strainer is 2.16 ft^3





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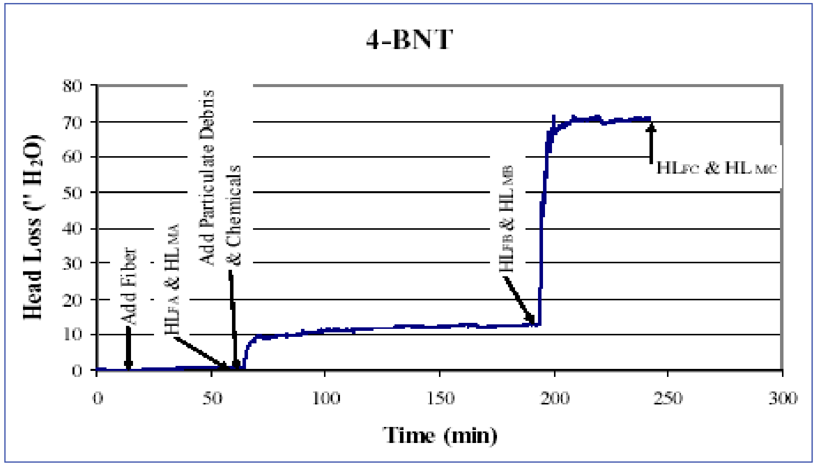
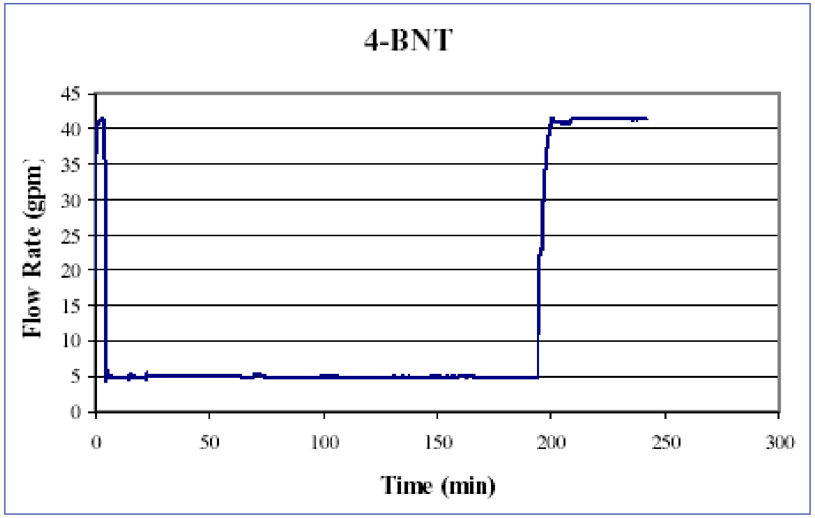
DCPP Fuel Grid Testing Results

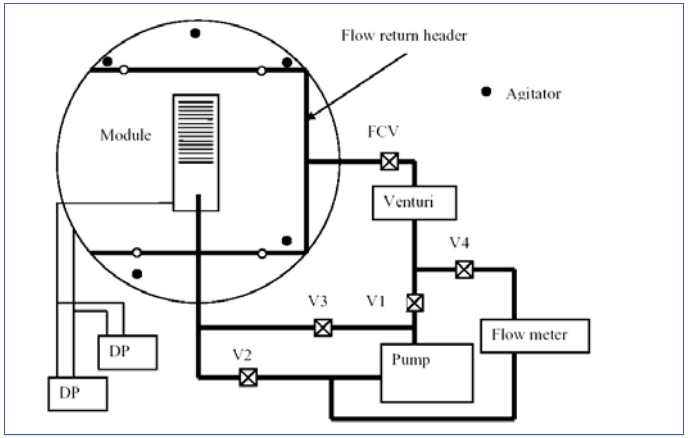
- Design basis fuel grid test result
- Fiber quantity was based on scaled limiting result from bypass tests.
- Flow run at 5 gpm to allow bed to accumulate, then increased to 41 gpm to find max. head loss.
- Flow was maintained through bottom nozzle and fuel grid during all tests





DCPP Back Flush Module Tests

- Plant Simulator confirmed multiple alignments for back flush are achievable
  - > 900 gpm flow rate
  - > 20 min for back flush alignment
  - > Base Case (Large Break) debris load



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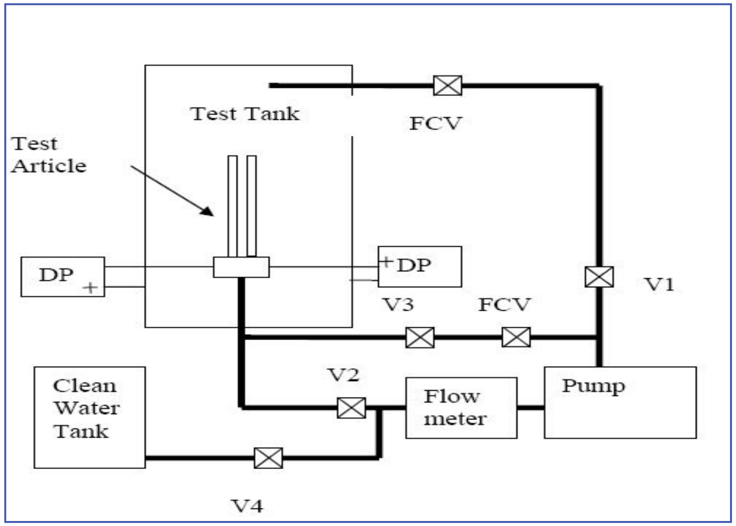
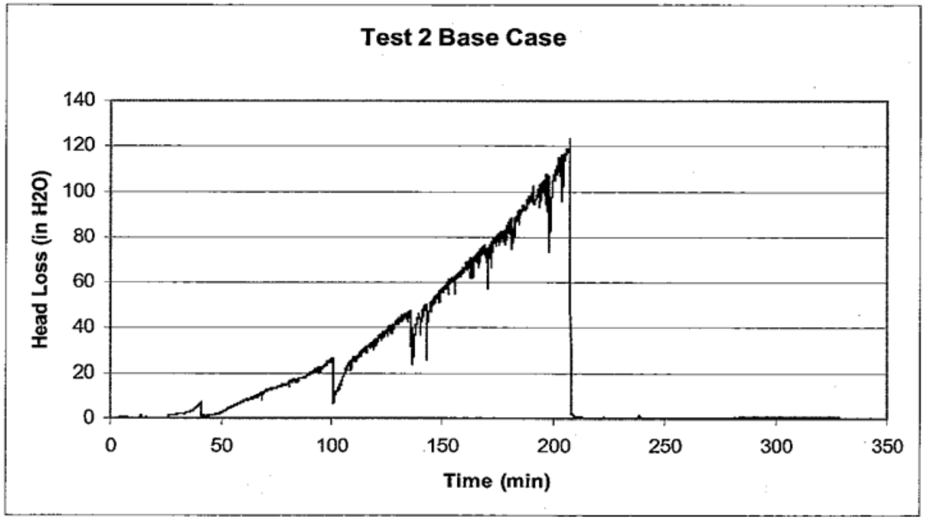
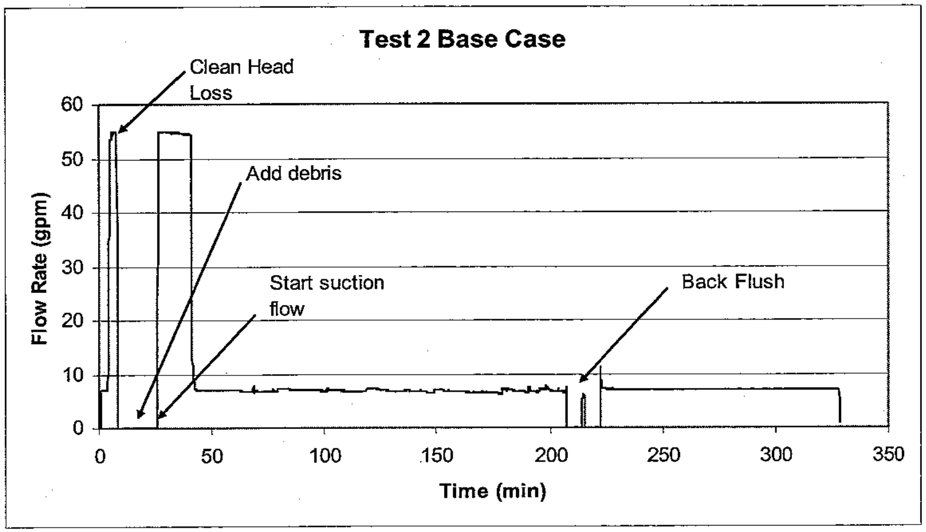
DCPP Back Flush Sector Tests

- Debris load - Pre-SG replacement with plant modifications
- 55 gpm flow rate, followed by 7.1/6.3 gpm
- 20 min. for back flush alignment
- Continuous core cooling







Summary of GE/DCPP Testing Program

1. Consistent results among the sector and module head loss tests
2. Physical properties of Aluminum oxyhydroxide change over time
3. Sufficient testing performed to understand the impacts of debris quantities and debris mix
4. Some remaining clean screen area is key to successful chemical effects testing
5. Fuel Grid tested at high and low flows (hot- and cold-leg recirculation)
6. Back flush proven as a viable backup mitigation measure
7. Flow was maintained through fuel grid and bottom nozzle with maximum fiber bypass and chemical precipitants