Agenda
Public Meeting
September 30, 2005
GSI-191 Chemical Effects

TOPIC - PUBLIC MEETING	PRESENTER	TIME
Meeting Opening/Introductions	Hopkins/All	9:00 am
Opening Remarks - Meeting Objective	NRC - Sheron/Martin/Mayfield	9:10 am
Information Notice 2005-26, Chemical Effects Head Loss Data	NRC - Klein/Tregoning	9:30 am
Break		10:15 am
Industry Activity, IN 2005-26	Industry	10:30 am
Lunch		11:50 am
Industry Activities in Chemical Effects	Industry	1:00 pm
NRC Address Public Comments		2:00 pm
Closing Comments	NRC	2:30 pm
Adjourn Public Meeting		

GSI – 191
Chemical Effects
Opening Remarks

Dr. Brian Sheron
Associate Director, NRR
US Nuclear Regulatory Commission

Opening Remarks

- Chemical effects were first identified as a potential issue in 2003.
- Integrated Chemical Effects Test – ICET were conducted at Los Alamos National Laboratory.

Integrated Chemical Effects Test

- The tests, developed jointly by the NRC and Industry, were ~~not~~ intended to be representative of PWR plant containment pool environments.
- Tests identified the formation of gel/chemical products. *(Head loss measurement was outside the scope)*
- Results indicate that variations in chemical composition of sump water can result in large variations in precipitate behavior.

Response to GL 2004-02

- Staff has repeatedly described expectations. June 30, 2005 - Industry was told responses to GL need to:
  - Identify margin in proposed sump modifications to accommodate chemical effects.
  - Describe program details (experimental and/or analytical) that will confirm the chemical effects design margin.
- Preliminary staff reviews indicate that submittals are not adequate with respect to chemical effects/head loss.

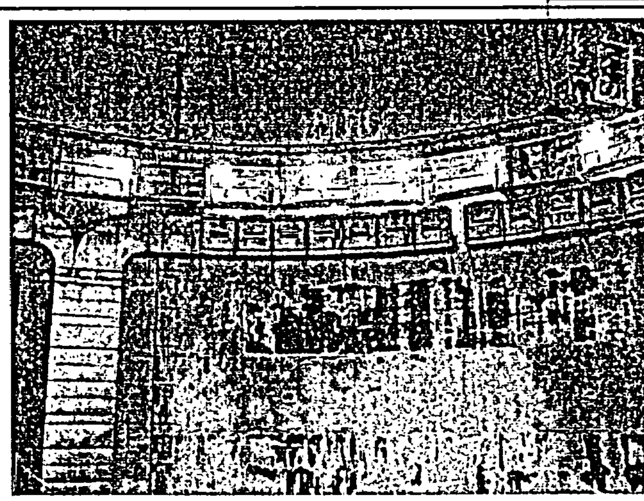
Additional Detail Required

- Staff needs more information/details on:
  - What experiments will be conducted?
  - How results will be used to demonstrate applicability to prototypical modified sump designs?
  - How the results apply to specific conditions (mix of chemicals, materials, transportation, etc.) of a given plant?

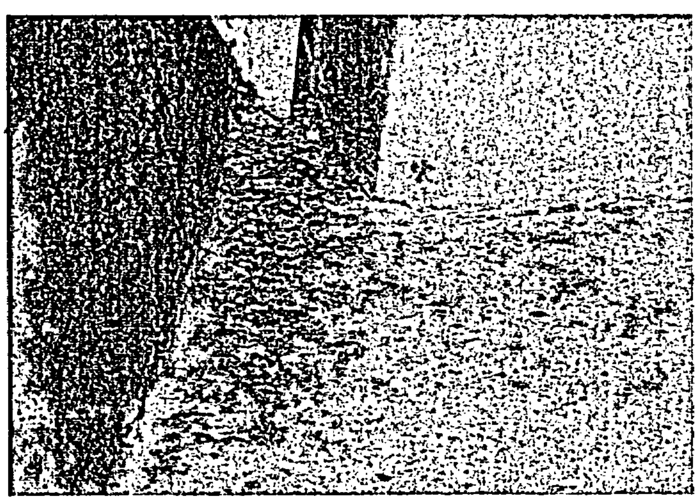
Outstanding Issues

- Debris Generation
  - How will the industry demonstrate that coatings categorized as "qualified" will adhere during and after LOCA conditions ?
    - Visual Inspections as recommended by ASTM
      - Do not assure qualified coatings will adhere.
      - Do not have an underlying technical basis.
    - Analyses should assume that all coatings that do not demonstrate adhesion after a LOCA will fail and be transported to the sump.

Coating Failure Inside Containment



Debris Inside Containment



Outstanding Issues

- Debris Transportation
  - Are tests planned by industry to demonstrate transportability of debris to sump?
    - Absent appropriate test data, analyses should conservatively assume all debris will transport to the containment sump.

Outstanding Issues

- Interaction between Debris and Chemical Precipitants:
  - On prototypical sump screens, are debris and precipitants assumed to accumulate uniformly or non-uniformly over the screen? What is the basis of the assumption?
  - What are the downstream effects, including consideration of any chemical products?

Outstanding Issues

- TSP and CalSil
  - Argonne National Lab tests show that CalSil and TSP form a calcium phosphate precipitate. On a mixed CalSIl and fiberglass debris bed, it caused a significant head loss. *(Loss attributed to arrival of calcium phosphate, not a CalSil/TSP interaction within the debris bed)*
  - The reaction between TSP and CalSil insulation can result in some or all of the phosphate being unavailable to act as a source term in an accident. How does this affect the assumptions made regarding source term in accident analyses.

buffer

Outstanding Issues

- TSP and CalSil
  - The staff has determine there are approximately 8-9 plants that have both TSP and CalSil that may be susceptible to sump screen blockage due to calcium phosphate precipitation.
  - The affected licensees are expected to either provide a justification why the issue is not a problem or describe actions to eliminate the condition for their current sump configuration.

Outstanding Issues

- TSP plants without CalSil interactions need to assess plant specific materials to determine whether other sources of calcium (e.g., insulation, concrete) could react with TSP to form sufficient concentrations of calcium phosphate that would be of concern to the staff.

General Conclusions and Observations

- Industry response to chemical effects issue is not adequate.
- NRC-lead testing continues to identify important issues and head loss testing will continue, as necessary. Industry is expected to promptly address applicability of test results that raise a safety concern.
- Industry has not shared details of proposed test regarding chemical effects. Staff needs to know what test are planned in order to assure testing program will be adequate.

General Conclusions and Observations

- Licensees that proceed with sump modifications before chemical effects and other outstanding issues are resolved will be required to implement further modifications if margins are not ultimately confirmed.

General Conclusions and Observations

- Staff will consider extensions beyond December 2007 if licensees:
  - Provide a justification for continued operation beyond December 2007.
  - Provide acceptable explanations why an extension is needed. Must include a description of what timely actions taken to address the issues (e.g., experimental test, analyses, etc.)

Information Notice 2005-26: Chemical Effects Head Loss Testing

Paul Klein
Rob Tregoning
Nuclear Regulatory Commission

Public Meeting on GSI-191 Chemical Effects
September 30, 2005
NRC Headquarters, Washington, DC

Agenda

- NRC IN 2005-26 Overview - Klein
- Integrated Chemical Effects Testing Background - Tregoning
- Initial Argonne National Lab Head Loss Test Results - Tregoning

GSI-191 Chemical Effects Knowledge Progression

- Initial Questions Concerning Chemical Effects
- Scoping Study - Los Alamos National Lab (LANL)
- Integrated Chemical Effects Tests - LANL
- Head Loss Testing – Argonne National Lab
  - **NRC IN 2005-26**

Information Notice 2005-26

- Related to initial head loss testing conducted at Argonne National Lab
- NRC issued Information Notice to promptly communicate the results to PWR licensees.
- Significant head loss was observed in tests:
  - Trisodium phosphate (TSP) and a dissolved calcium concentration representative of ICET Test 3
  - TSP with dissolved calcium concentrations less than ICET Test 3

Information Notice 2005-26

- Information is relevant to plants containing phosphates (e.g., use TSP) and calcium sources (e.g., insulation, concrete) that may dissolve within the post-LOCA containment pool and form calcium phosphate precipitate.
- Significant head loss can occur if sufficient calcium phosphate is produced in a sump pool and is transported to a pre-existing fiber bed on the sump screen.
- Head loss results obtained in a recirculating test loop are not intended to be prototypical of a PWR plant containment. Applicability to plant-specific environments may be affected by variables such as screen approach velocity, fiber bed thickness, plant materials, recirculation time, etc.

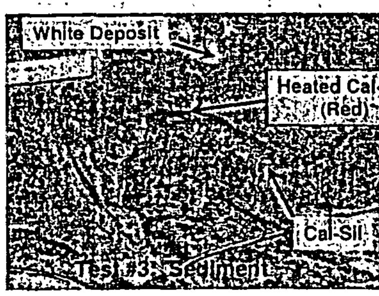
ICET: Test Description

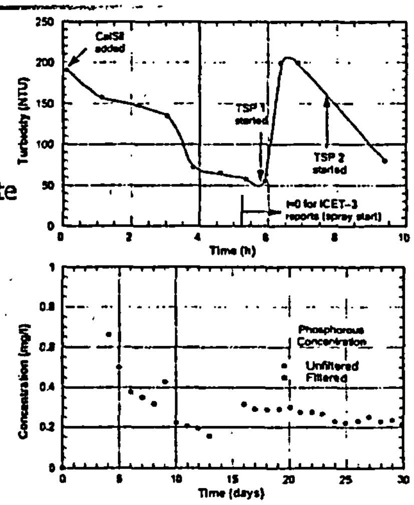
- **Objective:** Determine and characterize chemical reaction products that may develop in representative post-LOCA PWR containment sump/spray environments
- Five 30-day tests conducted; each intended to simulate a subset of current PWR fleet
- Tests intended to be representative of important sump pool variables
- Primary Variables: pH (buffering agent) and insulation materials

Test Number	Buffering Agent	Insulation Material	Completion Date
1	Sodium Hydroxide: pH ≈ 10	100% Fibrous (NUKON)	12/20/04
2	Tri-sodium Phosphate: pH ≈ 7	100% Fibrous (NUKON)	3/7/05
3	Tri-sodium Phosphate: pH ≈ 7	80% Particulate (CalSil) 20% Fibrous (NUKON)	5/5/05
4	Sodium Hydroxide: pH ≈ 10	80% Particulate (CalSil) 20% Fibrous (NUKON)	6/23/05
5	Sodium Tetraborate: pH ≈ 8	100% Fibrous (NUKON)	8/23/05

ICET Test 3: Observations & Findings

- White flocculent precipitate was visible and entrained in chamber flow 20 minutes after start of testing.
- Measured P levels < 1 ppm after a few days
- Precipitate is some form of calcium phosphate





Head Loss Testing

- **Motivation:** No testing information to assess possible net positive suction head loss (head loss) contributions due to calcium phosphate precipitate formation
- Test program developed and conducted by Argonne National Laboratory
- Testing Objectives:
  - Identify important variables that affect the amount of calcium phosphate that can form in ICET Test #3-type environments
  - Measure additional head loss due to the calcium phosphate concentration expected in ICET Test #3 under controlled test conditions (Test #1)
  - Measure additional head loss due to decreased calcium phosphate concentrations under controlled test conditions (Test #2)

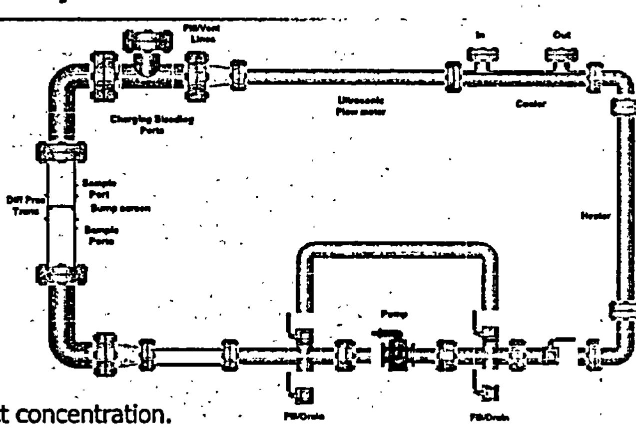
ANL Small Scale Dissolution Tests: Results

- Initial dissolved Ca concentration for ICET–3 ≈ 200 ppm
  - True for CalSil concentrations from 6 – 25 g/L
  - Initial dissolution in low pH environments occurs rapidly
- Mass balance predicts $Ca_3(PO_4)_2$ is PO_4 limited down to ≈ 2g/L CalSil (for TSP 4g/L)
- $Ca_3(PO_4)_2$ formed by initial Ca concentration is predicted by mass balance to be about 1/3 of total amount associated with complete depletion of PO_4

Initial pH	T(C)	Time	CalSil g/l	Final pH	ppm-Ca	ppm-Si	ppm-Na
4.0	60	35 min	6	7.5	176	26	82
	60	35 min	15	6.8	256	45	159
	60	35-min	25	6.8	244	40	253
4.0	60	4-h	6	6.7	196	58	138
	60	4-h	15	6.9	195	63	229
	60	4-h	25	7.1	195	72	371
4.5	60	4-h	6	6.7	156	49	169
	60	4-h	15	6.9	169	51	237
	60	4-h	25	7.1	184	66	386
7.0	62	4-h	2	7.1	45.0	19	85
	62	4-h	6	7.4	88 3	37	253
	62	4-h	25	7.2	68.6	27	124

ANL Test Facility

- Fluid volume = 4.2 ft^3
- Screen diameter = 6 in
- Transit time ≈ 4 min. @ 0.1 ft/s
- Screen = perforated plate

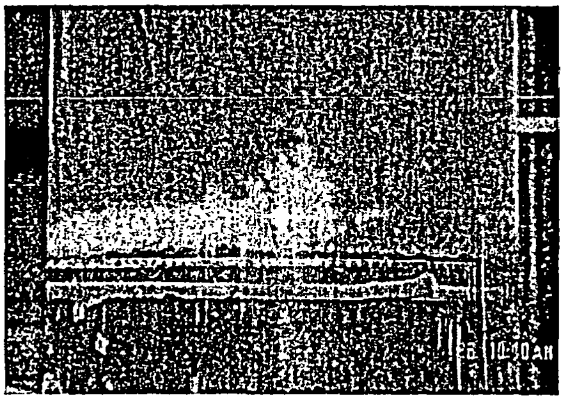


- Tests simulate product concentration.
- Product mass per unit screen area is fixed by screen size and volume of loop.
- 36,500 ft^3 containment pool volume implies a screen area of ≈ 1700 ft^2.

Head Loss Test #1: Test Description

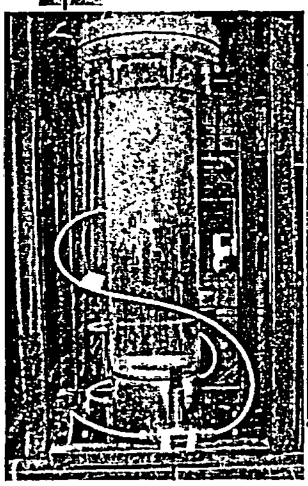
- Test loop filled with deionized water and heated to 130°F
- ICET-3 Boric acid and LiOH concentrations added
- TSP concentration of 4 g/L was then added to the loop to simulate complete phosphate dissolution at end of 4 hour dissolution
  - TSP added first to maintain pH
  - Slow calcium dissolution from CalSil
- Physical debris bed built by adding a slurry with 15 g NUKON/15 g CalSil with the loop flow at 0.1 ft/s resulting in a bed ≈ 3/4–in thick
- After recirculating for about 45 minutes, the flow rate was increased to 0.2 ft/s, compressing the bed to ≈ 5/8-in thick
- The flow rate was then reduced back to 0.1 ft/s

Head Loss Test #1: Test Description cont.



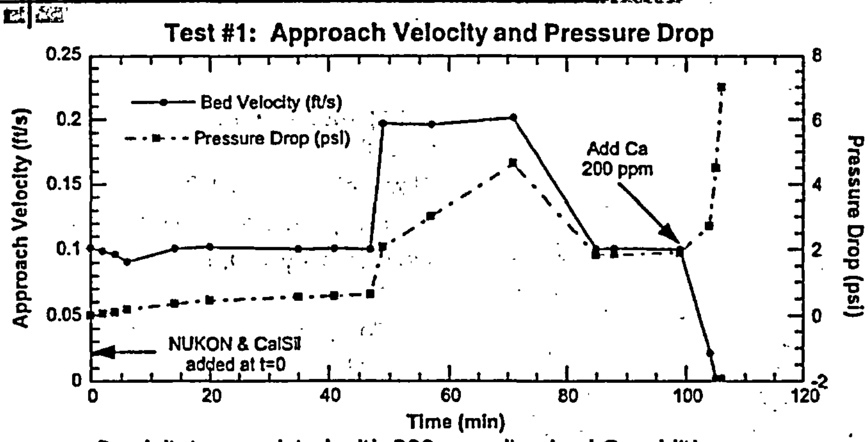
NUKON/CalSil bed before formation of the $Ca_3(PO_4)_2$ precipitate

Head Loss Test #1: Test Description cont.



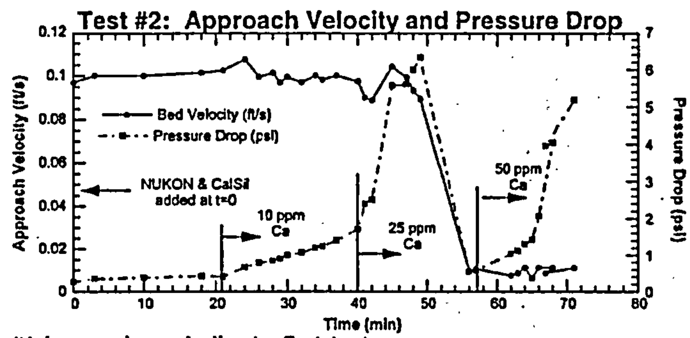
- 400 ml $CaCl_2$ solution added just above the clear test section over a 4 minute period
- Results in 200 ppm dissolved Ca inventory
- A fine, milky precipitate formed immediately after the introduction of the $CaCl_2$

Head Loss Test #1: Test Description cont.



- Precipitate associated with 200 ppm dissolved Ca addition produced a large pressure drop

Head Loss Test #2: Test Description



- Initial procedure similar to first test
- Debris bed made from 15 g of NUKON and 15 g of CalSil at 0.1 ft/s; No flow rate increase
- $CaCl_2$ additions made incrementally starting with 10 ppm dissolved Ca
- Subsequent additions corresponded to 25 and 50 ppm dissolved Ca

Head Loss Test #2: Test Description cont.

$CaCl_2$ addition at 0.01 ft/s

- Precipitate size may be a function of flow velocity
- Flow velocity = 0.1 ft/s
  - Finely dispersed milky cloud
- Flow velocity = 0.01 ft/s
  - Fine particles appear to agglomerate
  - Flocculent assemblies up to perhaps ¼ in diameter

Head Loss Testing: Summary

- Chemical products generated in ICET-3 environments contribute to test loop head loss. Head losses measured for concentrations about one twentieth of the expected ICET-3 initial dissolved Ca inventory.
- For the range of CalSil concentrations examined (6 – 25 g/L), approximately 200 ppm of dissolved Ca can form quickly.
  - Tests with an initial pH=7 show somewhat lower levels of dissolved Ca.
  - Results suggest initial rapid dissolution to a pH dependent $CaSiO_3$ solubility limit.
- Product associated with initial dissolved Ca inventory is about 1/3 of total product formed for CalSil loadings of ≈ 2-25 g/L with 4g/L TSP.
- Product appears to agglomerate at low fluid flow velocities.

NRC Meeting on GSI-191 Chemical Effects

September 30. 2005

NEI NUCLEAR ENERGY INSTITUTE

Overview

- Assessment of Argonne test discussed in NRC Information Notice 2005-26 [Link]
- Immediate actions by plants with Calcium-Silicate insulation and Tri-sodium Phosphate in containment building
- Comprehensive industry test plan on chemical effects
- Conclusions

Applicable Plant Actions

- Immediate actions
  - Entered into plant operating experience programs
  - Review compensatory actions identified in NRC Bulletin 2003-01 in light of IN 2005-26
  - Document review and identify any additional actions warranted or mitigating plant features
  - Docket response describing actions taken by November 30

Applicable Plant Actions

- Actions under consideration
  - Reduction, removal or sequestration of TSP
  - Reduction, removal or sequestration of Cal-Sil
- Regulatory considerations
  - TSP actions may require tech spec change or exemption
  - TSP actions may require more realistic source term or containment leakage values

GL 2004-02 Actions and Longer-term Considerations

- GL 2004-02
  - Removal of Cal-Sil
  - Larger screens/Active strainers
  - Reduction in approach velocities
- Longer-term
  - pH buffer replacement research and implementation

[Link]

Conclusions

- Argonne test provided some valuable insights, but is not representative of any PWR configurations
- Applicable plants are acting prudently
- Industry activities underway to comprehensively address chemical effects
- Need for a more holistic approach to resolving GSI-191

Assessment of Applicability of Argonne Cal-Sil/TSP Test Results

NRC/Industry Meeting on GSI-191

September 30, 2005

ALION SCIENCE AND TECHNOLOGY

Slide 2

Argonne Testing provided Valuable Data on Behavior of Cal-Sil/TSP Conditions

- Ca dissolution vs pH
- Ca dissolution vs quantity of Cal-Sil (caoncentration)
- Ca dissolution vs time

Slide 3

Argonne Testing Provided Insights on Potential Head Loss Impact of Calcium Phosphate

- Conditions tested are well beyond those found in current plants
  - Ca concentration
    - Cal-Sil Quantity
    - Cal-Sil debris characteristics
    - Pool pH
    - Time for Dissolution
  - Manner of Calcium Phosphate deposition behavior
  - Flow Rate

Slide 4

Effect of Pool pH on Ca concentration

- For a Cal-Sil debris quantity of 6 g/l at t=~4 hrs

pH	Conc (ppm)
4.0	196
4.5	156
7.0	88
10.1	17
* "Nominal" value = 4.1	

Slide 5

Effect of Cal-Sil Availability on Ca concentration

- For a pH of 7.0 at t=~4 hrs

Cal-Sil (g/l)	Conc (ppm)
2.0	45
6.0	88
25.00	69
* "Nominal" value = 25	

Slide 6

Effect of Cal-Sil Availability on Ca concentration

- For a pH of 7.0 with 2 g/l of Cal-Sil

Time	Conc (ppm)
4 hrs	45
24-hrs	73
* Nominally at steady-sate	

Slide 7

Comparison of Plant Conditions to Argonne Test Conditions

- "Early" Pool pH
  - RCS - ~7.0
  - RWST - ~4.6
  - Accumulator - ~4.6
  - Mix - ~5+
- Cal-Sil Quantity
  - Argonne - 25g/l based on 4000 cu-ft debris
  - Typical - 10-120 cu-ft debris based on Debris Gen Analysis
  - Maximum - at ~150 cu-ft, this translates to ~1 g/l
- Cal-Sil Debris
  - Argonne - 100% fines
  - Typical - ~50% fines (based on Canadian data)
- Time at Low pH
  - Typical - TSP dissolution starts very quickly
    - Significant dissolution at recirc mode switchover
    - Earlier dissolution/mixing dependent on TSP location

Slide 8

Conclusion From Review of Plant Data Relative to Argonne Test Parameters

- Expected Max Ca Concentration much less than the 200 ppm tested for head loss impact
  - Higher initial pH
  - Lower Cal-Sil quantity
  - Short Time Until pH neutralization
- Quantitative Estimate of Impact
  - Reduction in max Ca concentration by a factor of 5

Other Consideration

- Timing of Debris Deposition Relative to Calcium Phosphate Formation
  - Argonne tests: Ca Phosphate forms subsequent to debris bed formation and deposits on the surface of bed
  - Typical: Ca Phosphate forms concurrent with debris bed formation and deposits within the bed
- Based on Analogy with other debris combinations (Cal-Sil plus fiber)
  - Dispersed particulate has significantly lower head loss impact than "layered" bed

Industry Path Forward

- Rigorous Compilation of Impacted Plant Conditions (Preliminary Information Already Collected)Bench Scale Dissolution Tests – Short-term
  - Initial pH range of direct interest
  - Time frame of direct interest (pH history)
  - Typical Cal-Sil quantities
- Key part of Chemical-Effects Testing Program

Conclusion

- Industry Recognizes the Significance of Calcium Phosphate Head Loss Impact
- Results from Argonne Represent an Extremely Conservative Bound on Impact
- Engineering Assessment of Conditions Suggests the Impact Magnitude to be Significantly Less than Argonne Result
- Argonne Testing Has Provided Key Insights to Defining a Success Path for Resolution

Approach to Resolution of Chemical Effects on Head Loss Uncertainty

NRC/Industry Meeting on GSI-191

September 30, 2005

ALION
SCIENCE AND TECHNOLOGY

Slide 2

Four-Phase Approach

- Individual Plant Assessment
- Supplemental Small-scale Testing
- Development of Generic Chemical Effects Algorithms
- Plant Specific Testing as Required

Slide 3

Individual Plant Assessment

- Applicability of ICET Tests
- Understanding of differences
  - Plant-specific vs Generic data
  - Intermediate corrective actions
- Scaling of ICET Test Results (material quantity assessment)
- Identification of Outlier Materials

Supplemental Small-Scale Testing

- Material Compatibility
  - Insulation materials
  - Containment materials
  - Buffer solution

Generic Chemical Effects Algorithm - Approach

1) Replicate Basic Reaction Products

- Obtain baseline data on head loss for ICET material
- Obtain reference data on head loss for same debris w/o chemical reaction products
- Replicate ICET materials based on "known" chemistry
- Obtain head loss data for appropriate quantity of replicated material
- Compare head loss data to "validate" determination of "known" chemistry
- Quantify Effect of reaction products

Generic Chemical Effects Algorithm - Approach

2) Incorporate Effect of Supplemental Testing (If Generic)

- Repeat head loss testing on replicated material with addition of supplemental reaction products
- Quantify effect of supplemental reaction products

3) Develop Standard Chemical Reaction Product Mixture

- Constituents
- Quantities

Slide 7

Generic Chemical Effects Algorithm - Approach

4) Perform Head Loss Testing
- Based on "standard" chemical mix
- Varying type/quantity of insulation debris

5) Develop Chem Reaction Products Head Loss Impact Algorithm ("Bump-Up" factor)

Note, all testing would consider time-varying chemical effects and varying flow rates

Slide 8

Plant-Specific Testing (If Required)

- Needed for Outlier Materials from Step 2
- Optional Fully Time-Dependent Chemical effects/Head Loss Testing

Slide 9

Proposed Supplemental Testing to Address Cal-Sil/TSP Interaction

- Calcium Dissolution Data (Short-term)
  - Vary initial pH over range of interest (4.5-8.0)
  - Vary Cal-Sil concentration (0.1-1.0 g/l)
  - Time dependence
- Calcium Dissolution Data (long-term)
  - Calcium dissolution at higher pH w/ TSP present
  - Time-dependent Calcium phosphate production

Slide 10

Schedule

- 10/30 - Formal Test Plan distributed for review
- 11/15 - Final Test Plan adopted, start of testing
- 2/15 - Completion of Initial Test Reports (to support spring outages)