
Resolution of Chemical Effects Issues



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Purpose of Presentation

- Provide updated results from RES sponsored testing.
- Discuss technical issues related to chemical effects evaluations.
- Identify paths forward to resolution of issues.



Presentation Topics

- Recent research results (Torres)
- Other NRC staff activities: (Klein)
 - Chemical Effects WCAP review status
 - Alternate Buffer Test Observations
- Technical issues and path forward (Klein)



Head Loss in NaOH and Na₂B₄O₇ Environments

Approach

- Examine the influence of test temperature, time at temperature, and pH on head loss for various dissolved aluminum (Al) concentrations.
- Establish test loop chemistry and form initial NUKON test bed at 0.1 ft/s flow velocity.
- Add target dissolved Al at elevated temperature (140°F).
- Sequentially cool test solution within the loop to target temperatures (e.g., 120°F, 100°F, 80°F, 65°F).
- Hold loop at each target temperature until pressure drop stabilizes or for predetermined time period.

Test Constants

- Aluminum Nitrate Al(NO₃)₃ used to get equivalent dissolved Al concentrations
- All tests with initial 0.07 g/cm² NUKON debris bed on test screen (≈17 mm thick)



Head Loss in NaOH Environments

Test Conditions

- Six tests with various dissolved Al concentrations: 375 ppm, 200 ppm and 100 ppm
- Evaluation temperatures: 140°F, 120°F, 100°F, and 80°F
- Total Boron Concentration = 2800 ppm
- Initial pH = 10

Test Results

- Head loss in NaOH due to dissolved Al can be significant, even down to 100 ppm dissolved Al
- Head loss is a strong function of Al concentration, temperature and time at temperature
- Head losses are observed with no visible indication of precipitates
- Onset of significant head loss in NaOH environment is highly variable; a complex process and difficult to simulate



Head Loss in $\text{Na}_2\text{B}_4\text{O}_7$ Environments

Test Conditions

- First test: 50 and 100 ppm Al
 - NUKON debris bed
 - Evaluation temperatures: 140°F, 120°F, 100°F, and 65°F
- Second test: No dissolved Al
 - NUKON and CalSil debris bed
 - Evaluation temperatures: 140°F and 65°F
- Total Boron Concentration = 2400 ppm
- Initial pH = 8

Test Results

- First Test
 - No head loss after decreasing temperature to 65°F and holding for 5 days
 - Fluid temperature increased to 140°F and additional 50 ppm Al added; rapid head loss occurred
 - No visible indication of precipitates
- Second Test: Results are pending



Chemical Effects: NRC Head Loss Testing

Future Plans

- May – June: Complete post-test analysis, continue reporting and documentation.
- Final NUREG/CR on chemical effects head loss testing projected to be available September 2006.
- More information available at upcoming ACRS Thermal-Hydraulic Subcommittee Meeting: June 13 – 14, 2006.



WCAP 16530-NP Review Status

- NRC has accepted WCAP for review
- RAI draft target date is July 06
- SE draft target date is May 07

- Target SE was set with the recognition that additional testing may be necessary to address staff RAIs.
- Thoroughness and timeliness of RAI response will influence SE date.



Alternate Buffer Test Observations

- 4/27/06 NRC staff visit to Fauske Laboratories
- Observations:
 - Staff encourages continued investigation of alternate buffers.
 - Current tests, though informative, appear to be more screening tests than a comprehensive study to support a licensee's change to alternate buffer.
 - Adequate technical basis is needed if a licensee intends to switch to a new buffer.



Chemical Effects Evaluation Criteria

- Head loss resulting from plant specific conditions, including chemical effects, is less than available pump NPSH margin for the entire ECCS mission time.
- Uncertainty in determining chemical effects head loss is bounded by head loss margin.
- Potential chemical interactions in downstream environments and with downstream components are appropriately considered.



Chemical Effects Evaluations – Important Attributes

- Plant specific materials/environment interaction well characterized over range of debris and pool conditions.
- Uncertainty in chemical effects head loss is bounded by plant specific testing and analysis and accounted for by margin.
- Sound technical basis for use of “chemical surrogates”
- Strong justification for any chemical effects testing performed in a environment (e.g., tap water) not representative of postulated plant specific post-LOCA containment pool.



Chemical Effects - Technical Issues

1. Issue - The model developed in the WCAP is based on small-scale, short-term testing. Is this model applicable in large-scale post-LOCA containment environments over the mission time required for ECCS recirculation operation?

NRC Expectation - WCAP chemical model will be validated over the range of plant environments, uncertainty will be quantified, and interactions of multiple materials will be demonstrated by testing.

Path Forward – To be resolved as part of WCAP 16530-NP review.



Chemical Effects - Technical Issues

2. Issue - Can predominantly separate effects test results be used to account for interactions of multiple materials?

NRC Expectation – WCAP chemical model will be demonstrated to be conservative: (i) amounts of precipitate in combined materials test, (ii) combined materials tests do not produce new precipitates outside of chemical model predictions.

Path Forward - to be resolved as part of WCAP 16530-NP review.



Chemical Effects - Technical Issues

3a. Issue – Do chemical surrogates adequately represent both the chemical and physical properties of the actual product?

NRC Expectation – (a) Surrogates must adequately represent both the chemical and physical properties of the actual product.

Path Forward - to be resolved through interactions with industry (vendors, licensees).



Chemical Effects - Technical Issues

3b. Issue – Can chemical precipitate addition to non-representative test environments simulate plant specific chemical effects?

NRC Expectation – Either a technical justification is provided to support introduction of precipitate into non-representative environments or head loss tests are performed in representative environments.

Path Forward - to be resolved through interactions with industry (vendors, licensees).



Chemical Effects - Technical Issues

4. Issue - How will plant specific conditions such as debris materials (e.g., insulations, paints), pool pH, and temperatures that were not tested be evaluated?
- NRC Expectation – Plant specific evaluations outside the bounds of the testing knowledge base must have sufficient technical basis.
- Path Forward – WCAP review process, interactions with strainer vendors and plant licensees during audit process.



Chemical Effects - Technical Issues

5. Issue - Individual strainer vendors' chemical effects evaluation plans are needed for staff review.

NRC Expectation – NRC staff will be provided written plans for chemical effects testing for each strainer type.

Path Forward – Discussions with NEI and industry vendors during May 06 meetings. Ongoing interactions including staff visits to vendor facilities and licensee audits.



Chemical Effects - Technical Issues

6. Issue - Given low approach velocities and small openings, can chemical products by themselves cause head loss in the absence of a continuous fiber bed?

NRC Expectation – Tests will demonstrate if representative amorphous type chemical products can create head loss across a sparse bed or bare strainer surface.

Path Forward – demonstrated by strainer tests for licensees that take credit for clean screen area to counter chemical effects.



Chemical Effects – Technical Issues

7. Issue – Debris bed arrival sequence (e.g., arrival of chemical products relative to other plant debris) can affect bed saturation and head loss.

NRC Expectation – Introduction of chemical precipitates in head loss tests is consistent with expected chemical product generation and arrival in the plant specific environment.

Path Forward – Licensees will analyze plant specific chemical effects to ensure that arrival sequence is properly tested. Staff to verify during vendor visits, plant audits and GL 2004-02 supplements review.



Chemical Effects – Technical Issues

8. Issue – Downstream conditions (e.g., temperature cycle, boron concentration, flow) can affect chemical product formation/properties.

NRC Expectation – Plant specific downstream effect evaluations include considerations of chemical products.

Path Forward – will be included as part of downstream effect issues.



Chemical Effects – Technical Issues

9. Additional issues may be identified through future testing or analysis:
- Strainer vendor test results
 - Other NRC sponsored or industry sponsored tests
 - Chemical effects peer review panel reports



Chemical Effects – Path Forward

ITEM	NRC Action/Expectation	Industry Action
1. chem. model 2. separate effects	WCAP RAI & WCAP SE	RAI response
3. use of chem. surrogates & non-represent. environments	WCAP RAI & WCAP SE	Provide justification or conduct testing in representative environments
4. plant specific conditions outside tested conditions	WCAP Review Licensee audits	Plant specific evaluations have a sufficient technical basis
5 screen vendor chemical effects evaluation plans	NRC staff review and comment. Ongoing vendor visits&interaction	Chemical effects test plans for various strainer types provided to NRC staff



Chemical Effects – Technical Issues

ITEM	NRC Action/Expectation	Industry Action
6. chemical products on bare screen	Basis provided if licensee credits bare screen	Tests to demonstrate if chem products can cause head loss without a pre-existing bed
7. chemical product arrival time	NRC staff will verify relative arrival of chemical products	Screen vendor chemical precipitate additions relative to other debris are consistent with expected plant tests
8. downstream effects –chemical effects cycle	Addressed by cognizant staff in downstream area	Plant specific downstream effect evaluations includes potential chemical products.
9. additional issues	Provide test results and peer review panel results to industry	Provide results from chemical effects testing to staff



Summary

- Caucus
- Discussion
- Agreement on path forward



Acronyms

- Al – aluminum
- ECCS – emergency core cooling system
- ICET – Integrated Chemical Effects Test
- LOCA - Loss of coolant accident
- $\text{Na}_2\text{B}_4\text{O}_7$ – sodium tetraborate
- NaOH – sodium hydroxide
- NPSH – net positive suction head
- RAI – request for additional information
- RES – Office of Nuclear Regulatory Research
- SE – safety evaluation
- WCAP – PWR Owner’s Group Report WCAP16530-NP

