GSI-191 Public Meeting
PWR Sump Debris Blockage

Tom Martin

February 9, 2006

Presentation Outline

- Generic Letter 2004-02 Responses
  - Incomplete information
  - NRC concerns about progress
- Reminder of NRC Expectations
- Schedule Challenges

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September 2005 Generic Letter Responses

- Information needed to confirm progress
- Confirmed that all PWR licensees are upgrading or have recently upgraded their sump strainers.
  - 66 of 69 plants are replacing their existing sump screens
  - Remaining 3 plants had previously replaced their screens
- However, much of the requested information was incomplete

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Examples of Incomplete Information

- No licensee was able to completely answer the questions requesting specific results of their evaluations

- Many licensees did not provide:
  - An adequate general description of and planned schedule for changes to the plant licensing bases
  - A description of the existing or planned programmatic controls to control debris
  - An assessment of chemical effects
  - An assessment of downstream effects

4

Concerns Regarding Industry Progress

- Incomplete analyses as indicated by the inability to provide specific information on analysis results as requested in the GL
- Only several plants replacing their existing sump screens had final designs for the replacement screens
- Approximately 10% of plants have either requested or made inquiries about an extension

5

Reminder of NRC Expectations

- All actions completed by December 31, 2007
- Confirm adequacy of proposed modifications for each plant
  - Three plants that previously replaced sump strainers are expected to demonstrate adequacy using approved evaluation methodology and account for plant specific chemical effects
- Demonstrate that generic industry chemical tests bound plant specific chemistry of sump water
- Demonstrate that qualified coatings continue to meet qualifications or assume that they fail
- Update information requested by Sep 2005 to address identified shortcomings

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Schedule Challenges

- Approximately 10% of plants have either requested or made inquiries about an extension
- If corrective actions will not be completed by December 31, 2007, describe how the applicable regulatory requirements will be met
- Requests for delay will be more favorably viewed if interim compensatory measures include physical improvements

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Industry Activities to Address PWR ECCS Sump Performance

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NEI

GSI-191, PWR Sump Performance

- GSI-191 applies to all pressurized water reactor designs
  - 69 PWR units in U.S.
- Each unit is unique in one or more important design aspects:
  - Insulation materials
  - Containment coatings (both qualified and unqualified)
  - Containment design (compartmentalized, open)
  - Sump design
  - NPSH requirements
- The high level of design variation requires plant-specific resolution approach for each plant

NEI

Evaluation Guidance Development

- Development of Industry Evaluation Guidance began following issuance of NUREG/CR-6762, Parametric Evaluation for PWR Recirculation Sump Performance (2002)
- NEI 02-01, Debris Sources Inside Containment (2002) issued to begin plant data collection activities
- Bulletin 2003-01, Potential Impact of Debris Blockage on Emergency Sump Recirculation at PWRs (2003) called for compensatory actions

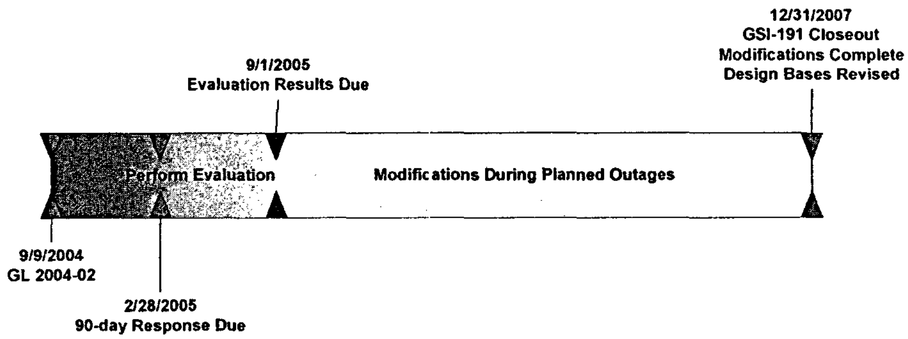
NEI

GL 2004-02

- GL 2004-02, *Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors,* issued September 2004
- Requested PWR licensees to perform an evaluation of recirculation functions and, if appropriate, take additional actions to ensure system function
- GL schedule:
  - By 2/28/05 – provide description of evaluation methodology to be used and schedule for completion
  - By 9/1/2005 – provide results of evaluation
  - By 12/31/2007 – complete all actions, including necessary plant modifications

NEI

GL 2004-02 Schedule



NEI

Industry Guidance (NEI 04-07)

- Evaluation guidance, developed in coordination with the WOG was issued December 2004
- Developed to provide a practical and realistically conservative set of methods to guide PWR resolution activities
- Conservative baseline methods allow for performance of scoping calculations
- Used to identify "problem areas" and focus on cost effective areas for refinement and resolution

NEI

NRC SER on NEI 04-07

- A safety evaluation report (SER) on NEI 04-07 released in December 2004
- SER modified NEI 04-07 guidance
  - Calls for more conservative treatment in some areas unless additional testing is performed
    - Example: 10D ZOI for qualified coating
  - removes some simplifications and calls for plant specific development and justification
    - Example: Coating thicknesses to be determined by each plant
  - Restricts realistic treatment for low risk spectrum of breaks
    - Example: "nominal" parameters not to be exceeded during normal operation

NEI

Supplemental Guidance

- WOG guidance was prepared to support evaluation in two areas not addressed in NEI 04-07
  - Downstream Effects
  - Results from Industry/NRC Chemical Effects tests

NEI

Downstream Effects

- WCAP 16406-P, *Evaluation of Downstream Sump Debris Effects in Support of GSI-191*
  - Issued June 2005
  - Addresses wear, abrasion and blockage impacts of sump screen bypass
  - Methods identified in WCAP used to perform Downstream Effects Evaluations for sump performance

Integrated Chemical Effects Tests

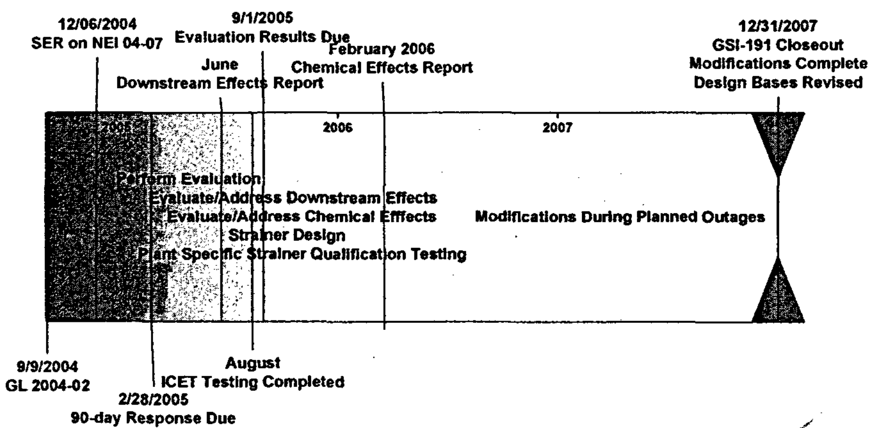
- Jointly sponsored by Industry and NRC
- Tests conducted between 11/2004 and 8/2005

Run No.	Date Started	Date Ended	Date Quick Look Report Publicly Released	Date Final Data Report Released
1	11/21/2004	12/21/2004	None released	Jun-05
2	2/5/2005	3/7/2005	20-Jul-05	Sep-05
3	4/5/2005	5/5/2005	20-Jul-05	Nov-05
4	5/24/2005	6/25/2005	12-Jul-05	Nov-05
5	7/26/2005	8/25/2005	28-Oct-05	Jan-06

Bench top Chemical Effects Tests

- WCAP-16530, *Evaluation of Post-Accident Chemical Effects in Containment Sump Fluid to Support GSI-191*
  - Issued February 2006
  - Addresses chemical reactions and products in containment sump fluid
  - Provides input for use in plant-specific evaluation of chemical effects

GSI-191 Resolution Schedule



Status of Industry Activities

- NEI distributed a short survey to industry on January 19th to collect information on plant GSI-191 resolution activities
- Survey responses from all 69 PWR units were returned on or before January 30th

NEI

Survey Results

- All 69 plants have completed evaluations necessary to assess need for strainer modifications
  - Three units have assessed that their current strainers are appropriately sized
    - Confirmation activities are underway including strainer validation tests
  - Sixty-six units plan to replace their current strainers

NEI

Strainer Vendors

- Of the 66 units planning to replace strainers, 65 have selected a vendor/design concept
  - One plant finalizing design evaluation before selecting vendor
  - Five strainer vendor teams:
    - Enercon/Alion/Westinghouse/Transco
    - Framatome/PCI
    - GE
    - CCI
    - AECL

NEI

Replacement Strainers

- Active – Passive – Undetermined
  - Four units intend to install active strainers
  - Remaining units are passive strainers
  - Two units expressed a need to reconsider active due to difficulties with expected size of their passive strainer

NEI

Estimated Strainer Size

- The estimated size of replacement strainers (passive only) ranges from 650 ft2 to 16700 ft2
  - Median size of PWR replacement strainers is 4400 ft2
  - Reflects estimated total screen area across all injection pathways
- For comparison, the median size of BWR strainers is 1386 ft2; ranging from 475 to 6253 ft2
- Final strainer sizes are subject to change based on ongoing evaluations and testing

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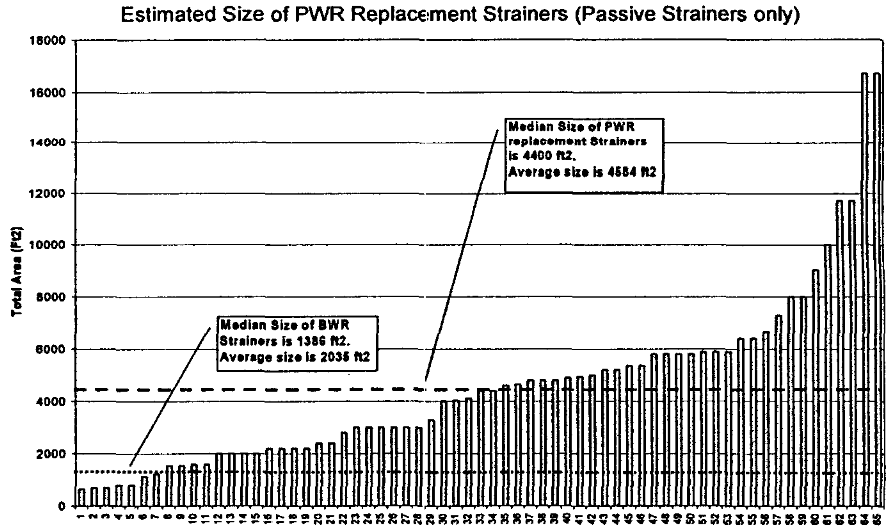
Estimated Size of PWR Replacement Strainers (Passive Strainers only)



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Factors Affecting Strainer Size

- The variability in sizes reflects a number of factors, including:
  - Plant design
  - Conservatism in methodology application
  - Retained Margin

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Plant Design Factors

- Plant design factors include:
  - NPSH margin
    - NPSH margin for plants ranges from greater than 10 ft to less than 1 ft
  - Containment insulation materials
    - All RMI plants vs. All Fiber plants
  - Coatings
    - Level of unqualified and degraded coatings

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Conservatism in Analysis

- The evaluation methodology includes a number of noted conservatisms
  - Included to facilitate evaluation
  - Others directed by NRC SER
- Use of NUREG CR 6224 correlation for headloss is noted area of conservatism
- All plants indicated that plant specific strainer qualification tests would be performed
- Plants may adjust their final strainer size based upon these results

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Addition of Margin

- Most plants indicated that their strainer size reflected the addition of margin to account for uncertainties
- Others sized their strainers based upon the maximum size accommodated by existing containment footprint

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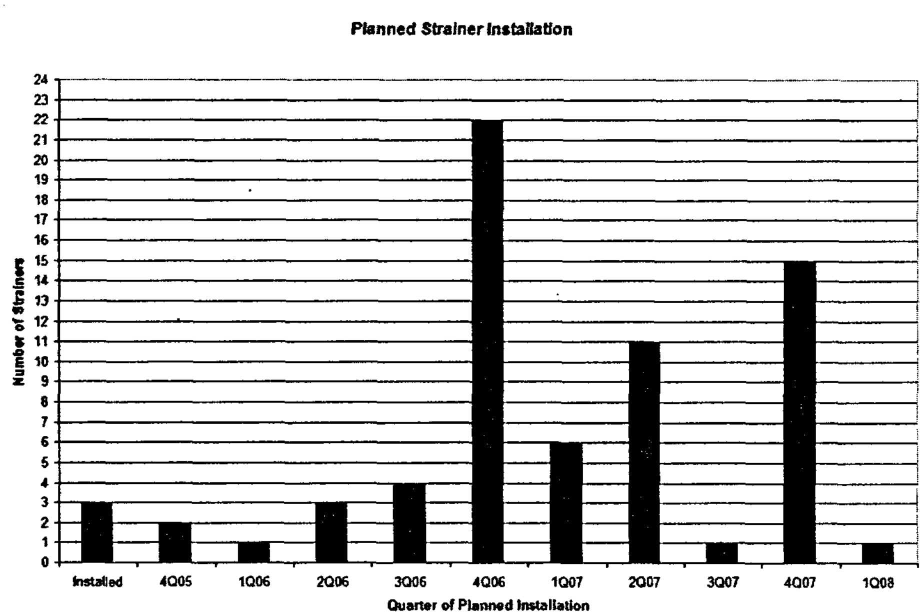
Installation Schedule

- Excluding 3 units who are retaining their current strainers
  - 2 units in 4th quarter 2005
  - 30 units in 2006
  - 33 units in 2007
  - 1 unit in 1st quarter 2008



Other activities

- Actions to address debris sources
  - ~45% identified near term actions to modify or reduce problematic insulation materials
  - ~20% identified non-programmatic changes to modify or reduce problematic coatings and latent debris
- Containment modifications beyond strainer installation
  - >30% identified modifications affecting debris transport (e.g., debris interceptors)
  - >20% identified other modifications affecting flood-up level, equipment storage
- Downstream effects
  - >50% indicated plans for modification of downstream flow pathways
- Programmatic changes

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Plant Specific Testing

- All 69 units identified plans for prototypic strainer testing
- ~35% identified plans for plant specific testing of debris generation and transport
- ~46% identified plans for plant specific testing of coatings debris generation and transport
- >50% identified plans for plant specific testing for downstream effects of debris bypass

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License Amendment Requests

- 16 stations identified resolution activities that included license amendment requests
  - Tech Spec "editorial" changes
  - Analysis model change for containment
  - RWST setpoint changes
  - Active strainers
- LAR submittal schedule
  - 2005 – 2
  - 1Q06 – 4
  - 2Q06 – 3
  - 3Q06 – 4
  - 4Q06 – 2
  - 1Q07 – 1

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Summary

- Activities for plant-specific resolution of GSI-191 are well underway
- Remaining uncertainties are being addressed through conservative application of evaluation methodology, testing and strainer design
- Industry sponsored and plant-specific testing activities will continue in support of final designs

NEI

Evaluation of Post-Accident Chemical Effects in Containment Sump Fluids

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February 9, 2006

Outline

- Purpose
- Scope
- Bench Testing Parameters
- Dissolution Tests
- Precipitation Tests
- Chemical Model
- Particulate Generator
- Transition to Sump Screen Testing

Purpose

Two-fold goal for WOG Chemical Effects testing:

1. Evaluate post-accident chemistry in containment sump pool
   - Bound plant temperature and pH conditions
   - Use representative containment materials and buffering agents
2. Provide input on chemical precipitates for screen vendor testing
   - Determine types and amounts of chemical precipitates which may form
   - Provide method for obtaining these precipitates for head loss testing

Scope

- Use industry surveys to define bench testing parameters, including:
  - Temperatures
  - pH values
  - Containment materials
  - Buffering agents
- Perform dissolution and precipitation tests presented in the Test Plan
- Develop chemical model from the test results for plant-specific prediction of chemical effects
- Develop and qualify particulate generator to produce representative precipitates for head loss testing

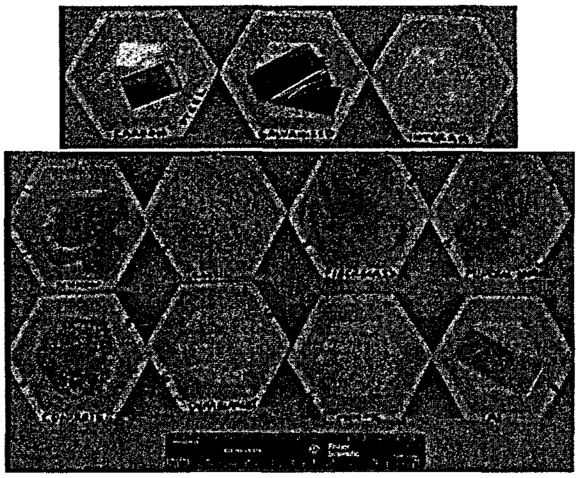
Bench Testing Parameters

- Dissolution tests temperature
  - High = 265 °F
  - Low = 190 °F
- Precipitation tests temperature = 80 °F
- pH range
  - Maximum = 12
  - Minimum = 4.1
- Containment materials for testing
  - Selection and representative amounts based on plant survey responses

Containment Materials Classification

Material Class	Materials in Class	Representative Material
Aluminum	Aluminum alloys, aluminum coatings	Aluminum (pure)
Aluminum silicate	Cerablanket, FiberFrax Durablanket, Kaowool, Mat-Ceramic, Mineral Fiber, PAROC Mineral Wool	FiberFrax Durablanket
Calcium silicate	Asbestos, Cal-Sil insulation, Kaylc, Marinite, Mudd, Transite, Unibestos	Cal-Sil Insulation
Carbon Steel	All carbon and low alloy steels	SA 508 Cl 2
Concrete	Concrete	Ground Concrete
E-glass	Fiberglass insulation, NUKON, Temp-Mat, Foamglas, Thermal Wrap	NUKON, Unspecified Fiberglass
Amorphous Silica	Min-K, Microtherm	Min-K
Interam E Class	Interam E Class	Interam E-5
Mineral wool	Min-Wool, Rock Wool	Min-Wool
Zinc	Galvanized steel, zinc coatings	Galvanized Steel
Copper	All copper alloys	None
Nickel	All nickel alloys	None
Organic Mastics	CP-10, ThermoLag 330-1	None
Other Organics	Armaflex, Kool-Phen, Benelex 401, RCP Motor Oil	None
Reactor Coolant Oxides	nickel ferrite and other oxides	None

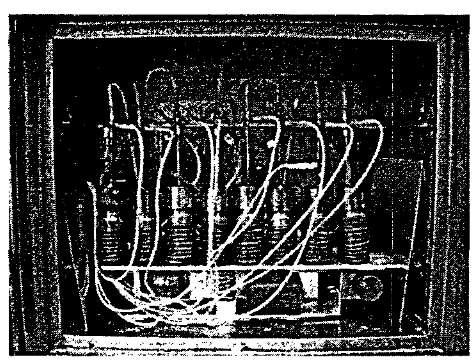
Tested Materials



- Carbon
- Galvanized steel
- Interam
- Nukon Fiberglass
- Cal-Sil
- Unknown Fiberglass
- Microtherm
- Concrete
- FiberFrax Durablanket
- Min-K
- Aluminum

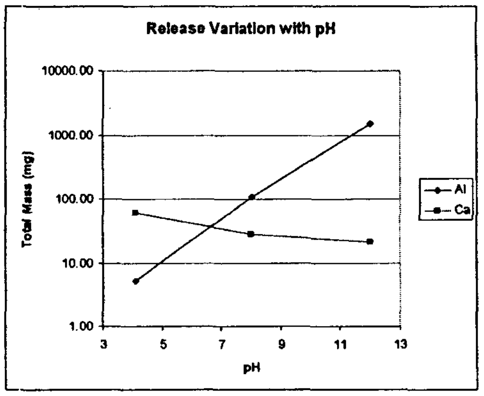
Dissolution Tests

- Eight reaction chambers and two solution reservoirs were used
- Elements with highest mass release:
  - Aluminum
  - Calcium
  - Silicon
- Cal-Sil and metallic aluminum provided the highest potential mass release



Mass Release Dependence on pH

- Variation in calcium and aluminum mass release with pH
- Determined from all runs at each pH
- Opposite trends observed:
  - Greater Ca release at low pH values
  - Greater Al release at high pH values



Precipitation Tests

Sixty precipitation tests were performed:

- 33 of the 60 tests were dedicated to determining if any precipitate formed due to exposure of containment materials to simulated coolant and cooling of the dissolved solution
  - 10 tests formed precipitate under this scenario
- Trisodium phosphate (TSP) and sodium tetraborate were separately added in 22 tests to adjust the solution pH to 8
  - The dissolved solutions for Cal-Sil and concrete formed phosphate precipitate when TSP was added
  - No solutions formed precipitate due to the addition of sodium tetraborate
- Of the 5 combinations of dissolved solutions made, only the combination of Cal-Sil and fiberglass formed a precipitate due to chemical reaction

Precipitation Test Results

Precipitation tests with measurable amounts of precipitate:

PPT Run	Precipitation Method	Precipitate Determined from SEM Analysis
1	Precipitation from cooling, Al pH 4	Hydrated AlOOH
2	Precipitation from cooling, Al pH 8	Hydrated AlOOH
3	Precipitation from cooling, Al pH 12	Hydrated AlOOH
12	Precipitation from cooling, Other Fiberglass, pH 12	NaAlSi3O8 with minor calcium aluminum silicate
13	Precipitation from cooling, Concrete, pH 4	Calcium aluminum silicate - Al rich
14	Precipitation from cooling, Concrete, pH 8	Calcium aluminum silicate
16	Precipitation from cooling, Mineral Wool, pH 4	Hydrated AlOOH
22	Precipitation from cooling, FiberFax, pH 4	Hydrated AlOOH
24	Precipitation from cooling, FiberFax, pH 12	NaAlSi3O8
30	Precipitation from cooling, Galvanized, pH 12	Zn2SiO4 (Willemite) with Ca and Al impurities
35	PPT of Phosphates, CalSil	Calcium phosphate and a silicate
38	PPT of Phosphates, Powdered Concrete	Calcium phosphate with AlOOH
60	pH 12 265 Fiberglass with high calcium from pH 4 CalSil	Sodium calcium aluminum silicate

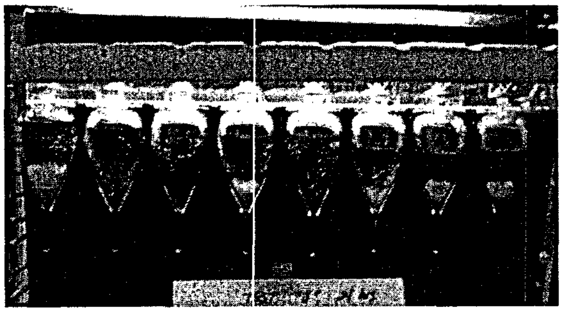
Predominant chemical precipitates: aluminum oxyhydroxide, sodium aluminum silicate, calcium phosphate (for plants which use TSP)

Precipitate Characterization

- Qualitative measure of settling rates of precipitates formed in bench testing:
  - Aluminum oxyhydroxide precipitates had the lowest settling rate, while calcium phosphate precipitates settled more quickly
  - Sodium and calcium aluminum silicate precipitates had settling rates in-between those determined for AlOOH and $Ca_3(PO_4)_2$
- In conclusion, the precipitates formed do not settle quickly, and so cannot be discounted as a concern for sump screen performance
- Aluminum and aluminum silicate precipitates were determined to have slightly higher filtration constants than the calcium phosphate precipitates

Precipitates Formed by Cooling

Example of precipitates formed by cooling of dissolved solutions to 80°F ~24 hours after exposure to post-LOCA simulated coolant:



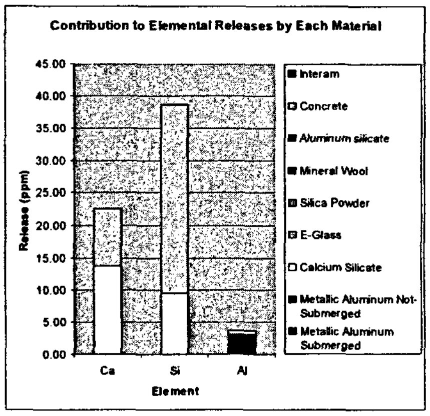
Chemical Model Development

- Inputs:
  - Post-LOCA temperature and pH values
  - Concentration of containment materials
  - Mass release from containment materials exposed to simulated coolant determined from results of dissolution testing
- Evaluations:
  - Determination of release rate equations as a function of pH, temperature, and concentration of each containment material
  - Determine quantity and type of precipitates formed from elements released using stoichiometric relations and solubility properties
- Outputs:
  - Elemental releases from containment materials as a function of time
  - Precipitates formed under post-LOCA conditions as a function of time

Chemical Model Results

Predicted mass release of Al, Si and Ca from plant-specific containment materials concentrations

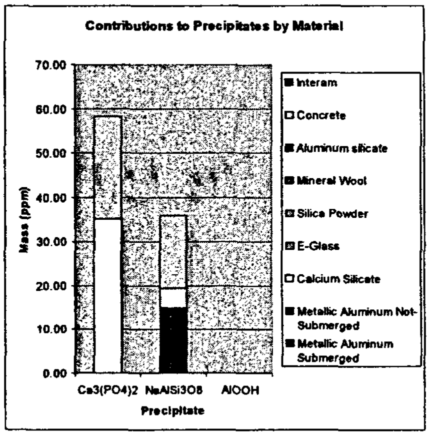
- Example of elemental releases for TSP plant
  - Largest contributors to Ca and Si releases are Cal-Sil and fiberglass
  - Corrosion from both submerged and non-submerged aluminum



Chemical Model Results

Predicted precipitate formation from mass release of Ca, Si and Al

- Example of precipitate formation for TSP plant
  - Significant amount of calcium phosphate formed from Cal-Sil
  - Large amount of sodium aluminum silicate formed from combination of Cal-Sil, fiberglass, and aluminum



Model Verification and Conservatisms

- Model predictions for Al corrosion agree with GENNY (an established containment hydrogen prediction code)
- Model predictions for Al corrosion agree with ICET #1
- Model predictions for Al corrosion at pH values not included in the bench tests agreed well with additional lab testing.
- Conservative because least corrosion resistant aluminum alloy tested with no oxide film.

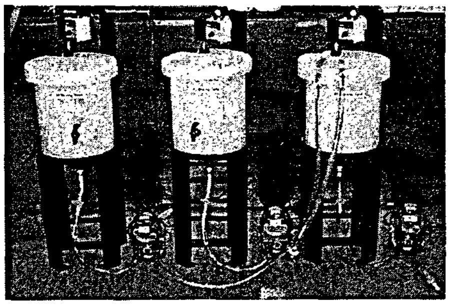
Model Verification and Conservatisms

- Model predicts that 95% of CalSil dissolves within 100 hours for a generic TSP plant in agreement with Argonne tests.
- Calcium concentrations predicted by model for Argonne tests were 1 – 2X measured Argonne levels.
- Conservative because all aluminum is assumed to precipitate.
- Conservative because silicate inhibition of aluminum corrosion not included.

Particulate Generator Development

Purpose: to create prototypical precipitates for use in sump screen testing

- Particulate generator design dependent on:
  - Size of test facility
  - Determined plant-specific precipitate mix
- A setup similar to that shown below may be modified for these variations by adjusting the number and/or size of the mixing tanks and transfer pumps



Particulate Generator Testing

- The filtration and settling behaviors of the generated precipitates were determined to be similar to those observed for precipitates formed in bench testing
- Testing confirmed that the quality and temperature of the water used to prepare the particulates is not critical to obtain similar characteristics to the precipitates
- Critical parameter in implementation of particulate generator:
  - Limitation on degree of concentration of particulates in mixing tank to avoid agglomeration of particulates
  - If large quantities of particulates are required, the particulates may need to be prepared in batches

Alternatives to Particulate Generator

If alternative materials are to be used for sump screen performance testing, the acceptability of these surrogate materials to simulate the amorphous and hydrated precipitates formed in bench testing must be demonstrated

- Settling tests may be performed to demonstrate similar or conservative settling behavior to the precipitates formed
- Also, filterability tests may be needed to demonstrate a similar impact on head loss
- Suggested minimum acceptance criteria for these tests are provided for each major precipitate

Transition to Sump Screen Testing

- Plant-specific prediction of precipitate formation using the chemical model and the following inputs:
  - Containment material amounts
  - Recirculation water volume
  - Post-accident sump and spray pH transients
  - Post-accident sump and spray temperature transients
  - Indication if TSP is used as a buffering agent
- Chemical model output provides types and quantities of precipitates for sump screen performance testing
- Precipitates for screen testing may be generated using the particulate generator or surrogate materials may be obtained
  - If surrogate materials are obtained, additional testing such as settling and filterability tests may be necessary
- Once the representative precipitates have been obtained, the intention is to scale and introduce the precipitates to the flume as another debris source

Summary

- Elements with largest contribution to mass release from containment materials:
  - Calcium
  - Aluminum
  - Silicon
- Key precipitates formed:
  - Sodium aluminum silicate
  - Aluminum oxyhydroxide
  - Calcium phosphate (for plants which use TSP)
- Chemical model predicts plant-specific formation of precipitates as a function of time
- Particulate generator may be used to generate prototypical precipitates for sump screen performance testing

Alternate Buffer for Emergency Core Cooling System (ECCS)

Presented by Ann Lane
Westinghouse Electric
412-374-6571

February 9, 2006

Purpose

Objective:

Identify a replacement buffering agent for trisodium phosphate (TSP) and sodium hydroxide (NaOH) for use in PWR Emergency Core Cooling Systems (ECCS)

Schedule:

Start Date: February 22, 2006

Completion Date: June 30, 2006

Tasks

- Identify possible replacement buffering agents and evaluate risks and benefits
  - Corrosion Inhibition
  - Calcium Complexation
  - Radiation Stability
  - Iodine Retention
- Perform bench scale tests with identified buffering agents to determine acceptability of buffer
  - Dissolution Rate
  - Precipitation
  - pH Control
  - Boric Acid Solubility

Westinghouse [redacted]

Coatings Jet Impingement Tests

Sponsored by: USA/STARS Plants

Technical Direction by: Timothy S. Andreychek
Westinghouse Electric Co.

Supported by: Keeler & Long/PPG
Carboline

Testing Performed by: Wyle Labs

February 8, 2006

Westinghouse [redacted]

Coatings Jet Impingement Test

COATING SYSTEMS TESTED:

- Steel Substrates;
  - Untopcoated inorganic zinc
  - Inorganic zinc primer, two coats of epoxy topcoat
  - Epoxy primer and epoxy topcoat
- Concrete Substrates;
  - Cementitious epoxy surfacer, two coats of epoxy topcoat
  - Epoxy primer and epoxy topcoat

Westinghouse [redacted]

Coatings Jet Impingement Test

TEST CONDITIONS:

- Initial Temperature of Fluid Source: 530°F
- Initial Pressure of Fluid Source: 2200 psia
- Nozzle Size: 2 inches
- Volume of Fluid Reservoir:
  - Sufficiently large as to allow for a 30-second blowdown simulation.
- Instantaneous Break Simulation:
  - Use a rupture disk actuation system.
  - Provides for:
    - Approximation of an instantaneous break opening, and,
    - Simulates a shock wave that might result from an instantaneous pipe break.

Westinghouse [redacted]

Coatings Jet Impingement Test

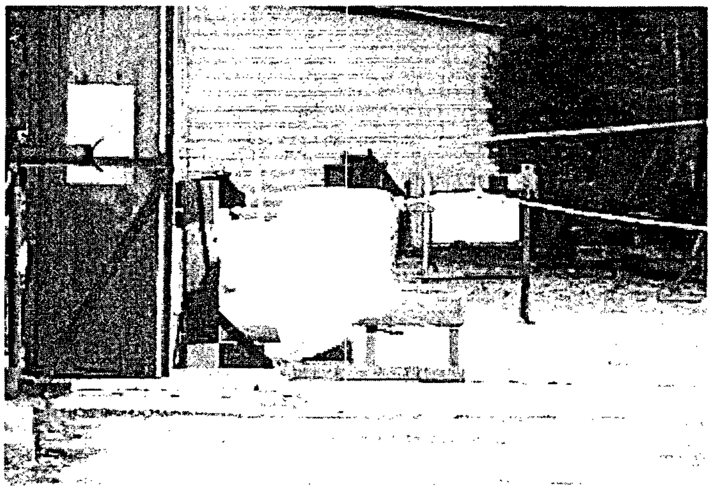
COUPON PLACEMENT AND SETTING DISTANCE FROM NOZZLE IN TEST RIG

Typical for All Tests and All Coupons

Burst Disk Assembly | Nozzle Attachment | Coupon Fixture | Jet Nozzle | Coupon Face

Westinghouse [redacted]

Coatings Jet Impingement Test



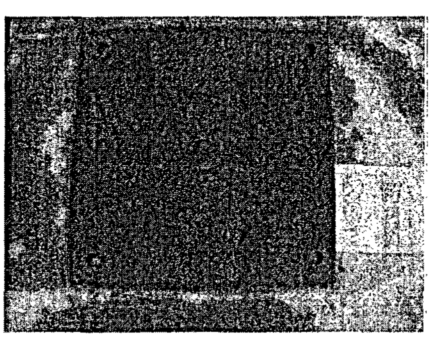
BNFL 2/09/06 CJIT_02_09_06_NRC Slide 5 Westinghouse

Westinghouse [redacted]

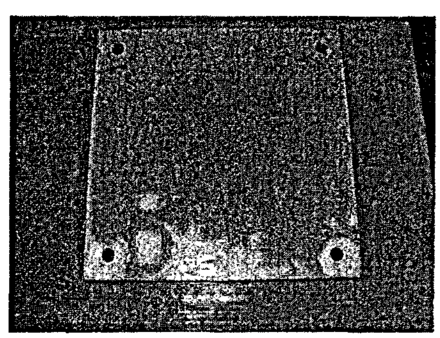
Coatings Jet Impingement Test

TYPICAL POST-TEST PHOTOGRAPHS

Test 2: Steel substrate, IOZ primer, two coats of epoxy topcoat



Test 3: Concrete substrate, epoxy primer, epoxy topcoat



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Westinghouse [redacted]

Coatings Jet Impingement Test

STATUS:

- Testing completed - eight test runs;
- Equivalent distance from break;
  - Steel and Concrete $L/D_{BREAK} < 5$ and $L/D_{BREAK} < 4$ (nominal)
  - IOZ $L/D_{BREAK} < 7$ and $L/D_{BREAK} < 8.5$ (nominal)
- Preliminary Results Immediately Following Test:
  - Epoxy-based coatings, regardless of the substrate, showed no coatings loss due to jet impingement at either $L/D_{BREAK} < 5$ or $L/D_{BREAK} < 4$.
  - Untopcoated Inorganic Zinc primer
    - Showed some loss of coating thickness at both L/D_{BREAK} ratios tested.
    - Less loss observed at $L/D_{BREAK} < 8.5$ than at $L/D_{BREAK} < 7.0$.

JOGAR TEST PROTOCOL OVERVIEW

JON R. CAVALLO, PE
CCC&L, INC.

GARTH DOLDERER
FLORIDA POWER AND LIGHT

LEE WILLIAMS
AREVA (FAMATOME-ANP)

1 February 9, 2006 USNRC MEETING

JOGAR TEST PARAMETERS

- All test samples positioned to permit freely expanding jet – no change in jet temperature due to back pressure
- All samples pre-shocked using 3,500 psig power washer
- All samples tested for 60 seconds after jet reached steady temperature of 305 – 310 F unless noted (IOZ panels)

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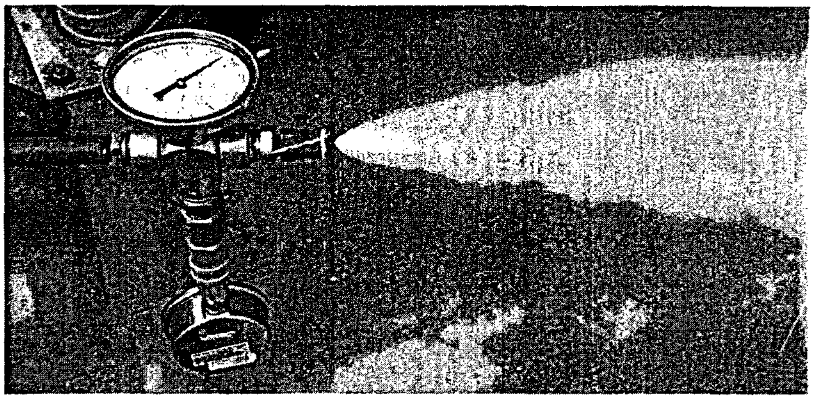
JOGAR STEAM JET



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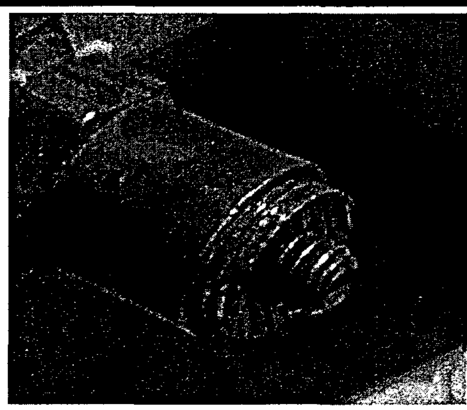
JOGAR STEAM JET NOZZLE TIP



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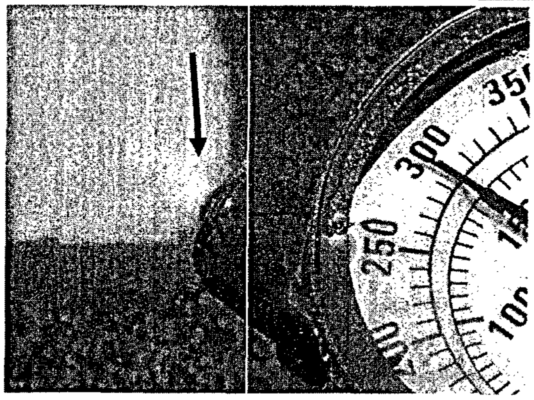
TWO-PHASE JET AT NOZZLE TIP



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TYPICAL JOGAR TEST RUN

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PHENOLINE 305 / CZ-11

- Steel Samples from 20 year old plant

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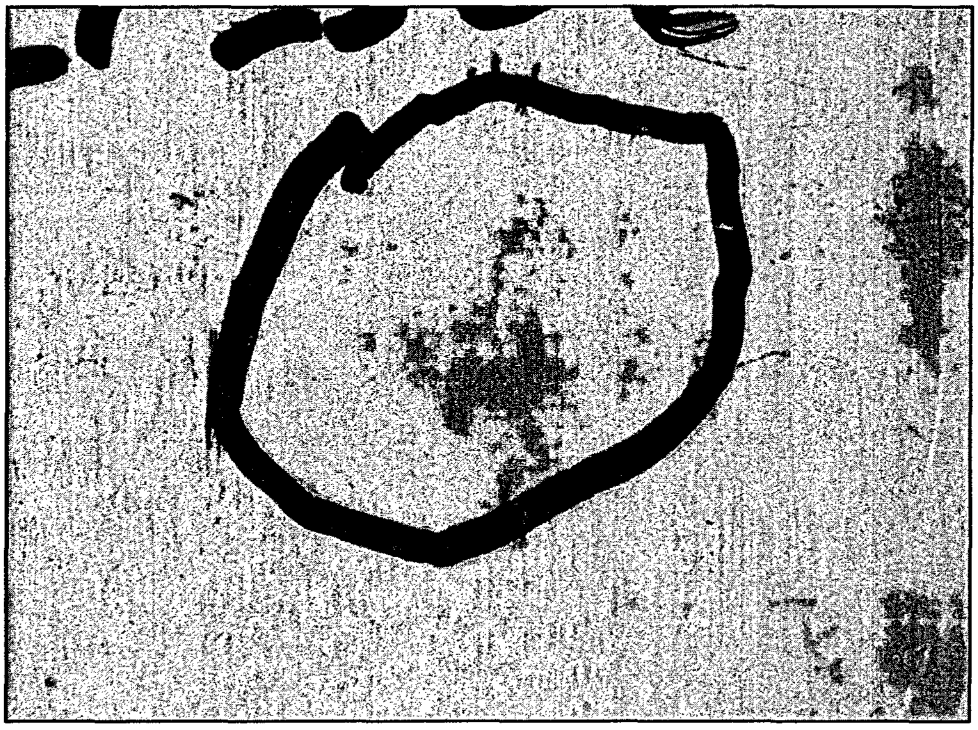

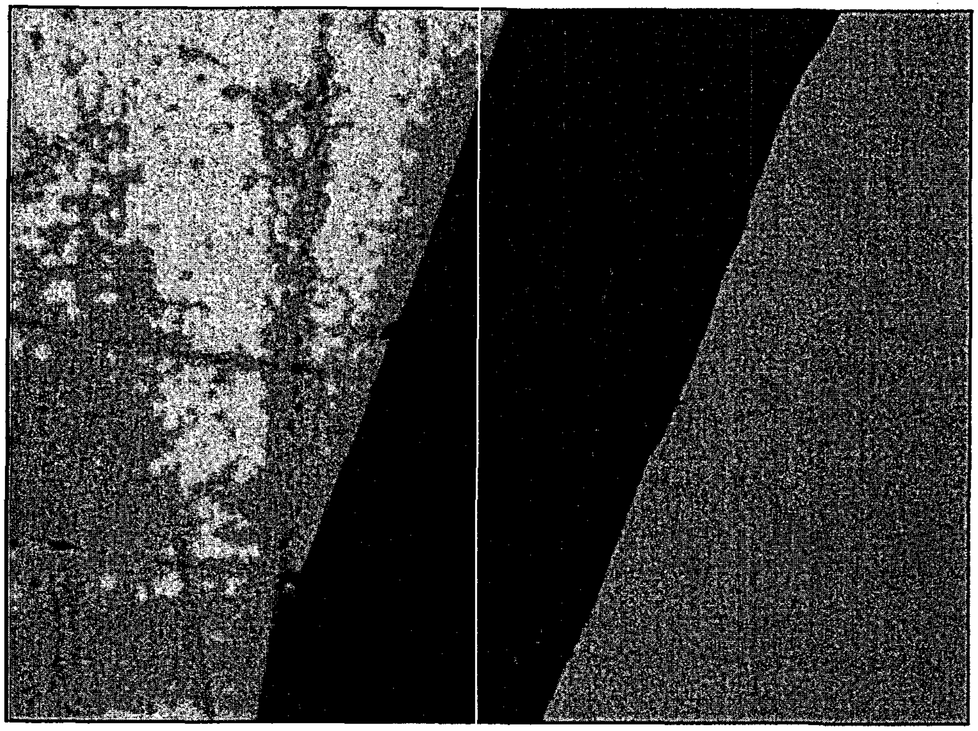

AMERON 114 / AMERCOAT 90

- Archive Panel

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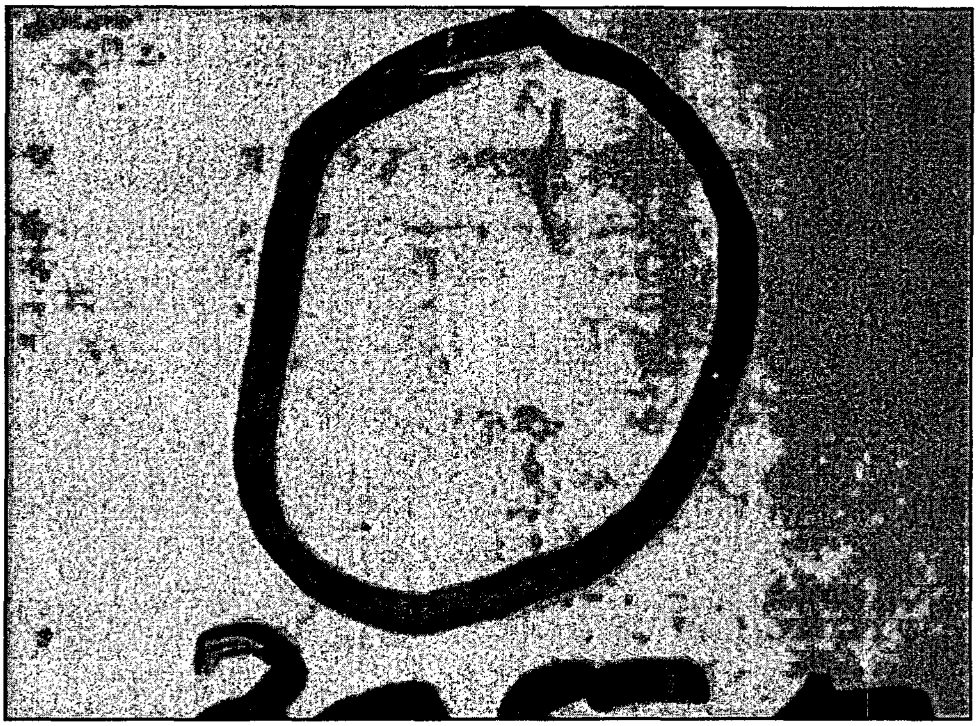

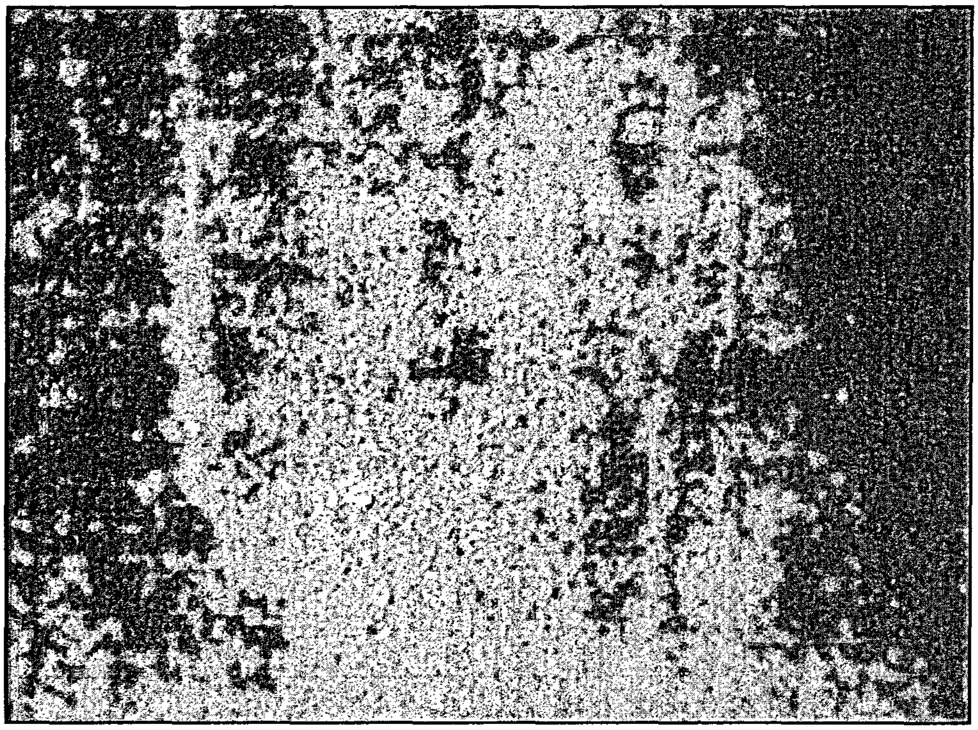

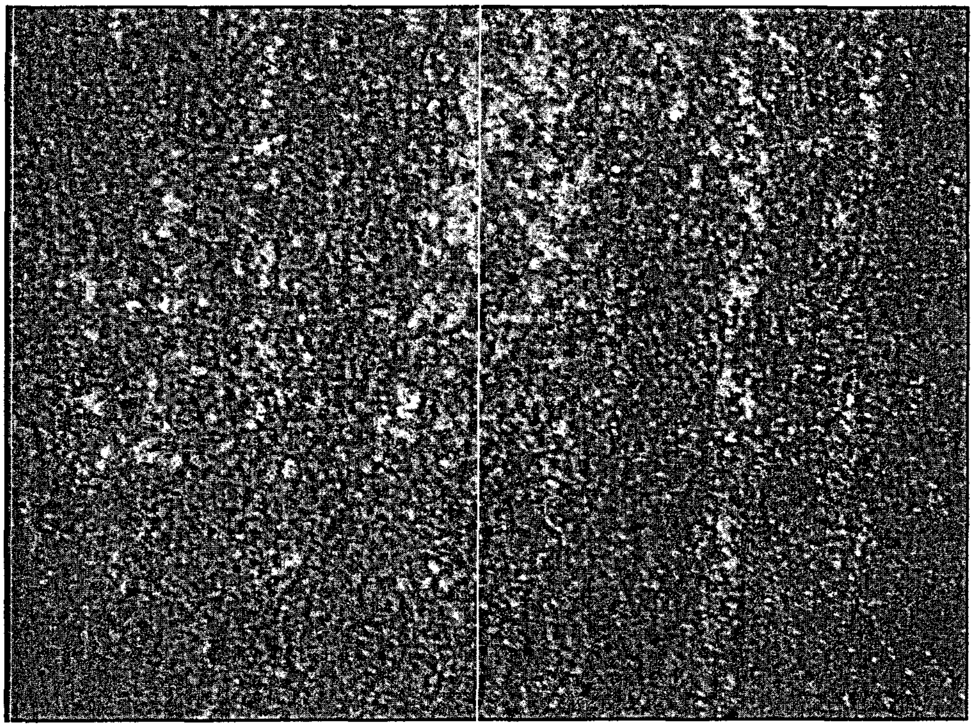

AMERON D-6 / 90

- Archive Panel

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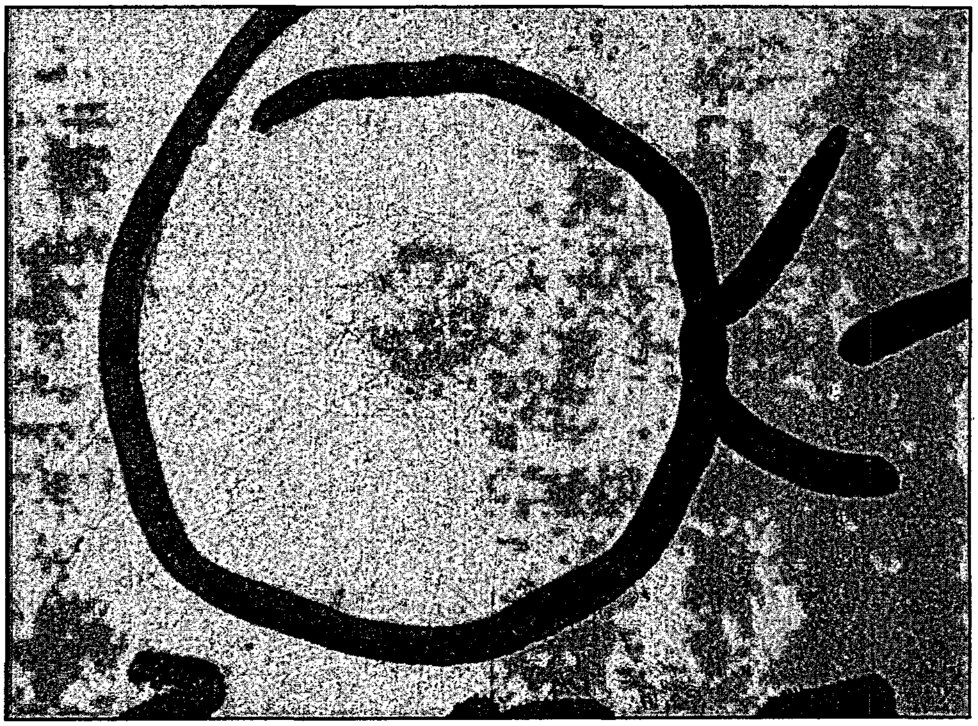

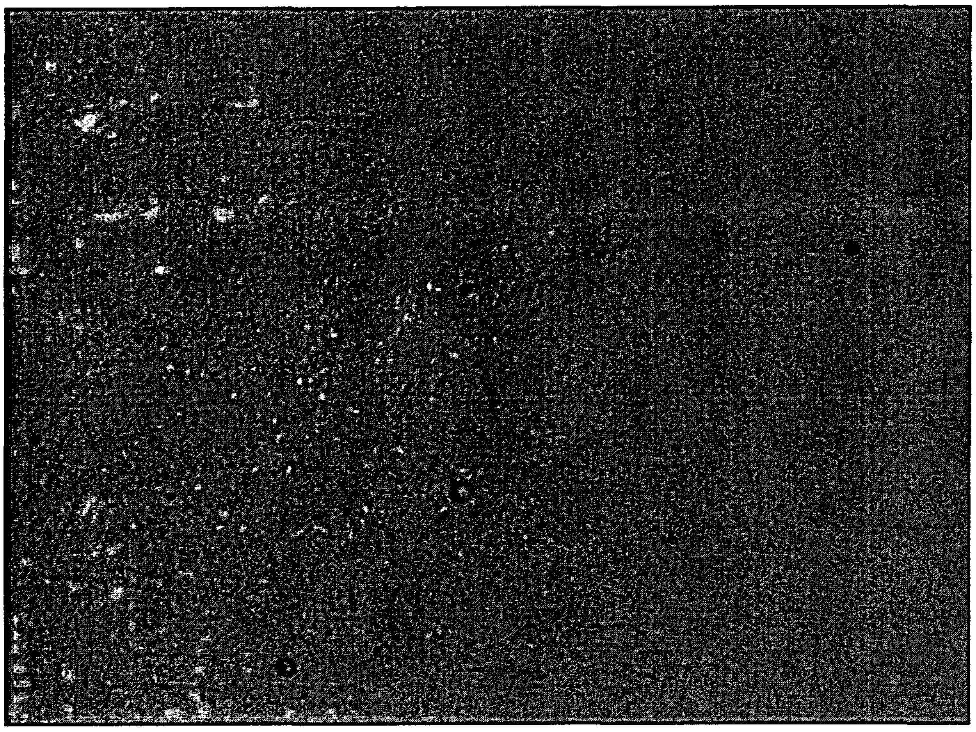

CZ-11 UNTOPCOATED

- Panel prepared at FP&L

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CZ-11 UNTOPCOATED

- Pre-Test Condition

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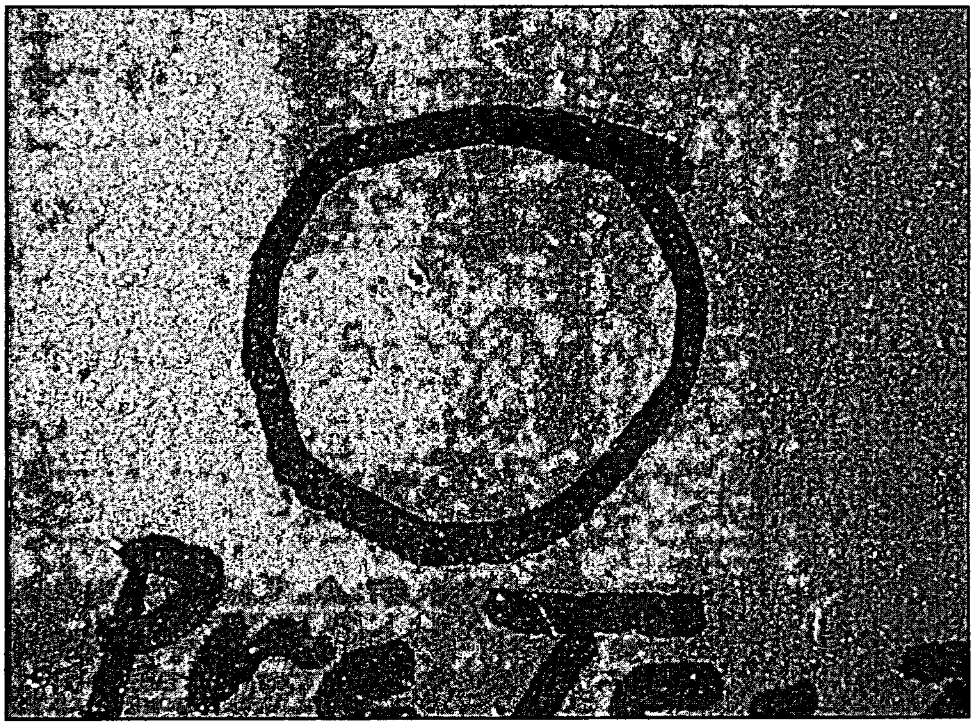

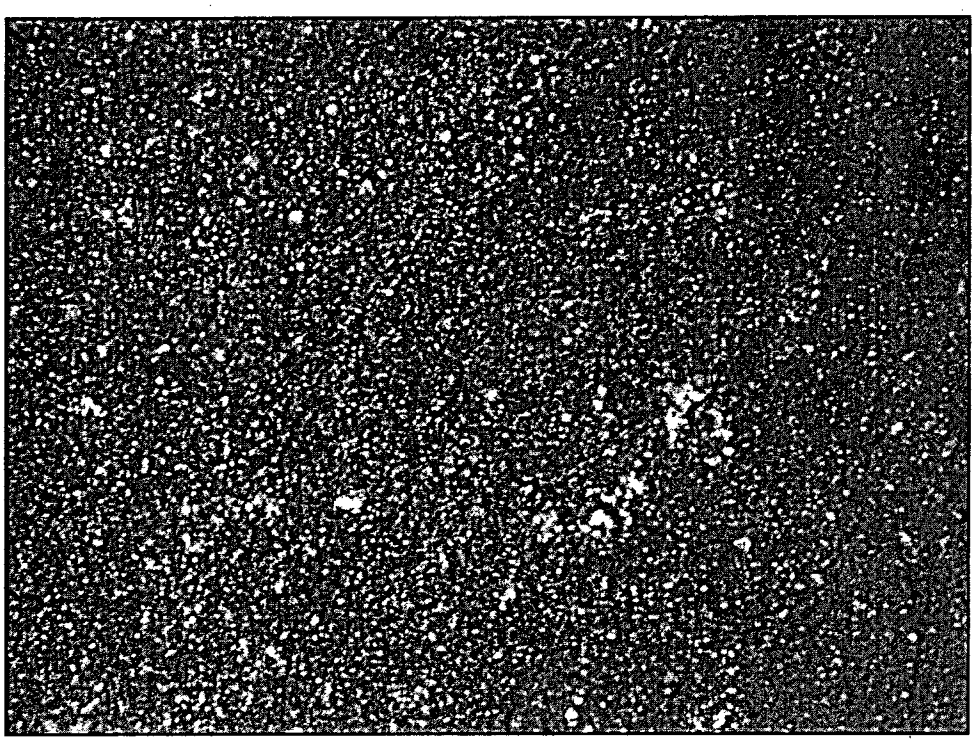

IOZ UNTOPCOATED – 305-310 F

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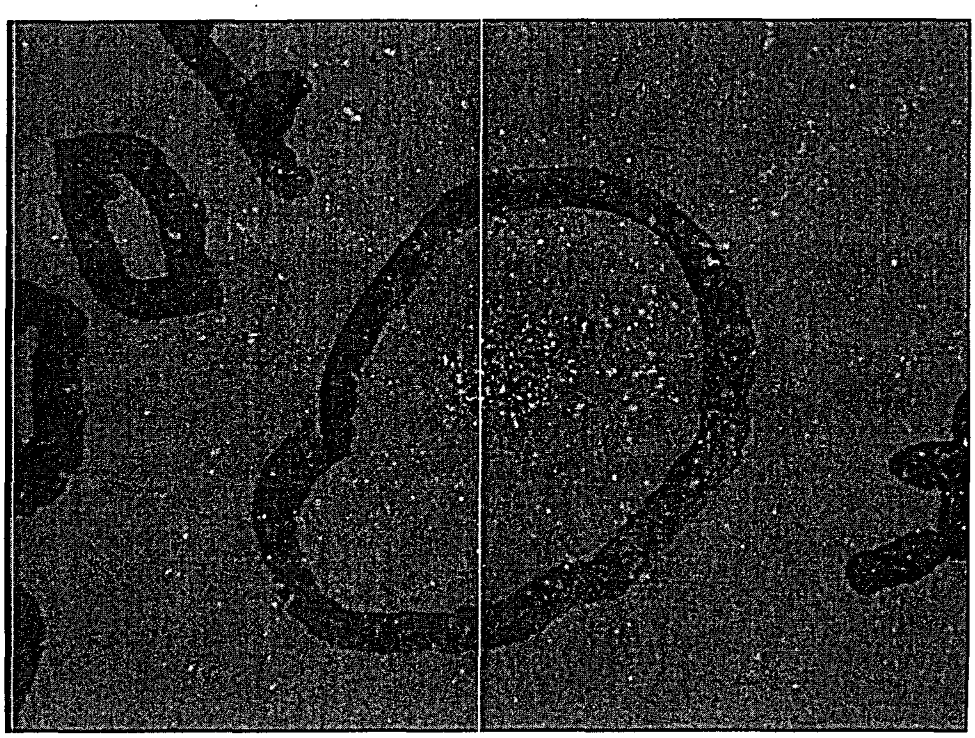

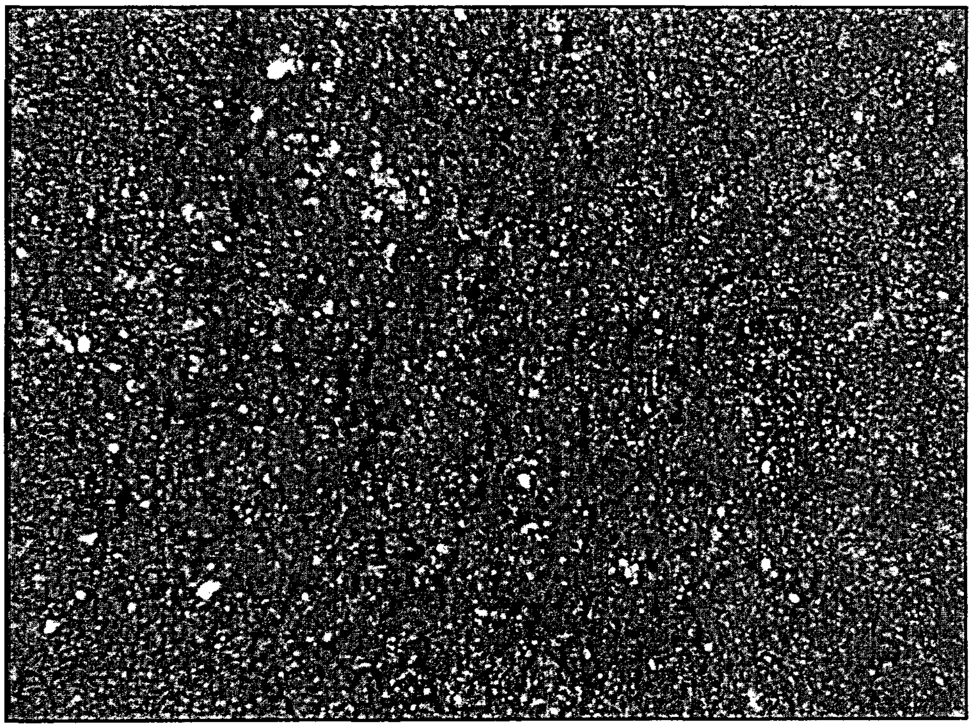

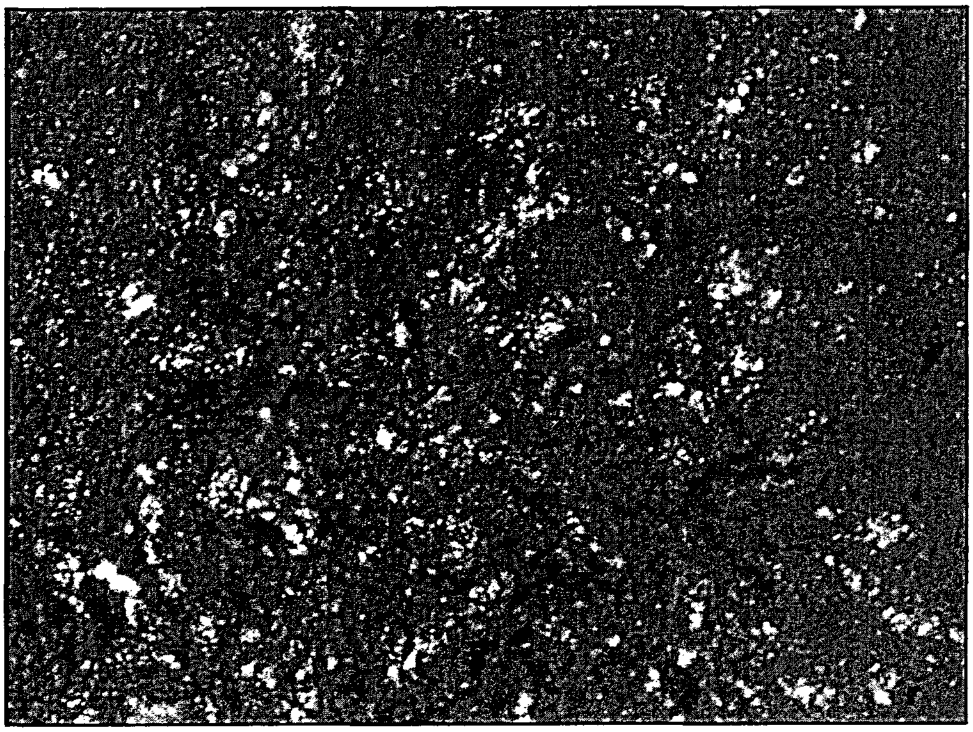

IOZ UNTOPCOATED – 265 F

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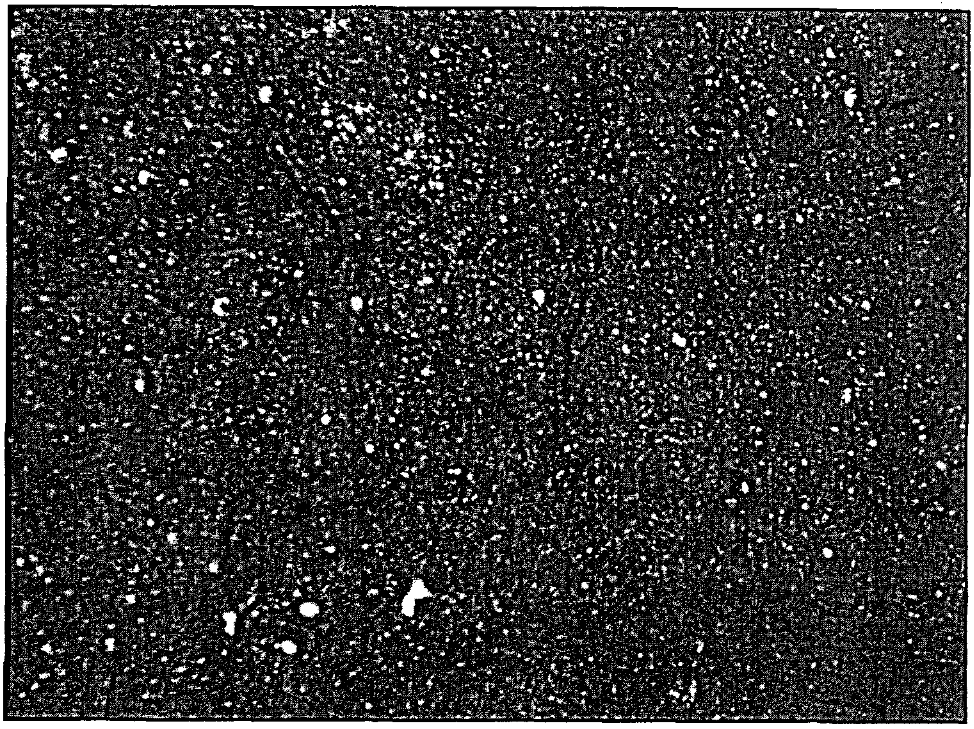

IOZ UNTOPCOATED – 250 F

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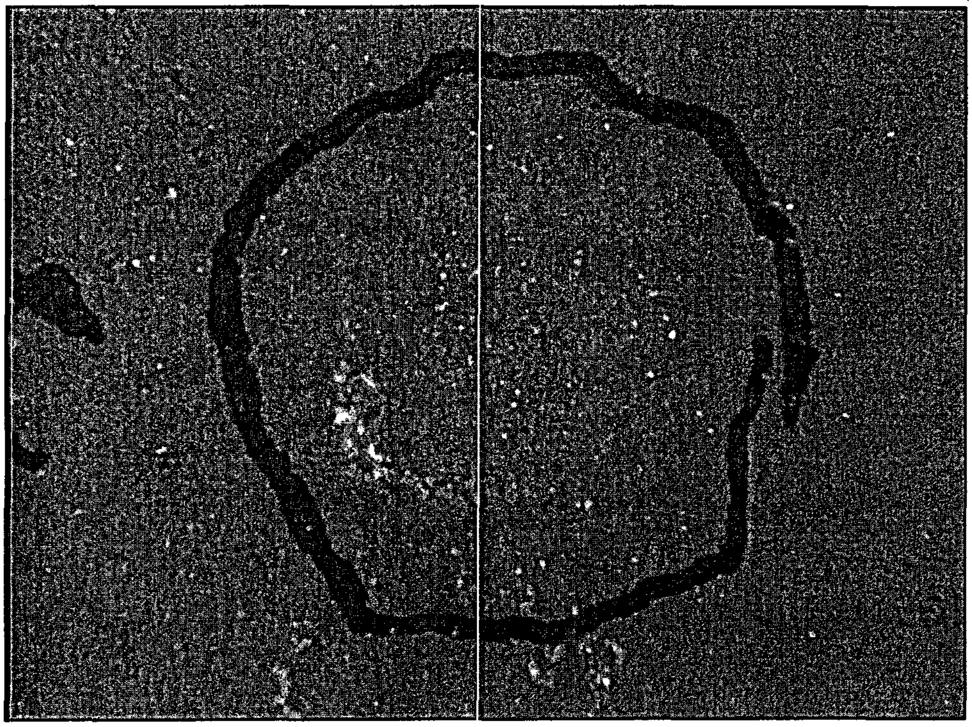
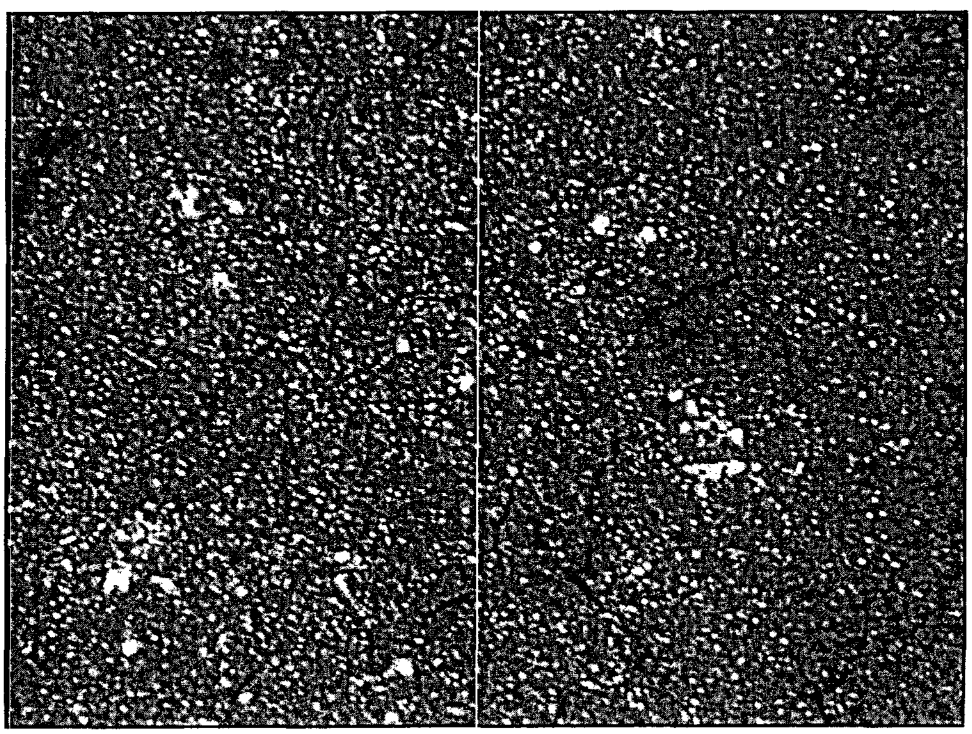
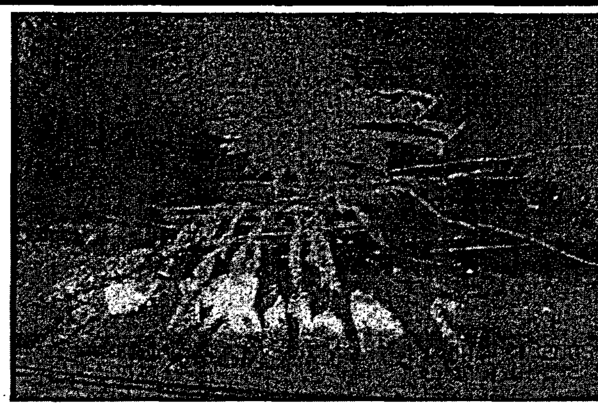




JOGAR TEST OF ALKYD COATING



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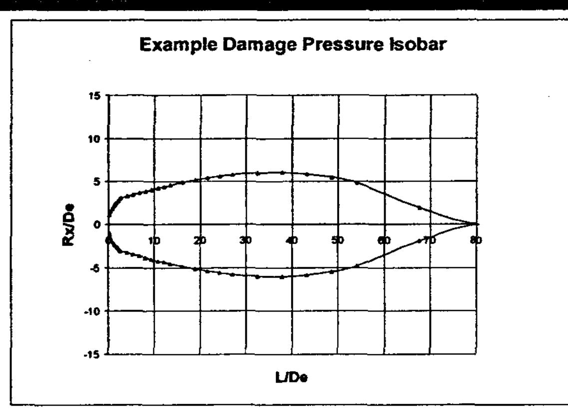
USE OF JOGAR TEST DATA IN VERIFYING COATINGS ZOI



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Correlating Results:
Problem Statement

- Correlate test conditions to those produced by a representative RCS Cold Leg break
  - Test Stagnation Conditions:
    - Po = 210 psig, To = 300 °F
  - Representative Cold Leg Stagnation Conditions:
    - Po = 2250 psig, To = 540 °F

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Correlating Results:
Methodology

1. Apply ANSI/ANS-58.2-1988 model to the test jet conditions. Use model to:
   - Calculate the jet centerline pressures and temperatures experienced by the coating sample at various distances from the nozzle.
2. Using results of Step 1 and observations from the test, assign a conservative damage pressure to coating.
3. Apply ANSI/ANS-58.2-1988 jet model using Cold Leg conditions and the coating damage pressure assigned in Step 2 to determine the coating ZOI.

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Chemical Effects: NRC Head Loss Testing and Resolution Expectations

Paul Klein
Rob Tregoning
Nuclear Regulatory Commission

Public Meeting on GSI-191 Chemical Effects
February 9, 2006
NRC Headquarters, Washington, DC

Agenda

- NRC IN 2005-26, Supplement 1 Overview - Klein
- Chemical Effects Testing Program - Tregoning
  - Background: Initial Testing Program (IN 2005-26)
  - Follow-on Testing Program (IN 2005-26, Supplement 1)
- NRC expectations for licensee chemical effect evaluations - Klein

Information Notice 2005-26, Supplement 1

- IN 2005-26 (9/16/05) informed PWR licensees that significant head loss was observed in tests conducted at Argonne National Lab:
  - TSP and dissolved calcium equal to early ICET Test 3 conditions
  - TSP and dissolved calcium less than early ICET Test 3 conditions
- Public meeting on 9/30/05 to discuss IN 2005-26 results:
  - Industry notified staff that updated plant survey information revealed ICET 3 calcium silicate insulation (cal-sil) loading was substantially higher than in actual plants.
- NRC sponsored additional testing: (1) cal-sil dissolution, (2) head loss with representative amounts of cal-sil and dissolved calcium (3) calcium phosphate settling.

IN 2005-26, Supplement 1 Overview

- Enough calcium dissolves from representative calcium silicate insulation loadings and with representative TSP dissolution rates to cause a "chemical effects" pressure drop across a test bed.
- Significant head loss may result from calcium phosphate which can form within the containment pool or from continued cal-sil dissolution within a sump screen debris bed.
- Calcium phosphate precipitate settling rate varied with concentration. At a 75 ppm calcium concentration and with no bulk directional flow, it did not settle quickly.

IN 2005-26, Supplement 1 Overview

- Information is relevant to plants containing phosphates (e.g., use TSP) and calcium sources (e.g., containment materials) that may dissolve within the post-LOCA containment pool and form calcium phosphate precipitate (i.e., not just plants containing cal-sil/TSP).
- 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, containment layout, recirculation time, etc.

Background: Initial Testing (Sept 2005)

Findings

- Calcium phosphate products generated in TSP-buffered environments contributed to test loop head loss.
  - Measured head loss for all dissolved Ca concentrations tested (down to 10 ppm).
  - Significant head loss for greater than 25 ppm of dissolved Ca.
- For the range of Cal-sil concentrations examined (6 – 25 g/L)
  - 200 ppm of dissolved Ca can form within 30 minutes in initially acidic (ph < 7) environments.
  - More dissolved Ca expected beyond 30 minutes as cal-sil dissolution continues.
- Calcium phosphate may agglomerate at low fluid flow velocities.

Follow-on Testing (IN 2005-26, Supplement 1)

- Motivation:
  - Evaluate chemical effects in TSP-buffered environments associated with lower cal-sil loading concentrations and longer operating times, not just initial 30 minutes of post-LOCA scenarios.
  - Evaluate propensity of calcium phosphate to settle.

- Three test series:
  1. **Dissolution Tests**: Investigate calcium dissolution from cal-sil over a range of simulated containment pool conditions.
  2. **Additional Head Loss Tests**: Examine effect of important post-LOCA environmental variables on the pressure drop across debris beds created by various mixtures of cal–sil, fibrous insulation, and calcium phosphate precipitates.
  3. **Settling Tests**: Measure maximum expected calcium phosphate settling rate.

Follow-on Test Program: Dissolution Tests

Test Variables

- Three different TSP addition histories
  1. Add TSP before cal–sil addition (instantaneous dissolution of TSP).
  2. Titrate TSP over 1 hr period into solution after cal–sil addition (nominal case).
  3. Titrate TSP over 4 hr period into solution after cal–sil addition (very slow TSP addition).
- Cal-sil concentrations: 0.5 and 1.5 g/L.

Test Constants

- Base Solution: 2800 ppm B, 0.7 ppm Li as LiOH.
- Total TSP concentration = 3.4 g/L.
- Temperature = 60°C.

Follow-on Test Program: Dissolution Tests

Test Results

- *Cal–sil dissolution rate is not strongly dependent on the TSP* dissolution rate for realistic TSP dissolution histories.
- Equivalent dissolved Ca exceeded 75 ppm in a few hours for cal-sil concentrations down to 0.5 g/L.
- 75 ppm of dissolved Ca shown to produce pressure drops of ≈ 5 psi at an approach velocity of 0.1 ft/s across a 15g (0.71 kg/m^2) NUKON debris bed.

Follow-on Test Program: Head Loss Tests

- **Principal Test Variables**
  - Degree of cal–sil dissolution that occurs prior to debris bed formation.
  - Relative arrival time of the precipitates and insulation debris at the test screen.
  - NUKON and cal-sil screen loading.
  - Dissolved calcium sources: cal-sil or $CaCl_2$.
- **Test Procedures**
  - Procedure for each test varied based on principal test variable being studied.
  - Baseline (no TSP) tests conducted to assess effect of calcium phosphate.
  - NUKON and cal-sil were presoaked in many tests at 60°C for 30 minutes to simulate residence time prior to recirculation.
  - Various TSP fractional quantities initially added to either presoak or test loop; any remaining TSP was titrated in after forming the debris bed.

Follow-on Test Program: Head Loss Tests

Test Results

- Calcium phosphate head loss contributions are greater than a corresponding amount of cal-sil.
- The initial calcium phosphate present affected the rate of head loss accumulation.
- Total head loss was governed by the total calcium phosphate amount.
- No significant difference in maximum head loss apparent as a function of the relative calcium phosphate arrival time.

Follow-on Test Program: Head Loss Tests

Test Results

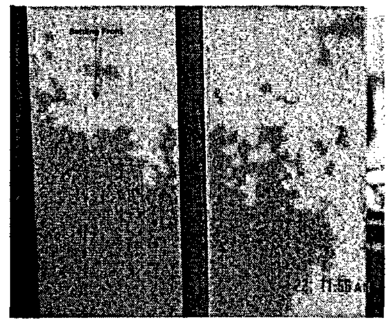
- Relative calcium phosphate head loss contributions depend strongly on the debris loading.
- **25 g cal–sil/7 g NUKON**: head loss significant without chemical product.
- **15 g cal–sil/15 g NUKON**: head loss significantly increased by calcium phosphate.
- **< 10 g cal-sil/15 g NUKON**: head loss not significantly increased by calcium phosphate.

- Greater than 25 ppm of dissolved Ca significantly increased head loss across 15 g NUKON beds.

Follow-on Test Program: Settling Tests

- Test Procedure
  - Performed in settling tower initially filled with B, LiOH, and TSP.
  - $CaCl_2$ solution added.
  - Solution stirred initially to provide uniform concentration.
  - Periodic sampling to quantify settling.
- Results
  - No agglomeration within column.
  - Chemical product did not rapidly settle.
  - **75 ppm Ca**: Est. settling rate of 0.8 cm/min.
  - **300 ppm Ca**: Faster settling (3.8 cm/min) front which removed ≈ ½ of product.

Settling front in a 300 ppm Ca test



Chemical Effect Head Loss Testing

- **Upcoming Plans**
  - Complete analysis of results for TSP/cal-sil environment tests.
  - Conduct NUKON/cal-sil benchmark testing without chemical products.
  - Examine head loss due to chemical products in sodium hydroxide buffered environments.
  - Examine head loss due to chemical products in sodium tetraborate buffered environments.
- **Test Schedule**
  - February: Benchmark testing.
  - February – March: Sodium hydroxide environment.
  - March: Sodium tetraborate environment.
  - April: Complete testing.
  - May – June: Analysis, reporting and documentation.

NRC Test Results Summary

- Calcium from representative calcium silicate insulation loadings and with representative TSP dissolution rates caused a "chemical effects" pressure drop across a test bed.
- Significant head loss may result from calcium phosphate which can form within the containment pool or from continued cal-sil dissolution within a sump screen debris bed.
- Calcium phosphate precipitate settling rate varied with concentration. The estimated settling rate at a 75 ppm calcium concentration and with no bulk directional flow was 0.8 mm/min.

NRC Expectations - Licensee Chemical Effects Evaluations

- NRC expectations for chemical effects evaluations are the same for TSP plants with cal-sil and PWRs with different post-LOCA containment environments.
- GL 2004-02 requested licensees determine a plant specific maximum head loss, including contributions from chemical effects.
- Licensees must demonstrate sufficient ECCS pump NPSH margin exists for all postulated debris sources, including chemical effects, for the entire ECCS mission time.

Chemical Effects Evaluations – Important Attributes

- Plant specific materials/environment interaction well characterized over range of debris and pool conditions.
- Plant specific testing and analysis fills in the knowledge gaps resulting from NRC and industry testing.
- 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.
- Uncertainties assessed in a rigorous manner

GSI-191 WEB SITE

http://www.nrc.gov/reactors/operating/ops-experience/pwr-sump-performance.html