GSI-191 Chemical Effects Status Report

NRC Presentation

August 23, 2007

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Outline

- Objective
- Resolution Approach
- Methods
- Results
- Coating Investigation

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Objective

- To provide a technical and defendable basis for evaluating the impact of chemical effects on debris head loss:
  - Based on plant specific environments and debris loads,
  - Applied in a conservative manner, and
  - Based on experimental data

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Approach

Type 1: Utilize WCAP-16530 with prototype testing.

Type 2: Utilize WCAP-16785 precipitate loads for prototype testing based on plant specific chemistry testing.

Type 3: Perform 30 Day integrated chemical effects head loss testing.

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Type 1 Approach

- Standard WCAP-16530 precipitates added as additional debris source during the prototype testing.
- Example: Nuclear Plant 1
- Open Issues: SER on WCAP, termination criteria, temperature correction for precipitate head losses

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Test Conditions

- Full scale prototype strainer assembly (235 ft2)
- Tap water testing at ~80 deg F
- Precipitates manufactured and verified outside of test tank per WCAP-16530
- Approach velocity equivalent to replacement strainer
- Scaled debris mixture added in batches to ensure thorough mixing and proportionate to WCAP generation
- Perform test until head loss stabilizes to 1% in 1 hour.
  - Intermediate points consider pool turnover and timing.

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Test Conditions

Test #	Nukon (lbm)	Min-K (lbm)	Ground Silica (lbm)	Dirt/Dust (lbm)	*Sodium Aluminum Silicate (g) {~gal}*	*Aluminum Oxyhydroxide (g) {~gal}*
3A	0	0	0	0	*0*	*0*
3B	1.8	15.1	26.1	10.6	*599 g {14.4 gal}*	*0*
3C	0	0	0	0	*980 g {23.6 gal}*	*0*
3D	0	0	0	0	*494 g {11.9 gal}*	*0*
3E	0	0	0	0	*656 g {15.8 gal}*	*146 g {3.52 gal}*
3F	0	0	0	0	*8.10 g {0.198 gal}*	*786 g {18.9 gal}*
3G	0	0	0	0	*0*	*0*

** Continuous Testing with Incremental Additions*

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Test Photos

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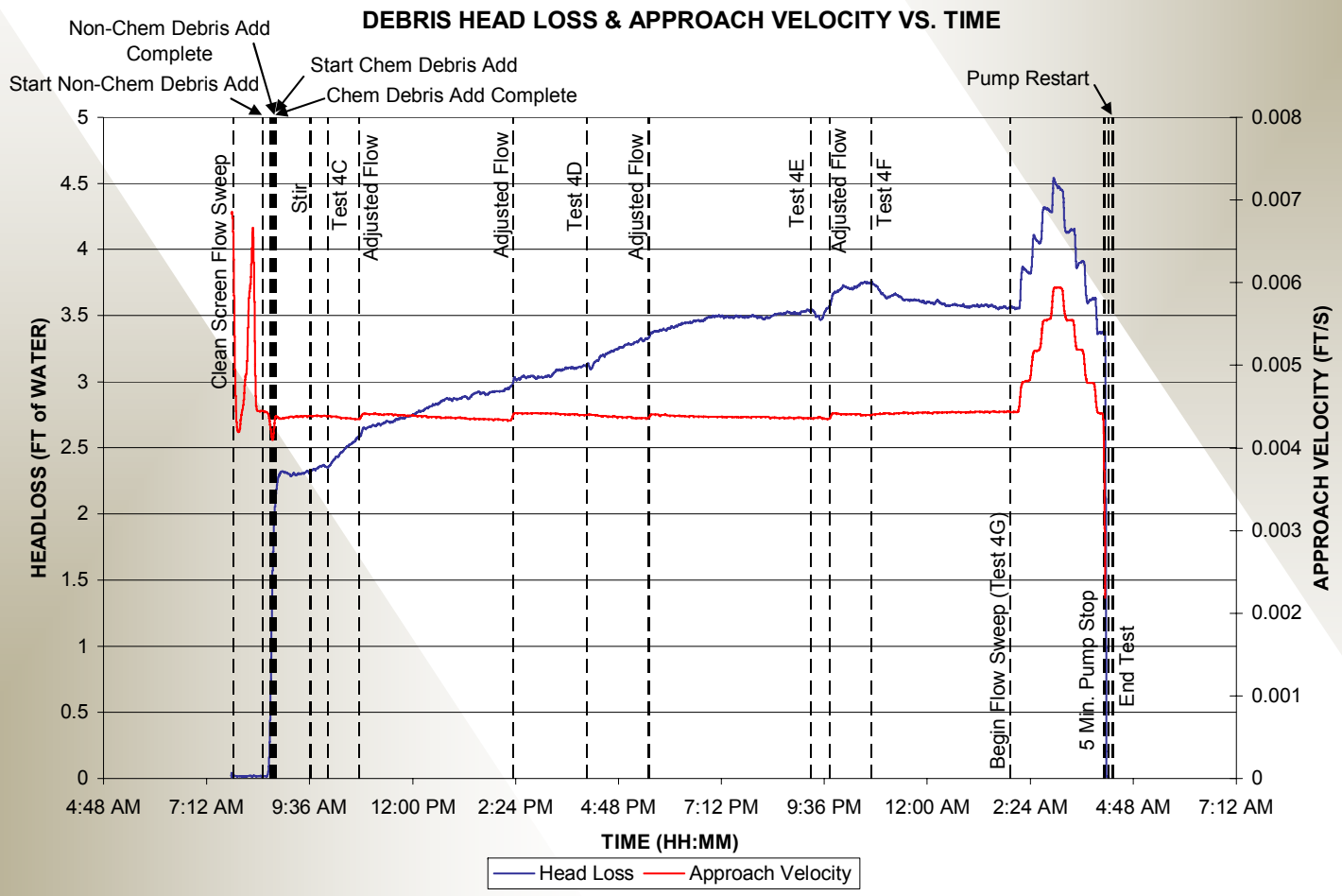
Test 4 Results



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Type 2 Approach

- WCAP-16785 precipitates added as additional debris source during the prototype testing
- Example: Nuclear Plant 2 – testing underway
- Open Issues: Completion of benchtop experiments, and NRC issues with new WCAP.

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Test Plan

- Perform testing similar to Type 1 except:
  - Reduction in WCAP loading based on silica inhibition validated through plant specific bench chemistry testing.
  - Perform plant specific bench testing to confirm no chemical effects (solubility levels) for first 3 day after which additional NPSH margin available

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Test Conditions

- Full scale prototype strainer assembly (121 ft2)
- Tap water testing at ~80 deg F
- Reduced quantity of precipitates per WCAP-16785 for silicon inhibition – buffer NaTB
- Precipitates manufactured and verified outside of test tank per WCAP-16530
- Approach velocity equivalent to replacement strainer
- Scaled debris mixture added in batches to ensure thorough mixing and proportionate to WCAP generation
- Perform test until head loss stabilizes to 1% in 1 hour.
  - Intermediate points consider pool turnover and timing.

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Test Conditions

Test #	NUKON® (lbm)	Temp-Mat® (lbm)	Equivalent Bed Thickness	Cal-Sil (lbm)	Wollastonite 520H (lbm)	Ground Silica (lbm)	Dirt/Dust (lbm)	*Sodium Aluminum Silicate (g) {~gal}*
1A	0	0	0	0	0	0	0	*0*
1B	8.39	4.33	0.38"	80.9	15.3	40.6	10.3	*0*
1C	0	0	0.38"	0	0	0	0	*549.7 g {13.20 gal}*
1D	0	0	0.38"	0	0	0	0	*343.5 g {8.25 gal}*
1E	0	0	0.38"	0	0	0	0	*206.1 g {4.95 gal}*
1F	0	0	0.38"	0	0	0	0	*206.1 g {4.95 gal}*
1G	0	0	0.38"	0	0	0	0	*206.1 g {4.95 gal}*
1H	0	0	0.38"	0	0	0	0	*206.1 g {4.95 gal}*
1I	0	0	0.38"	0	0	0	0	*274.8 g {6.60 gal}*
1J	0	0	0.38"	0	0	0	0	*0*

** Continuous Testing with Incremental Additions*

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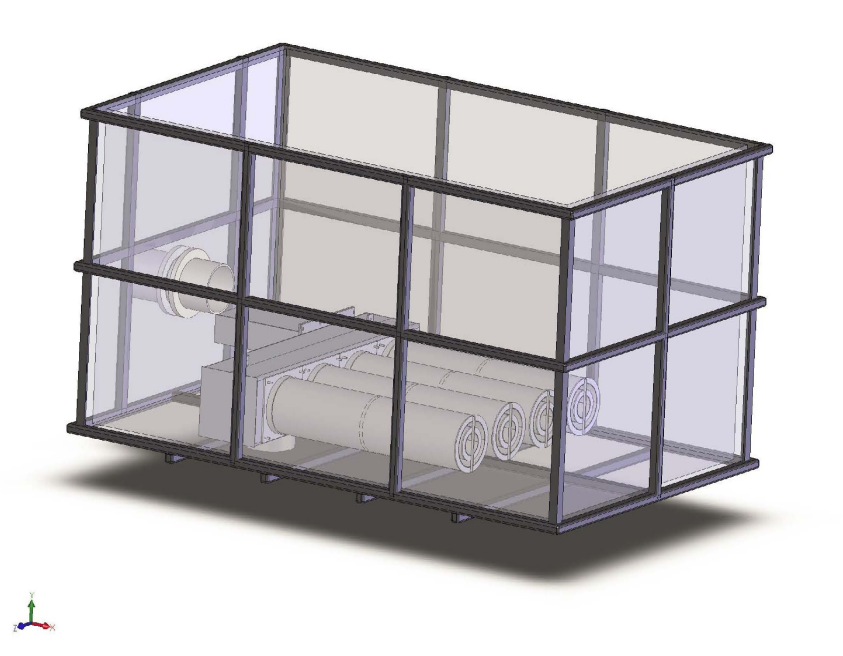
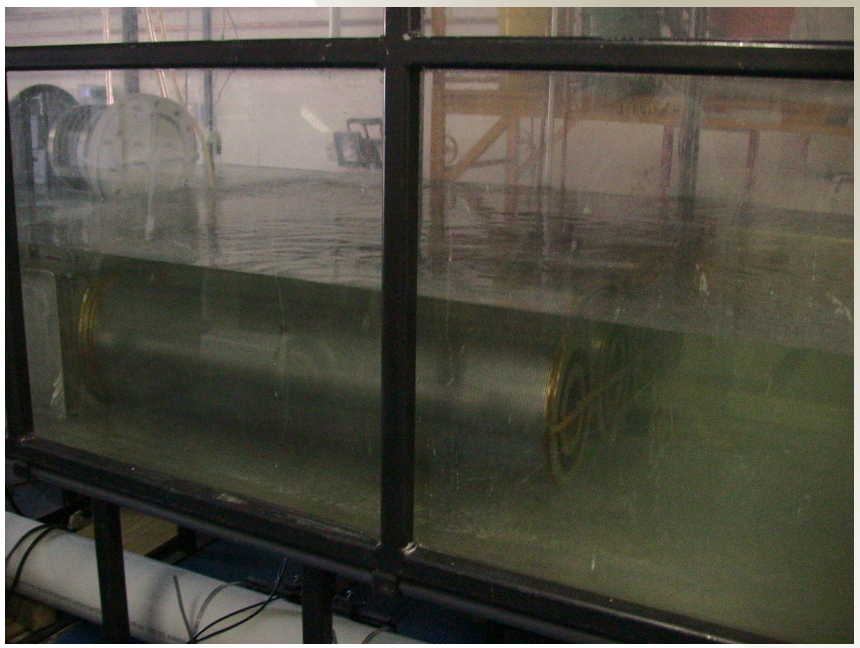
Test Configuration





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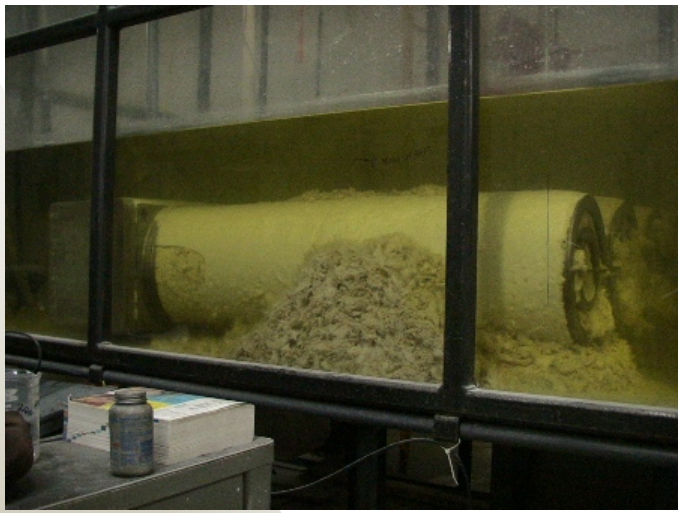
Test Photos



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Type 3a Approach

- Small scale 30 day chemical effects head loss testing on flat plate with plant specific debris load
- Examples: SONGS, TMI-1
- Open Issues: variability in pH, gas evolution

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30 Day Test Conditions

- Replicate sump chemical environment history
- Plant specific temperature history
- Plant specific pH (7.5, 8.5) – TSP
- Screen Area ~.135 ft2 – flat plate
- Approach velocity equivalent to replacement strainer
- Includes Aluminum, Zinc, Copper, Concrete

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Small Loops

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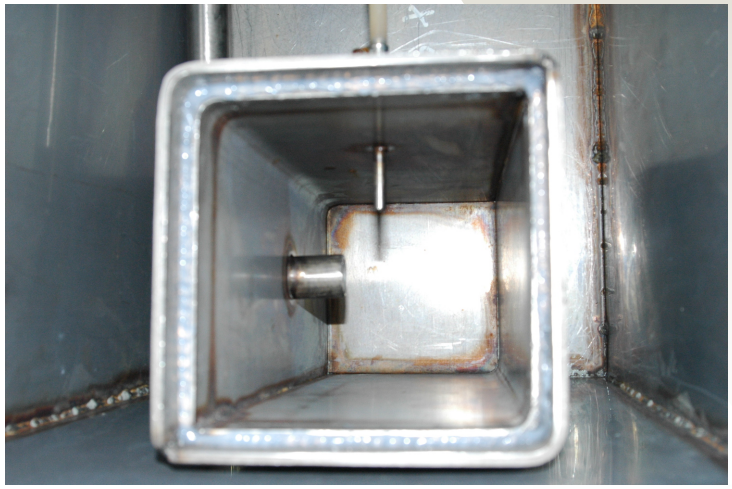
Test Photos



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Test Observations

- Reaction of aluminum coupons visibly increased as pH was raised above 8.0 vs. 7.5.
- Gas voids forming under the screen affected bed stability and apparent dP.
- No visible precipitation in solution in experiment.
- Impact of chemical effects on head loss did not appear until approximately 10 days after start of test.

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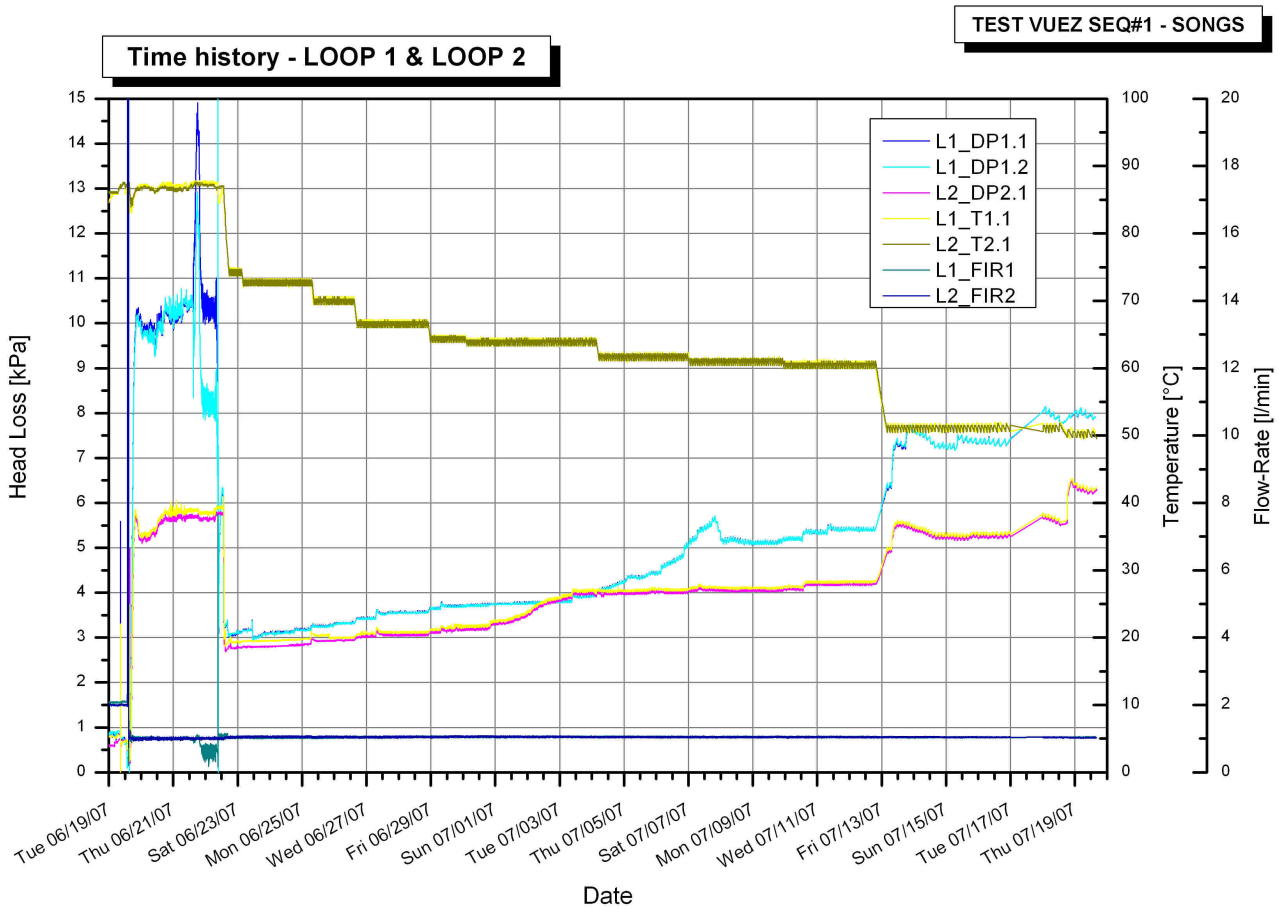
Head Loss Test Results



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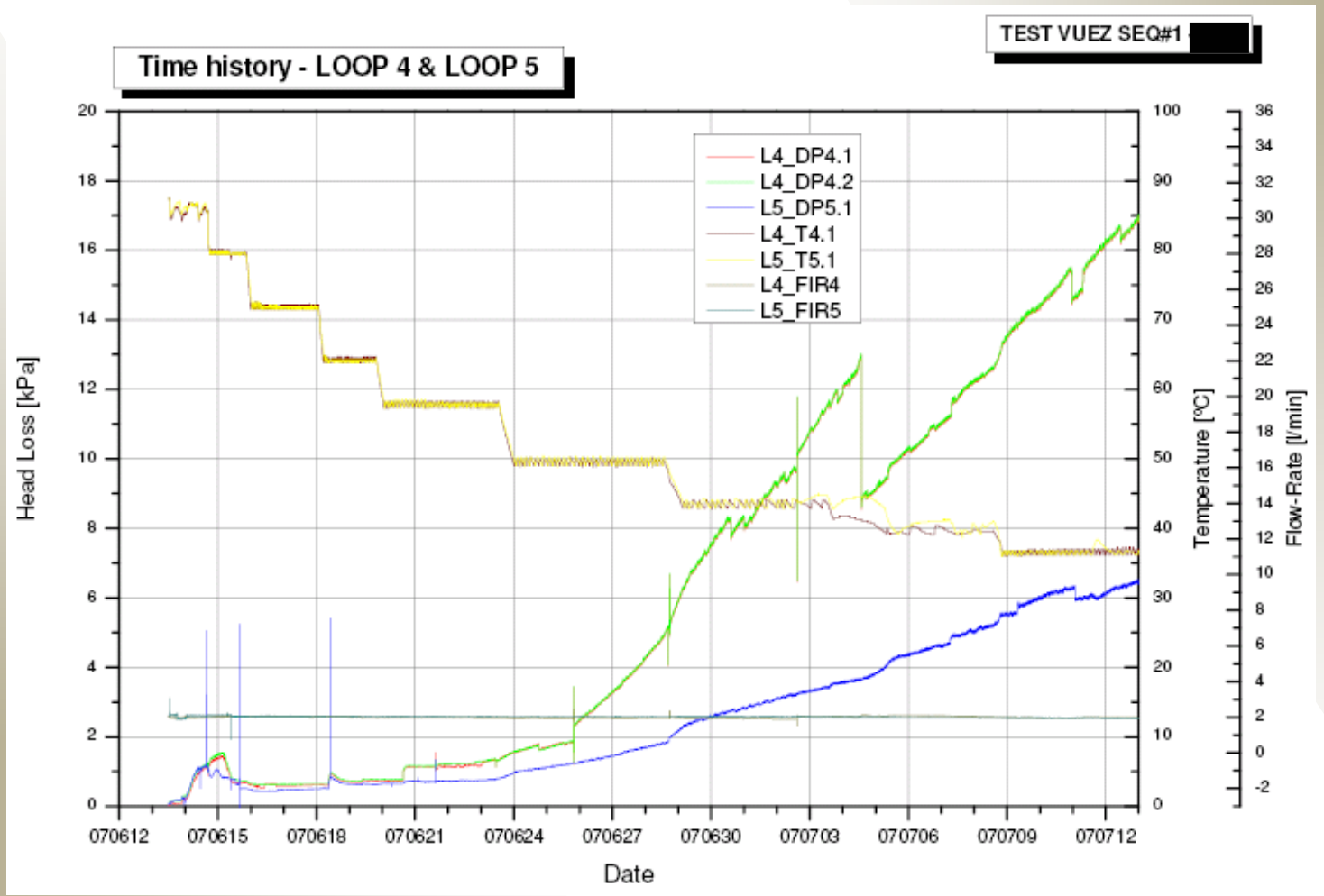
Head Loss Test Results



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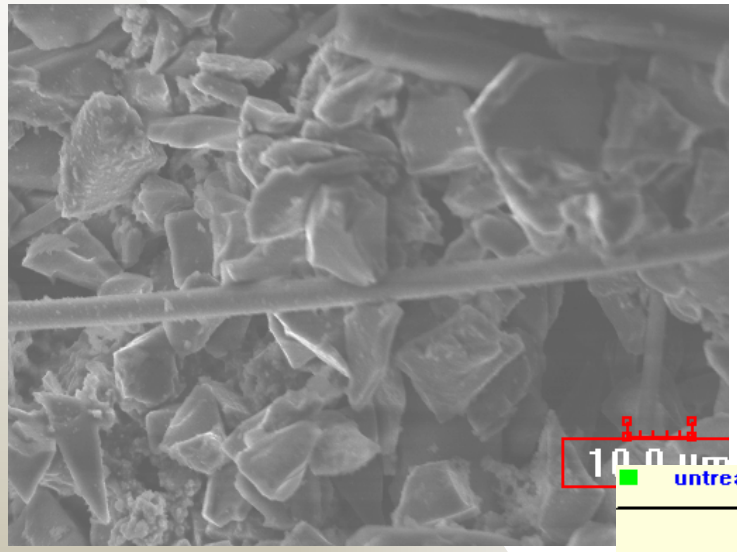
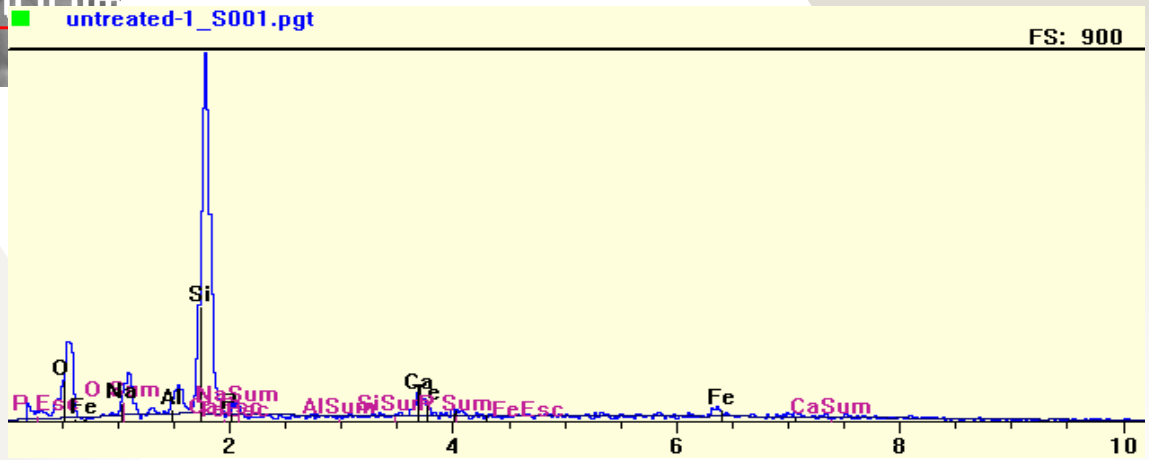
SEM/EDS Results



June 21, 2007

Debris Bed Sample – Loop 4



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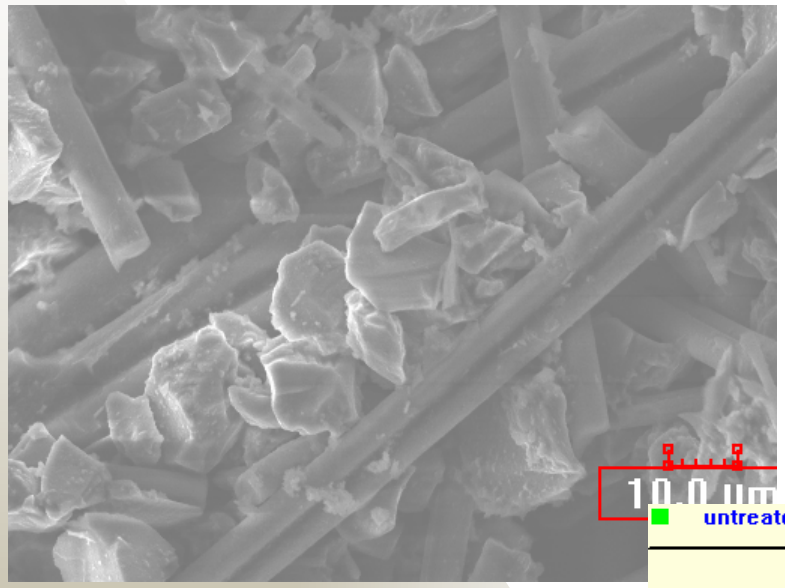
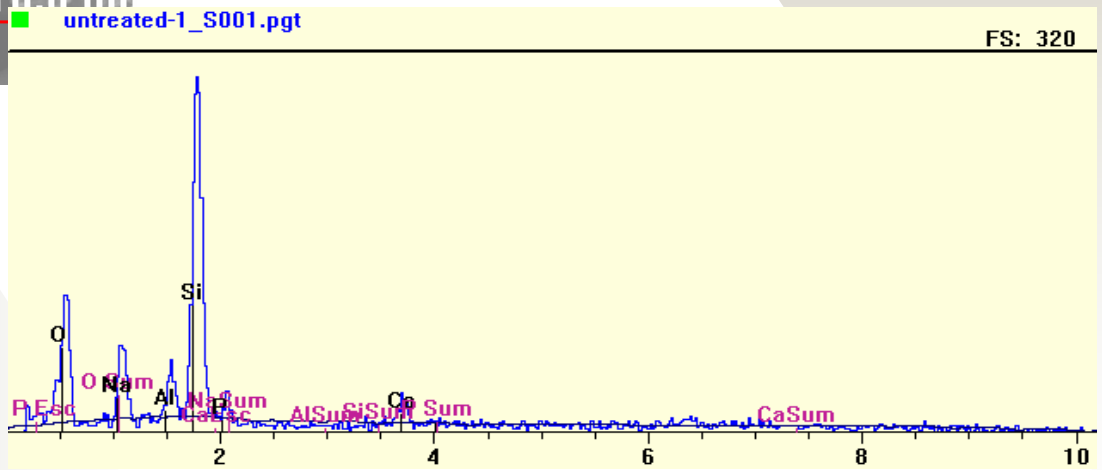
SEM/EDS Results



June 23, 2007

Debris Bed Sample – Loop 4



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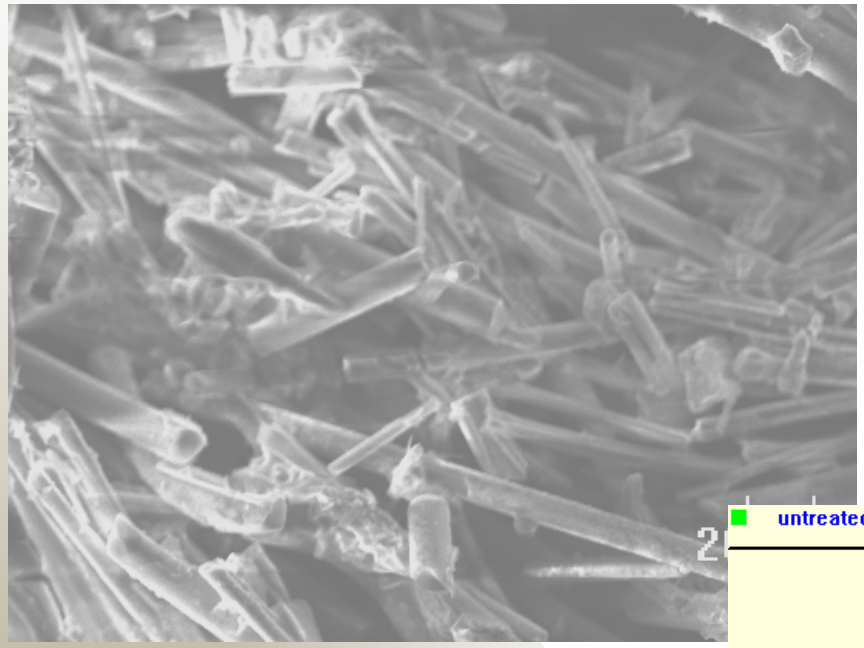
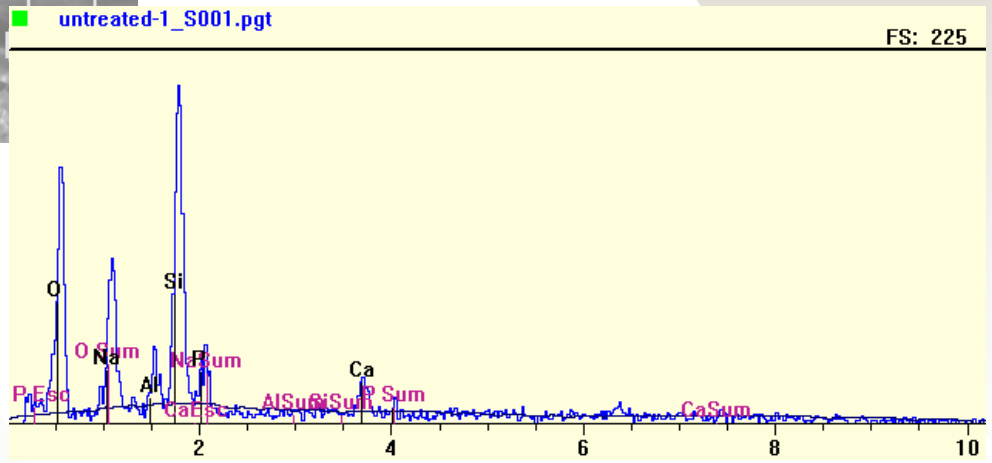
SEM/EDS Results



June 26, 2007

Debris Bed Sample – Loop 4



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ICP Results

Aluminum Concentration

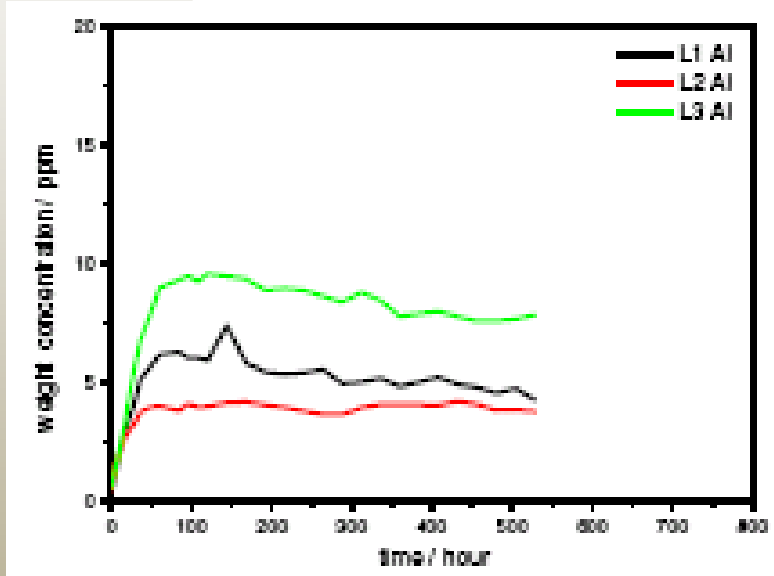

Figure 5.1-2: Al concentration (tests 1, 2, 3)

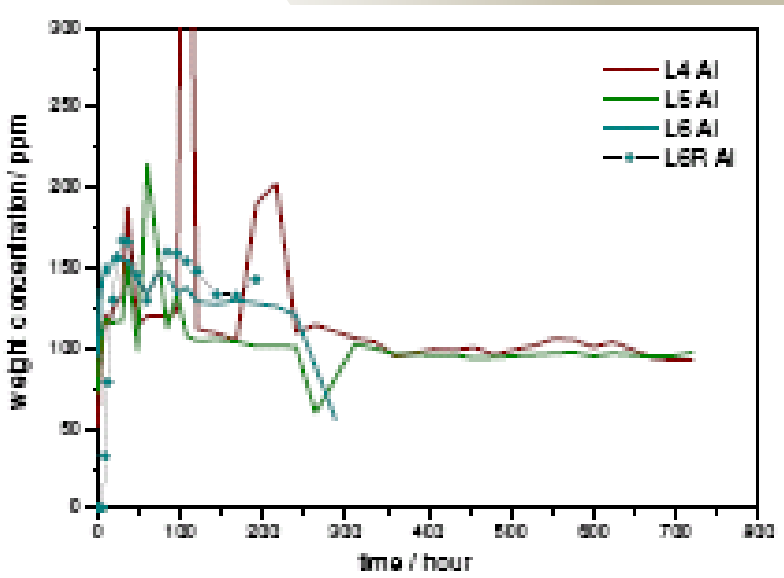

Figure 5.2-3: Al concentration (tests 4, 5, 6 (mod.))

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ICP Results

Silicon Concentration

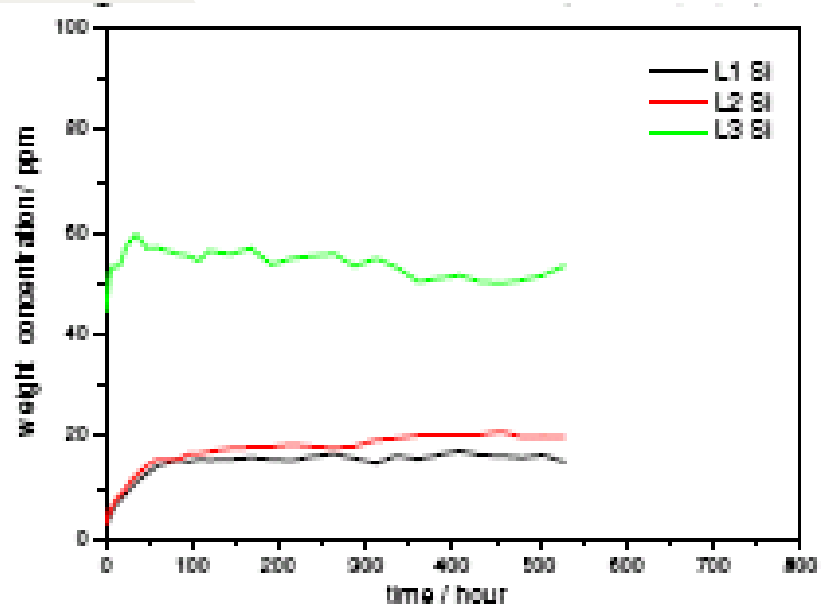

Figure 5.1-3: Si concentration (tests 1, 2, 3)

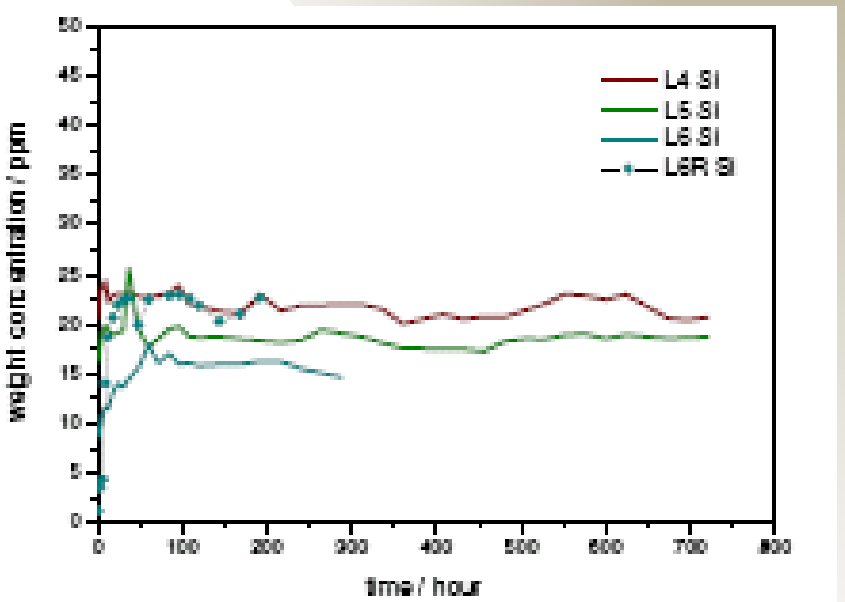

Figure 5.2-4: Si concentration (tests 4, 5, 6 (mod.))

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SEM Images of Fiber

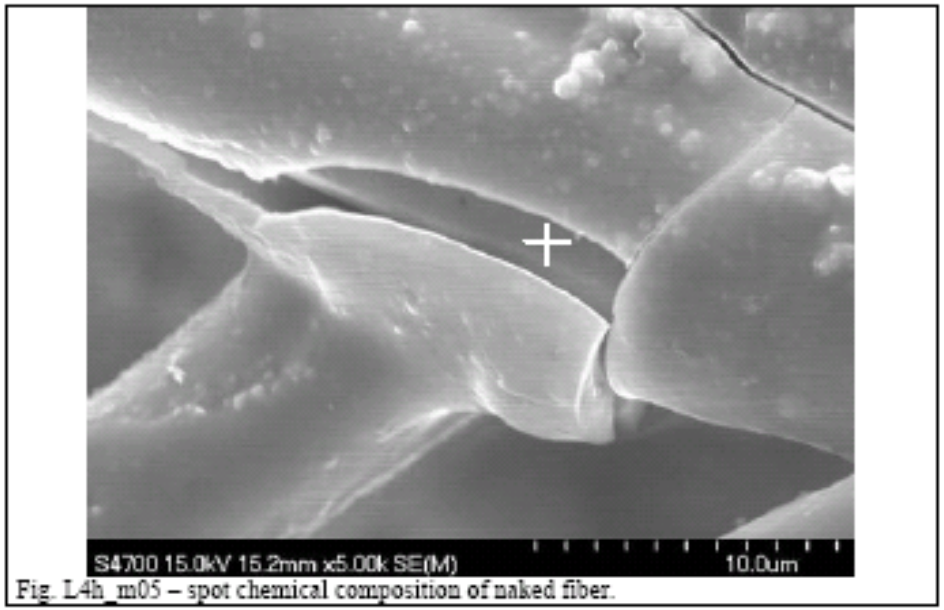
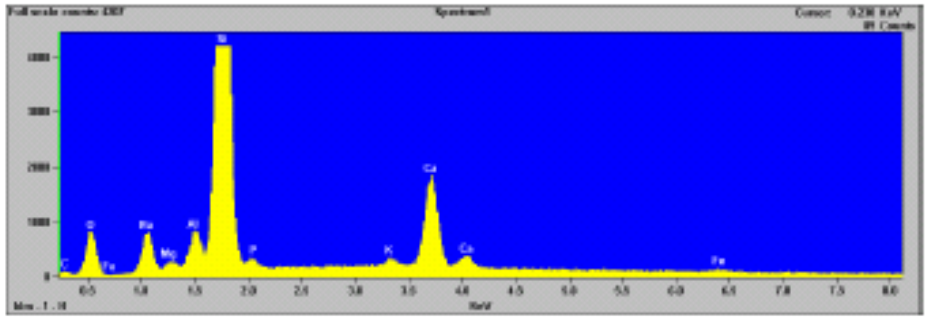


Fig. L4h_m05 – spot chemical composition of naked fiber.



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SEM Images of Fibers

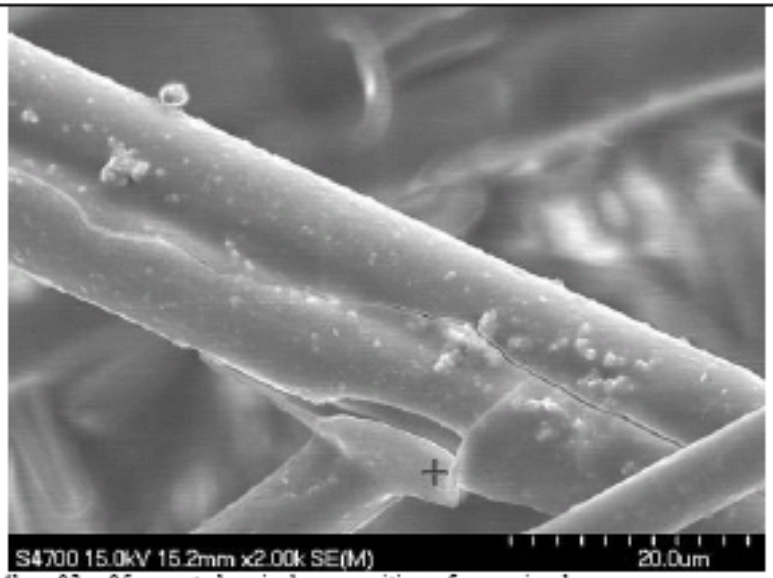
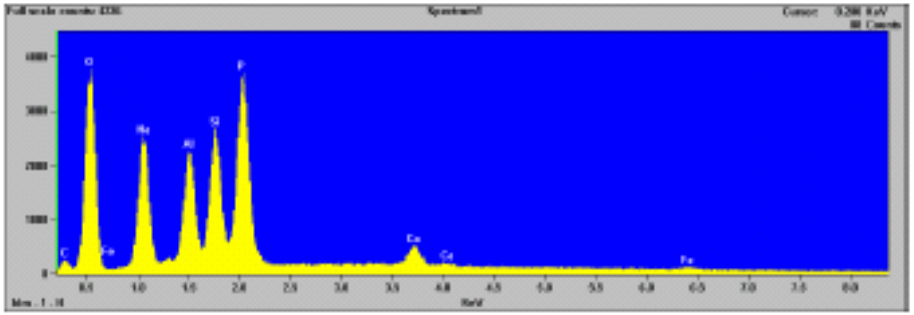


Fig. L4h_m03 m05 – spot chemical composition of corrosion layer.



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SEM Images of Fiber

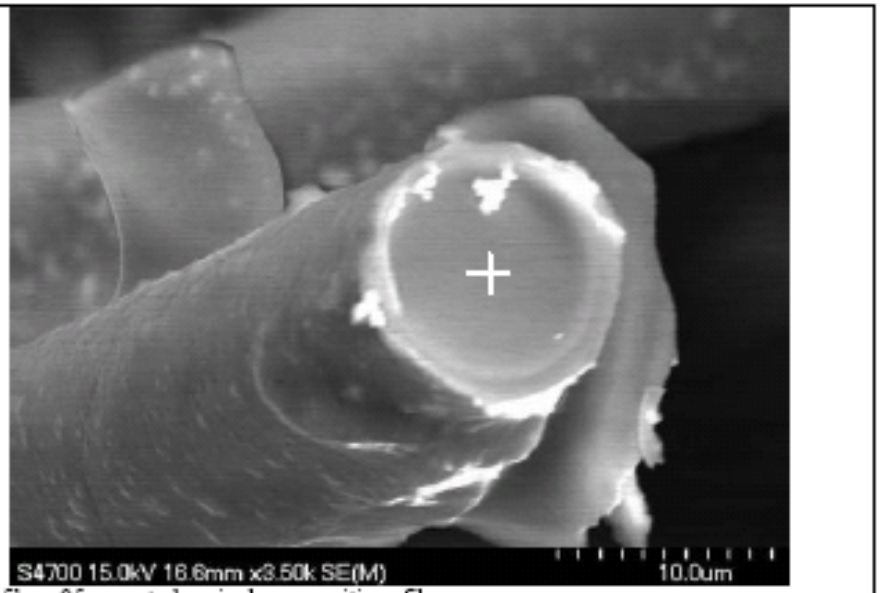
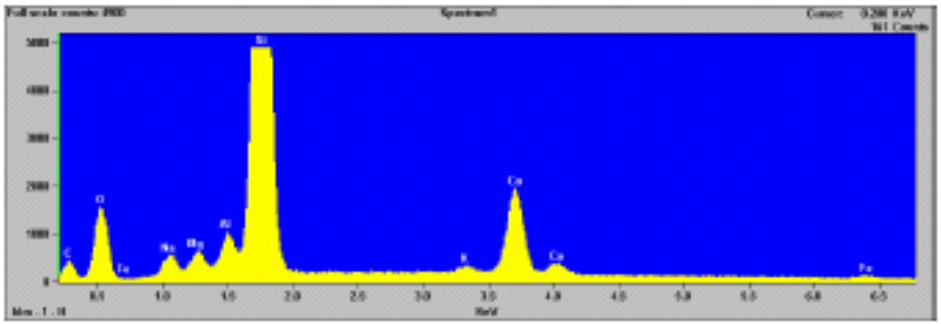


Fig. L5h_m05 – spot chemical composition, fiber core.



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SEM Images of Fiber

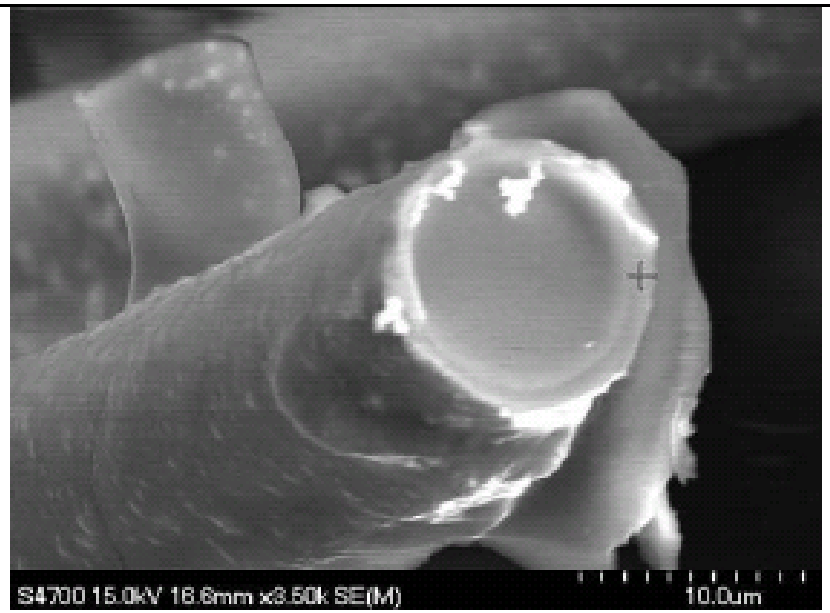
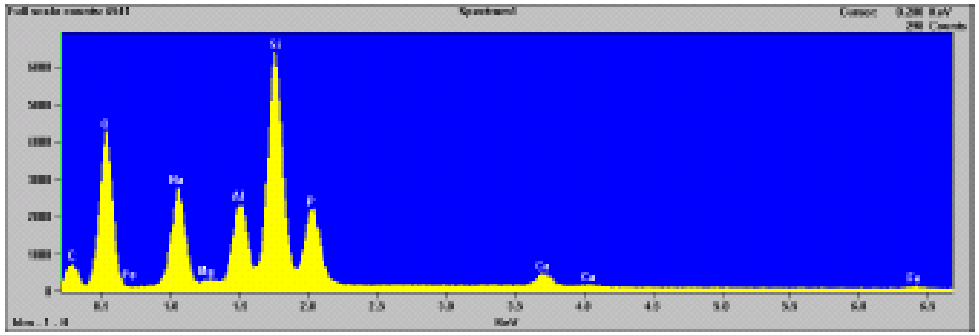


Fig. L5h_m06 – spot chemical composition, fiber corrosion layer.



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Test Conclusions

1. Aluminum corrosion significantly increased from pH 7.5 to 8.5.
2. Chemical effects increased based on aluminum corrosion/concentration.
3. The onset of chemical effects did not occur until about day 10 of the 30-day test.
4. Precipitate occurred on fibers within the debris bed and fibers settled in tank.
5. Gas evolution during high temperature phase can impact head loss on flat plate.

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Application of Results

- The experimental results yield a time dependent, temperature corrected bump up factor.
- This factor is applied to the non-chemical prototype testing to yield a time dependent head loss.
- Time dependent NPSH required can be calculated.
- Time dependent NPSH margin can be calculated.
- NPSH margin needs to be evaluated for high and low containment temperature profiles at high and low flow rates.
- Initial (pre-accident) containment pressure is assumed in the NPSH calculation.

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Type 3b Approach

- Large scale 30 day chemical effects head loss testing on prototype strainer with plant specific debris load
- Examples: DC Cook (CCI Design)
- Issues: Selection of conservative inputs (pH, temperature)

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30 Day Test Conditions

- Replicate sump chemical environment
- Plant specific temperature history
- Plant specific pH – NaOH, NaTB
- Screen Area ~5.0 ft2 – CCI Pocket Design
- Approach velocity equivalent to replacement strainer
- Includes Aluminum, Zinc, Copper, Concrete, RCP Oil

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Large Elisa Loop

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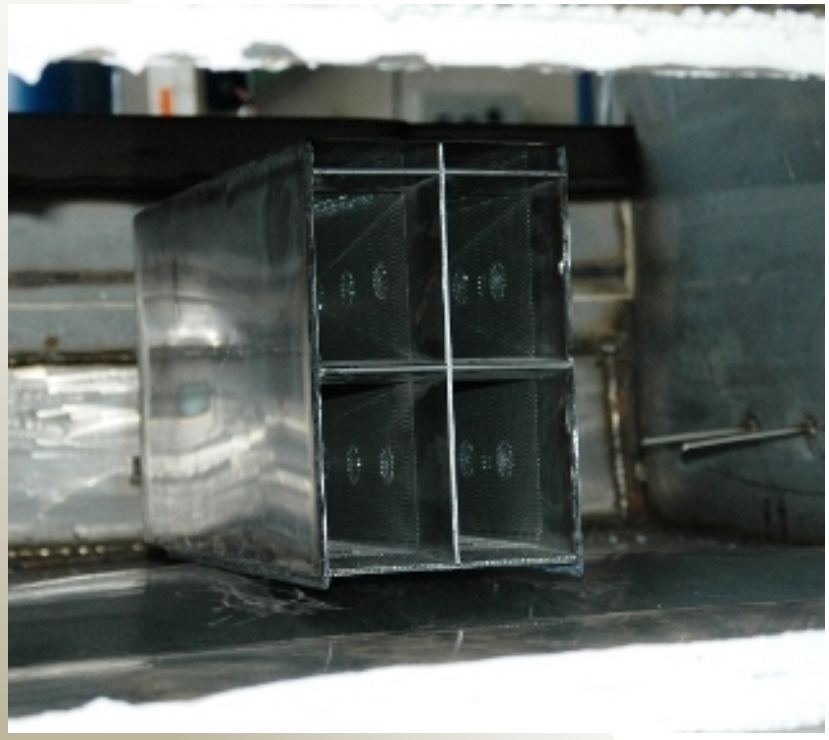
Screen Mounting



Clean Screen in Tank

Post Test Debris Loaded Screen

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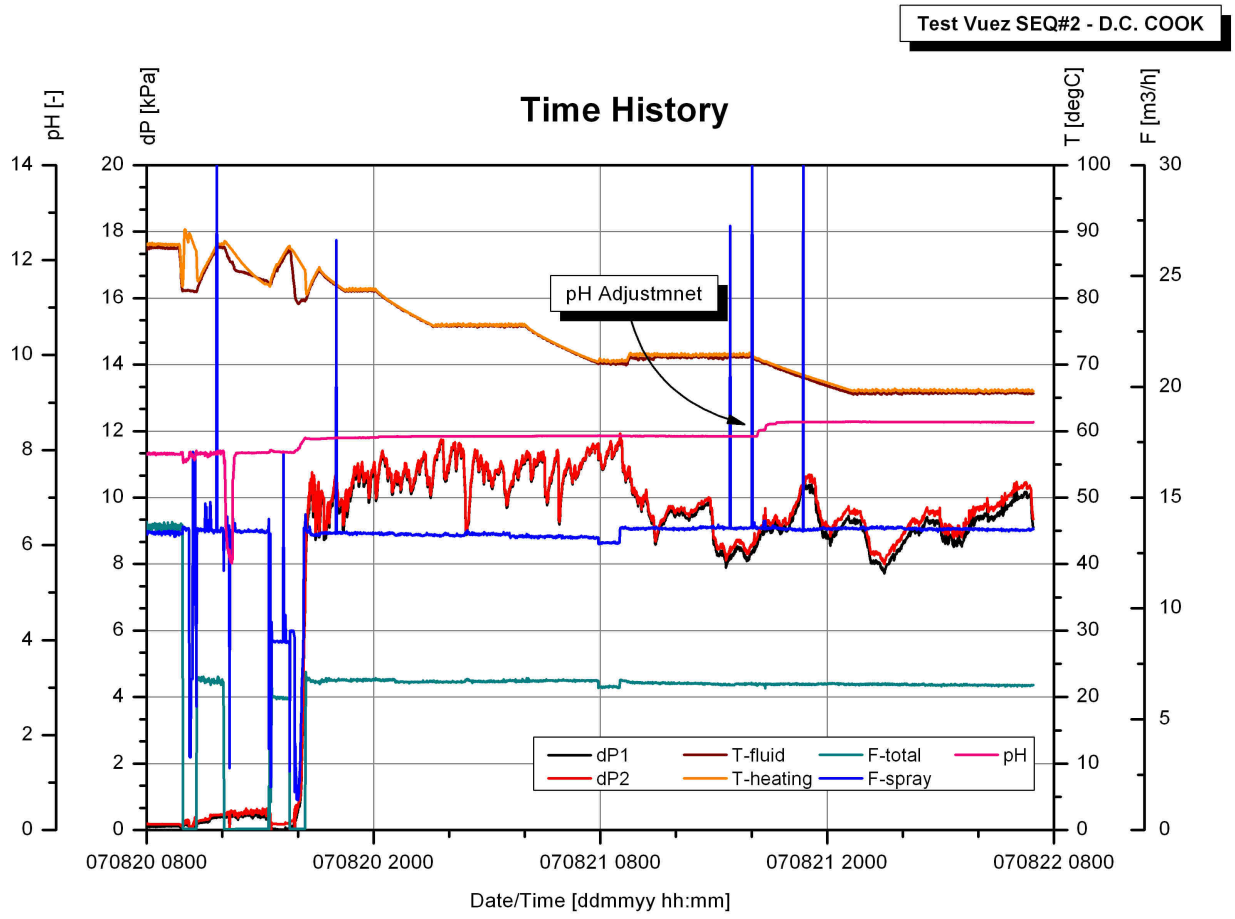
Test Results



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Test Results

- Debris materials include fiber, calcium silicate and particulates.
- Test is currently at Day 4 (dP ~ 10 kPa) with no significant changes in head loss.
- Results to be presented at later date.

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NPSH versus Time

$$NPSH_a = \frac{144}{\rho} \cdot \frac{g_c}{g} \cdot (P_a - P_v) + H_s - H_f$$

P_a = Containment Atmosphere Pressure

P_v = Sump Inventory Vapor Pressure

H_s = Containment Water Level Static Head Above RHR and CS Pump Impeller

H_f = RHR and CS Suction Line Losses

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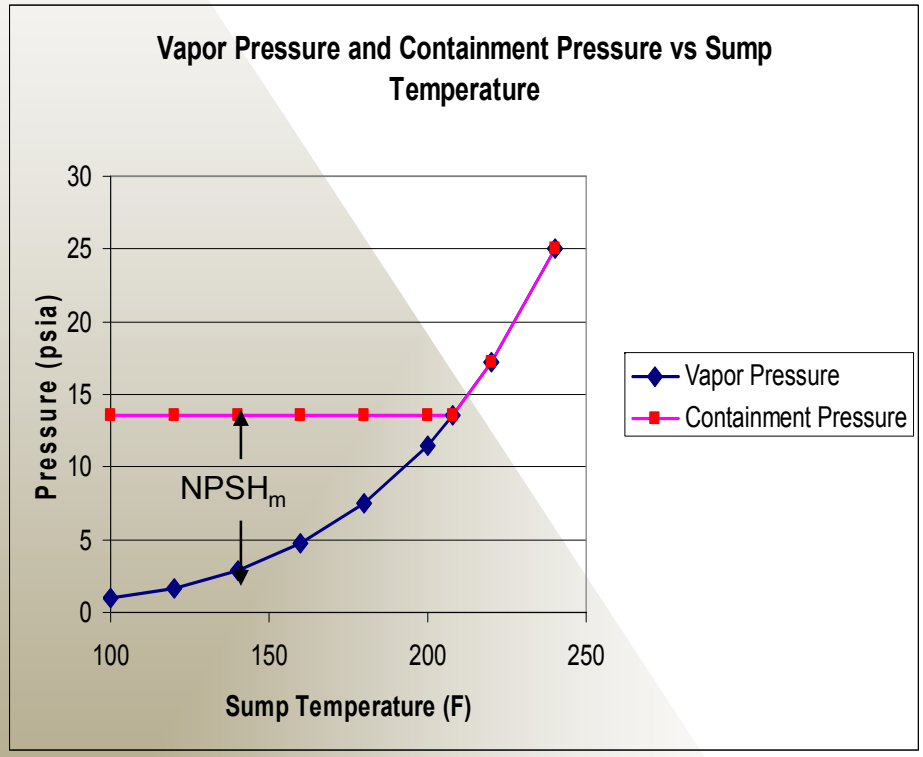
NPSH versus Time



- Minimum containment pressure prior to the accident is 14.3 psia (typical)
- As recommended by Regulatory Guide 1.82, the containment atmosphere pressure is set equal to the vapor pressure of sump inventory for sump temperatures exceeding 210 F (saturation temperature at 14.3 psia)
- This approach conservatively assumes that the sump inventory is saturated.
- At sump temperatures below 210 F, the containment pressure remains constant at the minimum containment pressure prior to the LOCA while the vapor pressure decreases.
- Difference between the containment pressure and vapor pressure provides additional NPSH margin
- Caution: Decreasing sump temperature may result in increasing head loss due to increased viscosity effects -- this is small compared to the gain above

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NPSH versus Time

- Based on the containment analysis, peak post-accident sump temperature reaches approximately 260 F.
- Sump temperature during post-LOCA accident mitigation
  - Temperature drops below 208 F between 6 and 8 hours after the accident.
- Using the WCAP precipitant methodology, large quantity of precipitants formed prior to 6 – 8 hours post-LOCA
- Integrated corrosion rates test could demonstrate that corrosion rates early after the accident predicted by the WCAP could be overly conservative.

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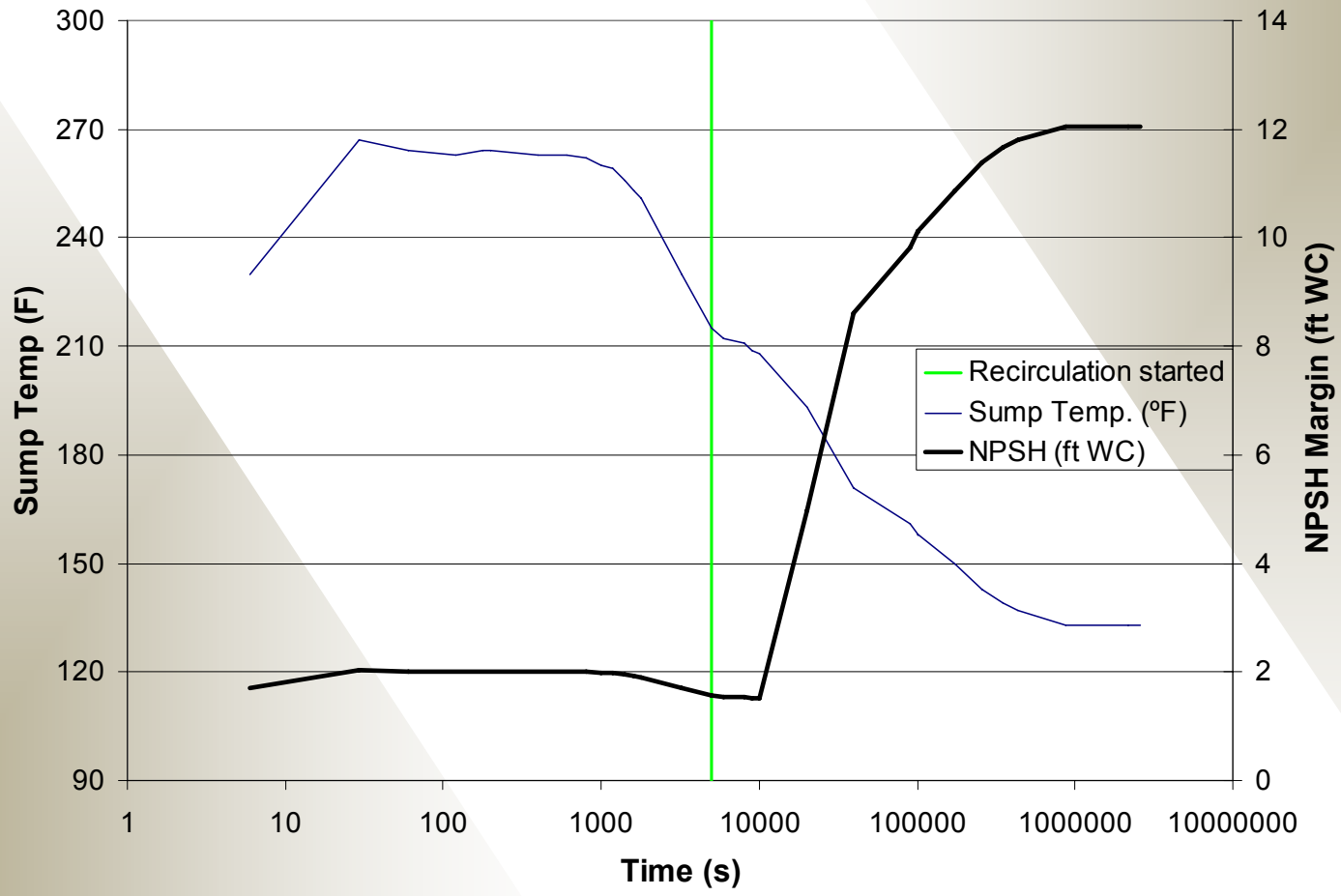
NPSH versus Time



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Summary

- Incorporating a time based approach for the formation of precipitates, the impact on head loss and the NPSH available through sub cooling can provide a solution path to the resolution of chemical effects.

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