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Your ref: Docket No. 52-006
Our ref: DCP_NRC_002816

March 9, 2010

Subject: Transmittal of AP1000 Containment Debris Fuel Assembly Testing and RAI Response Summary Presentation (Non-Proprietary)

Westinghouse is submitting the Non-Proprietary version of the AP1000 Containment Debris Fuel Assembly Testing and RAI Response Summary Presentation.

The proprietary version of this presentation was submitted via DCP_NRC_002812 on March 5, 2010.

This document is submitted in support of the AP1000 Design Certification Amendment Application (Docket No. 52-006). The information included in this response is generic and is expected to apply to all COL applications referencing the AP1000 Design Certification and the AP1000 Design Certification Amendment Application.

Questions or requests for additional information related to the content and preparation of these reports should be directed to Westinghouse. Please send copies of such questions or requests to the prospective applicants for combined licenses referencing the AP1000 Design Certification. A representative for each applicant is included on the cc: list of this letter.

Very truly yours,

D. O. Lindgren /FOR

Robert Sisk, Manager
Licensing and Customer Interface
Regulatory Affairs and Standardization

/Enclosure

1. AP1000 Containment Debris Fuel Assembly Testing and RAI Response Summary Presentation (Non-Proprietary)

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NRO

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ENCLOSURE 1

AP1000 Containment Debris Fuel Assembly Testing and RAI Response
Summary Presentation (Non-Proprietary)

Westinghouse Presentation to the NRC Staff

AP1000 Containment Debris Fuel Assembly Testing and RAI Response Summary

March 5, 2010

AP1000™

Westinghouse Non-Proprietary Class 3

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AP1000 Containment Debris:
Fuel Assembly Testing and RAI Response Summary

Purpose of the Meeting:

- Discuss specific resolutions to recent RAIs that have been submitted
- Demonstrate how the test reports, technical reports, RAI responses, and DCD information submitted to the NRC in January and February 2010 satisfy GSI-191 for AP1000
- Support NRC completion of Chapter 6 SER related to GSI-191 resolution

AGENDA – March 5, 2010

9:00 A.M.	Introductions and Opening Remarks	
9:05 A.M.	Overview of RAIs	T. Schulz, WEC
9:30 A.M.	**WCAP-17028 -** Summary of Head Loss Tests CIBAP #31 – 39	T. Schulz, WEC
10:45 A.M.	BREAK	
11:00 A.M.	**APP-GW-GLR-092 -** Statistical Analysis of Head Loss Test Results	M. Leslie, WEC
12:15 P.M	BREAK – LUNCH	

AGENDA – March 5, 2010

1:00 P.M.	**APP-GW-GLR-110** – Post-LOCA Boric Acid Precipitation	B. Kellerman, WEC
	APP-PXS-GLR-001 – Long Term Core Cooling	T. Schulz, WEC
	Additional Technical Report Revisions	J. Catalano, WEC
	- **WCAP-16914** – Screen Debris Test Report	
	- **APP-GW-GLE-002** – DCD/ITAAC Changes	
	- **APP-GW-GLR-079 (TR-26)** – Summary Overview	
2:45 P.M	BREAK/CAUCUS	
3:00 P.M.	Discussion/Schedule Feedback/Action Items	
3:30 P.M.	ADJOURN	

Overview of RAIs

Overview of RAIs Responded to in Jan/Feb '10 (1 of 7)

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Overview of RAIs Responded to in Jan/Feb '10 (2 of 7)

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Overview of RAIs Responded to in Jan/Feb '10 (3 of 7)

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Overview of RAIs Responded to in Jan/Feb '10 (4 of 7)

AP1000 GSI-191 - Significant NRC (staff) and ACRS Ques:						
NRC#	Title	Detail Ques	Resolution Approach	Resolution Steps	Date Sent to NRC	Reports Impacted
SRSB-32	W-CT uncertainties vs 90%		Discussion	Show that the inputs to W-CT are conservative / bounding and that W-CT is valid for conditions analyzed.	1/29/10	none
SRSB-33	Non-Uniform debris across core	Can more debris be transported to a significant part of the core (center or one side) cause excessive dP and inadequate core cooling.	Evaluation	Discuss possible flow / debris distributions and dPs. Include CFD analysis showing uniform flow distribution. Discuss implications on core cooling. Reference previous FA blockage analysis.	1/29/10	GW-GLR-079, GW-GLR-009
SRSB-34	STC FA test pump	Does current STC FA test loop pump change the fiber length when the debris passes through the pump.	Discussion	Discuss how it is unimportant what the limiting debris.	1/29/10	WCAP-17028
SRSB-35	NRC guidance for FA testing	WEC references NRC guidance for con-current debris addition in the FA testing that was issued for screen testing. Discuss adequacy of test matrix.	Discussion	Discuss why test matrix is sufficient. Comment that reference was simply to help justify why con-current debris addition could be considered - not why it was sufficient.	1/29/10	none
SRSB-36	Acceptance criteria at less than 8.66 hr	Provide an evaluation that covers earlier times (than 8.66 hr).	Discussion	Already addressed in LTC report (as well as WCAP-17028). Words added/revised to further clarify.	1/29/10	GW-GLR-079, WCAP-17028

Overview of RAIs Responded to in Jan/Feb '10 (5 of 7)

AP1000 GSI-191 - Significant NRC (staff) and ACRS Ques:						
NRC#	Title	Detail Ques	Resolution Approach	Resolution Steps	Date Sent to NRC	Reports Impacted
SRSB-37	Inputs to LTC analysis	Provide table of input boundary conditions including decay heat, sump level & temp, RV level & temp. Explain how these values were obtained.	Discussion	Provided table of LTC inputs in RAI response.	1/29/10	none
SRSB-38	Is a DVI LOCA in PXS room more limiting than in loop compartment	Why is DVI LOCA in PXS room not limiting vs DVI LOCA in loop compartment. Discuss event progression for each.	Discussion	Already have some discussion in LTC report. Added additional words to clarify.	1/29/10	PXS-GLR-001, GW-GLR-079
SRSB-39	W-CT Validation	Is W-CT valid for conditions seen in sensitivity studies. Provide validation report.	Discussion	W-CT has been validated against tests with conditions that bound those seen in the AP1000 sensitivity analysis. Provide references to this validation and show why it is applicable to AP1000.	1/29/10	none
SRSB-40	Min Time to transport debris	How break and PXS flows vary with time - why assume linear?	Evaluation	Used test data to justify time.	1/29/10	GW-GLR-079, PXS-GLR-001
SRSB-41	Clarify DVI flow split	Which line (A or B) is broken. Time vs %. Add table for DECL LOCA.	Discussion	Added DECL LOCA flow split table.	1/29/10	GW-GLR-079

Overview of RAIs Responded to in Jan/Feb '10 (6 of 7)

AP1000 GSI-191 - Significant NRC (staff) and ACRS Ques:

NRC#	Title	Detail Ques	Resolution Approach	Resolution Steps	Date Sent to NRC	Reports Impacted
SPCV-25	ZOI Coatings Debris	Does limit apply to HL as well as CL LOCAs? If not what amount of ZOI coatings was assumed?	Discussion	Clairify that 50 lb only applies to CL LOCAs. Discuss why HL LOCAs are not limiting. Refered to FA testing showing air dispurses debris bed.	2/26/10	TR26
SPCV-26	Screen Head Loss		Discussion	Changed max flow to RNS limit.	1/29/10 & 2/26/10	WCAP-16914, GW-GLR-079
SPCV-27	Upstream Effects	MRI clogging refueling cavity drains	Discussion	Discuss why acceptable.	1/29/10	GW-GLR-079
SPCV-28	Design Changes	RNS impact on core and screen flows.	Discussion	Clairify.	1/29/10 & 2/26/10	GW-GLE-002

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Overview of RAIs Responded to in Jan/Feb '10 (7 of 7)

AP1000 GSI-191 - Significant NRC (staff) and ACRS Ques:						
NRC#	Title	Detail Ques	Resolution Approach	Resolution Steps	Date Sent to NRC	Reports Impacted
CIEN-26	Screen Test termination criteria	Screen testing used at termination criteria of high AlOOH solid conc. Defend.	Discussion	Provided justification.	1/29/10	none
CIEN-27	Screen test termination criteria	Provide additional information, clarify discrepancies.	Discussion	Provided justification.	1/29/10	WCAP-16914
CIEN-28	Concrete debris	Discuss why for a range of break sizes and locations how the LOCA blowdown jet would (or would not) damage concrete and generate physical / chemical debris. How has this debris been considered?	Evaluation	Provide evaluation of different LOCA sizes / break locations on the potential for jet impingement damage of concrete. Closest locations are probably in PXS rooms.	1/29/10	none
errata	WCAP-17029	Pages 6-34, D-12, 5-3.	Fix		2/26/10	WCAP-17029
errata	TR26	Pages 10, 24	Fix		2/26/10	CN-CLR-070

New RAIs Not Yet Responded To

- CIB1-28, R1; concrete debris generation follow-up question
  - No changes considered necessary to GSI-191 doc.
- CIB1-30; change ZOI for inorganic zinc to 10D
  - Implemented in APP-GW-GLR-079 and APP-GW-GLE-002
- 6.1.2CIB1-01; Service Level II COL coatings program
  - DCD change added to APP-GW-GLE-002
- SPCV-31; part a) and b) on testing uncertainties and tolerances
  - No changes to GSI-191 doc as discussed in phone calls

Summary of Head Loss Tests CIBAP #31 – 39
WCAP-17028

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HL LOCA Outer FA Exploratory Test (#35)

- Flow was reduced as bed resistance increased

– Before	52 gpm	0 psi
– 1st batch	52 gpm	0.70 psi
– 2nd batch	27 gpm	0.85 psi
– 3rd batch	6 gpm	0.85 psi
– 4th batch	0.5 gpm	0.85 psi
– 5th batch	<0.5 gpm	0.85 psi

- After 5 of 7 debris batches were added, test #35 was stopped when flow was decreased < 0.5 gpm

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Figure 9-2 Fibers Photographed Near End of Test CIBAP11

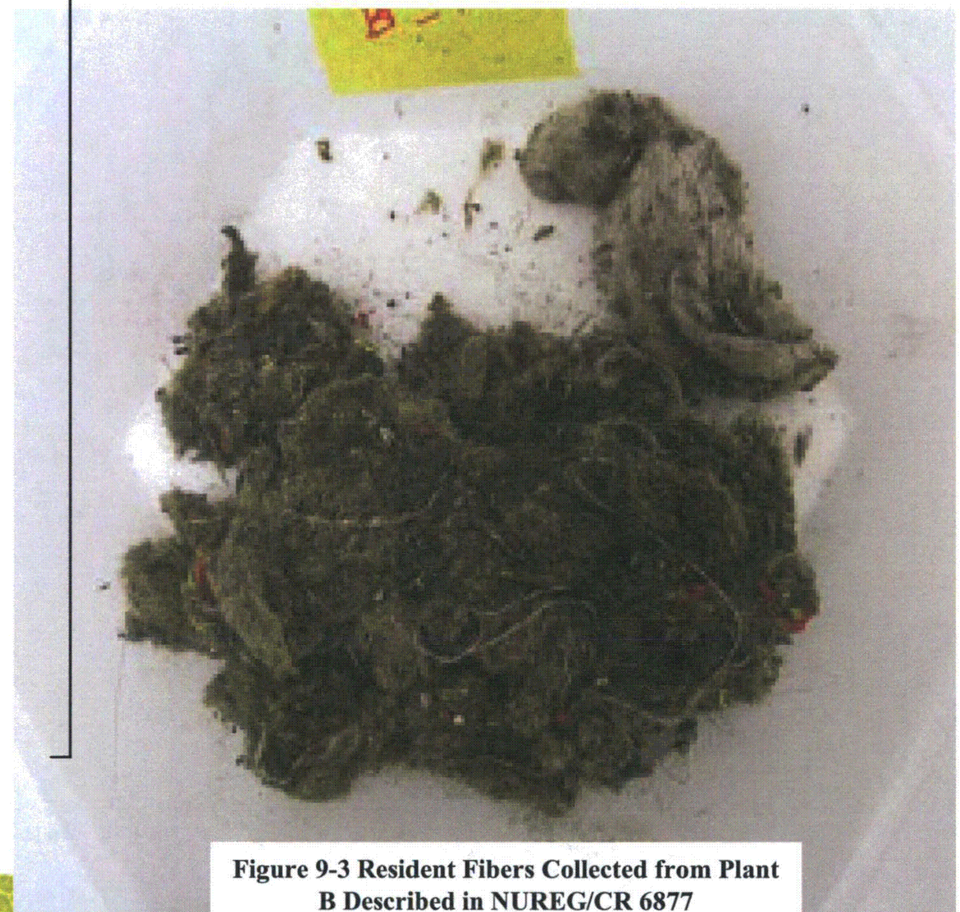

Figure 9-3 Resident Fibers Collected from Plant B Described in NUREG/CR 6877

Statistical Analysis of Head Loss Test Results
APP-GW-GLR-092

Outline

- Purpose of statistical analysis
- Analysis approach
- Selection and characterization of test subset of interest
- Results

Purpose of Statistical Analysis

- AP1000 fuel assembly debris-loading head-loss test data shows variability
- Statistical analysis uses AP1000 fuel assembly debris-loading head-loss test data to
  - Explain how variations in the test results are accounted for in the final evaluations and
  - Show that the design basis containment debris does not induce a head loss which would invalidate the conclusions of the AP1000 post-LOCA long term core cooling safety case.
- Consistent with two requests for additional information related to test variability:
  - RAI-SRP6.2.2-SRSB-28
  - RAI-SRP6.2.2-SRSB-30

Applicable Safety Analysis Limit

- Figure of merit from test results: adjusted pressure drop
  - Maximum pressure drop when measured pressure drop and flow are scaled to expected pressure drop at 3.1 gpm flow per assembly
  - Measure of the debris bed resistance
- Safety analysis acceptance criteria from WCOBRA/TRAC LTC Case 10
  - 4.1 psid at 65 lbm/s core flow (3.1 gpm per assembly)
    - Safety analysis assumes uniform high resistance across all assemblies
    - In plant, expect a distribution of resistance across assemblies
  - Statistical analysis approach:
    - First consider the probability that any one assembly will exceed the acceptance criteria
    - Next consider the effective core inlet resistance across 157 assemblies and core inlet pressure drop at minimum core flow

Applicable Safety Analysis Limit (cont'd.)

- LTC Case 10 acceptance criteria more applicable than Case 3 acceptance criteria
  - Case 3 decay heat at 2.6 hr after break when recirculation begins
  - WCAP-17028-P shows [ ]^{a,c} (concurrent addition tests)
  - In WCAP-17028-P the exponent used to scale the measured pressure drop and flow for comparison to this acceptance criteria was [ ]^{a,c}
- Analysis focuses on cold leg and DVI break scenarios
  - Debris enters the core from the break through the downcomer, lower plenum
  - Test results indicate that for hot leg breaks debris bed buildup will not occur; therefore these breaks are not of interest in this work

General Approach of Statistical Analysis

- Select and characterize test subset of interest for analysis
- Perform linear regression of data
- Empirically model the adjusted pressure drop considering results of linear regression analysis and a Gaussian noise factor to account for variability in the test results unexplained by input parameter variation
  - Perform normality check on data to support use of Gaussian noise factor
  - Calculate upper bound standard deviation values at different confidence levels
  - Consider adjusted pressure drop and natural log of adjusted pressure drop
- Use empirical model with upper bound standard deviation values to calculate the probability for any one assembly to exceed the acceptance criteria
- Use empirical model with upper bound standard deviation to develop a conservative discrete distribution of core inlet resistance
- Evaluate core inlet pressure drop at minimum core flow compared to acceptance criteria

Selection of Test Subset of Interest

- Many variations in test conditions over evolution of the test matrix
- Select tests which:
  - Have similar test procedures
  - Are more prototypic of expected plant behavior
- A division could be made based on:
  - Variable flow vs. constant/oscillatory flow tests
  - Concurrent vs. sequential debris addition

Selection of Test Subset of Interest (cont'd.)

- Initial division made based on flow type
- Examine Tests 18-34
  - More prototypic of expected plant behavior than constant/oscillatory flow tests 1-16 with sequential addition
  - Test 17 excluded as invalid test
  - Tests 36, 37 conservatively neglected from analysis
    - Performed at higher temperature, with additional changes to fluid chemistry [ ]a,c more prototypic of post-LOCA conditions
    - Results qualitatively compared to results of Tests 18-34 to inform interpretation of the analysis results
- Subset of interest later refined to the concurrent addition tests

Characterization of Test Subset of Interest
- Summary of input for statistical analysis

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Linear Regression Results

Linear regression model adjusted pressure drop or natural log adj. dP:

[ ]a,c

Summary of coefficients for natural log model linear regression analysis

[ ]a,c

- Examine P-values of coefficients
  - P-value: corresponds to smallest level of significance which would lead to rejection of the null hypothesis (that the correlation coefficient is zero)
  - Typical P-value limit: 0.05
- Tests 18-34:
  - Linear regression results [ ]a,c
  - [ ]a,c
  - [ ]a,c

Linear Regression Results (cont'd.)

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Linear Regression Results (cont'd.)

Summary of coefficients for natural log linear regression analysis - concurrent addition tests

[ ]a,c

- Linear regression results of concurrent addition tests
  - [ ]a,c
    - Linear regression results [ ]a,c
    - [ ]a,c
  - [ ]a,c
- Refine test subset for analysis to concurrent addition Tests 22, 24-34

Matrix of Scatter Plots – Tests 18-34

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Visual representation of adjusted pressure drop results against varied test input parameters

Probability Calculations: Model

- Follow the same steps for pressure drop, natural log pressure drop
- The adjusted pressure drop or natural log of adjusted dP is modeled as the sum of a constant intercept and a Gaussian noise factor: $\ln(dP) = C' + \sigma' * Z$
  - Then the probability for any single assembly to exceed the acceptance criteria is:

$$P\left[dP > dP_{\max}\right] = P\left[Z > \frac{\ln(dP_{\max}) - C'}{\sigma'}\right]$$

  - C' is [ ]a,c
  - Determine upper bound standard deviation values [ ]a,c
    - [ ]a,c
      - [ ]a,c
      - [ ]a,c

Test Data Normality

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- [

  ]a,c
- [

  ]a,c
- [

  ]a,c
- Normality test results are
  [

  ]a,c

Probability Calculations
– Upper Bound Standard Deviations

- For a parameter U with chi-square distribution the probability that the parameter is greater than the cutoff is equal to the integral of the chi-square PDF between the cutoff: $1-\alpha = P\left(U \ge c_{1-\alpha}^{(d)}\right) = \int_{c_{1-\alpha}^{(d)}}^{\infty} f_d(u)du$

- For a series of n independent Gaussian variables the quantity $\frac{(n-1)s_n^2}{\sigma^2}$ has a chi-square distribution with

  (n-1) degrees of freedom
- Therefore the upper bound standard deviation δ_n for a given quantile may be determined $\delta_n = \sqrt{\frac{(n-1)s_n^2}{c_{1-\alpha}^{(n-1)}}}$

Probability Calculations

– Upper Bound Standard Deviations for Natural Log Model

[ ] a,c

- Nominal standard deviation: [ ]a,c
- Therefore, we have
  - [ ]a,c confidence the standard deviation is less than [ ] a,c
  - [ ]a,c confidence the standard deviation is less than [ ] a,c
  - [ ]a,c confidence the standard deviation is less than [ ] a,c

Probability Calculations: Results for a Single Fuel Assembly

- Probability that the pressure drop in an assembly at 3.1 gpm flow will exceed 4.1 psid:

[ ]a,c

- Two sensitivity calculations for [

]a,c probability for a single assembly to exceed 4.1 psid at 3.1 gpm.

Distribution of Core Inlet Resistance

- Concurrent addition tests considered as samples of adjusted pressure drop from 12 of the 157 fuel assemblies in the core.
- Since adjusted dP values are scaled to the same flow they are a measure of debris bed resistance
- Distribution of debris bed resistance across the fuel assemblies in the core is assumed to follow a normal distribution $\ln(dP) = C' + \sigma' * Z$
  - Mean, standard deviation normal distribution from [

]a,c

Distribution of Core Inlet Resistance (cont'd.)

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- Transform the continuous normal distribution into a discrete census
  - Divide distribution into 8 bins
  - Bin 1-7: [

    ]a,c
  - Bin 8: [

    ]a,c

Effective Core Inlet Resistance

- Use basic relationship between pressure drop dP, resistance R, flow Q, and exponent e to calculate effective resistance for each bin and effective core inlet resistance $dP_i = R_i Q_i^e$
- Assumptions:
  - The pressure drop across [ ]a,c is the same for each fuel assembly in the core
  - Total core flow is the sum of the flow through each assembly (also applicable to flow through a bin of assemblies)
  - The exponent, e, [ ]a,c

$$R_B = \frac{dP_i}{Q_i^e N^e}$$

Equivalent resistance for each bin of N assemblies

$$R_{core} = \frac{1}{\left[\frac{1}{R_1^{1/e}} + \frac{1}{R_2^{1/e}} + \ldots + \frac{1}{R_8^{1/e}}\right]^e}$$

Equivalent resistance across core inlet for 8 bins

Conclusion: Pressure Drop Across Core Inlet at Minimum Core Flow

- Based on the defined distribution, the pressure drop for minimum core flow of 65 lbm/s (3.1 gpm per assembly) at the core inlet is [ ]^{a,c}
- This result demonstrates considerable margin to the safety analysis limit of 4.1 psid at 65 lbm/s core flow

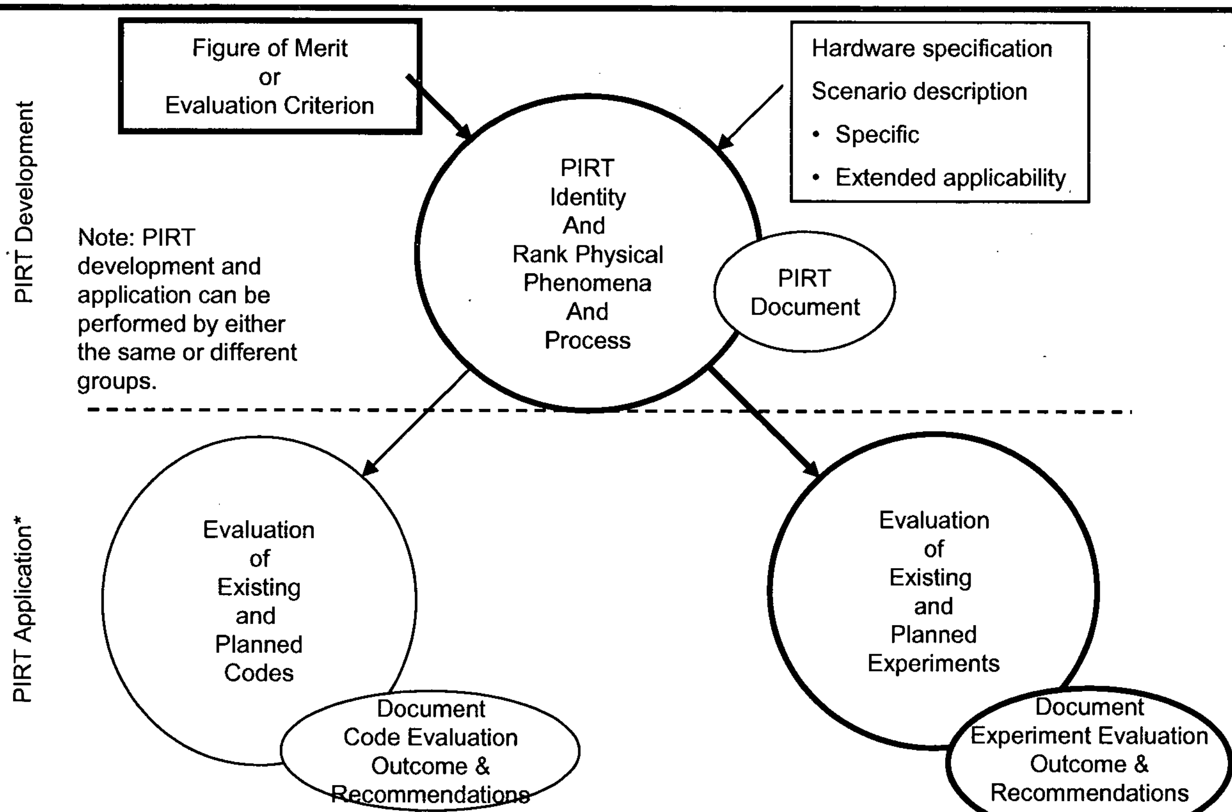
Bin	N_A	$dP_{adj,i}$ Characteristic Adjusted Pressure Drop for Bin (psid)	R_B (psi/gpm$^{1.65}$)
1	39	0.53	1.934E-04
2	39	1.16	4.257E-04
3	16	1.56	2.491E-03
4	15	2.15	3.805E-03
5	16	3.11	4.957E-03
6	16	5.20	8.294E-03
7	8	7.96	3.982E-02
8	8	Fully blocked (infinite)	Fully blocked (infinite)

Post-LOCA Boric Acid Precipitation
APP-GW-GLR-110

Post-LOCA Boric Acid Precipitation
APP-GW-GLR-110

- AP1000 passive core cooling utilizes automatic depressurization valves to depressurize RCS
  - ADS stage 4 lines are connected to both HLs and discharge to containment
  - During their operation, significant water is discharged with the steam (steam qualities 35%-50%)
  - This water venting effectively limits the buildup of boric acid concentrations post LOCA to < 7400 ppm boron
  - Eliminates concerns over boron precipitation in lower plenum
- Evaluation looks at the possibility of precipitation on fuel rod surfaces

Post-LOCA Boric Acid Precipitation – APP-GW-GLR-110
Application of PIRT Process



*Evaluate code or experiments relative to highly ranked PIRT phenomena

* B. E. Boyack and G. E. Wilson, "Lessons Learned in Obtaining Efficient and Sufficient Applications of the PIRT Process," Best Estimates 2004.

Post-LOCA Boric Acid Precipitation – APP-GW-GLR-110
Application of PIRT Process

WCAP-17047-NP

- Phenomena Identification and Ranking Tables (PIRT) for Un-Buffered/Buffered Boric Acid Mixing/Transport and Precipitation Modes in a Reactor Vessel During Post-LOCA Conditions

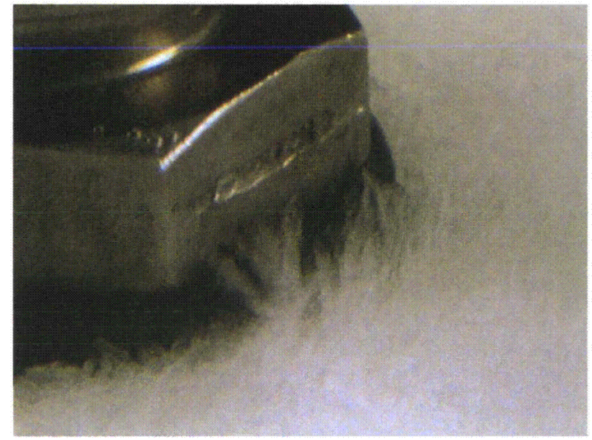
Figure of Merit – Precipitation Modes

- Buffered or Un-Buffered Boric Acid Concentration Local/Regional/Bulk Limit

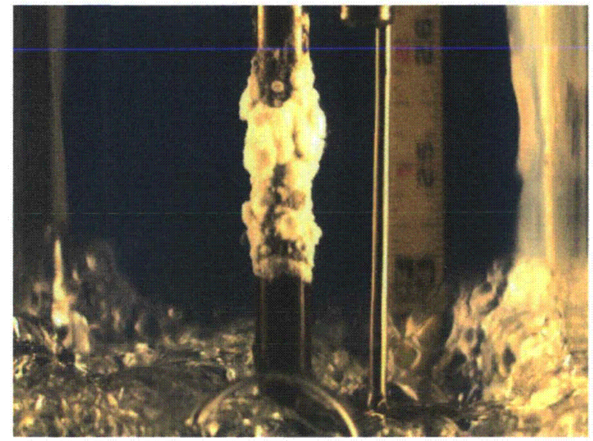
Post-LOCA Boric Acid Precipitation – APP-GW-GLR-110
Precipitate Forms

Crystalline

- Highly ordered, compact structure
- Relatively low surface area to volume ratio
- Driven by level of super-saturation, diffusion limited
- Nucleates and grows on cool surfaces



Post-LOCA Boric Acid Precipitation – APP-GW-GLR-110
Precipitate Forms



Amorphous

- Irregularly ordered, voided structure
- Relatively high surface area to volume ratio
- Driven by level of super-saturation, limited by rate of replenishment
- Nucleates and grows on hot surfaces

Post-LOCA Boric Acid Precipitation – APP-GW-GLR-110
Nucleation Processes

Homogeneous precipitation

- Bulk or global (total mixing volume) precipitation
- Requires uniform concentration and temperature
- Not observed in system tests (REWET, VEERA, [ ]^{e})

Heterogeneous precipitation

- Localized or regional precipitation
- Local limit dependent on solute and material/topology of surfaces
- Various modes observed in system tests (REWET, VEERA, [ ]^{e})

Post-LOCA Boric Acid Precipitation – APP-GW-GLR-110
Review of Existing Tests

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Post-LOCA Boric Acid Precipitation – APP-GW-GLR-110
Review of Existing Tests

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Post-LOCA Boric Acid Precipitation – APP-GW-GLR-110
Review of Existing Tests

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Post-LOCA Boric Acid Precipitation – APP-GW-GLR-110
Review of Existing Tests

REWET-II

- Small-scale (power to coolant volume ratio preserved)
  - 19 full-length heater rods (~ 8' length, 0.360" OD)
- Observations
  - Concentration gradient in core region
  - Precipitation[1] observed at top of mixture (with moisture separator) at boron concentration much greater than expected in AP1000
  - Concentration equilibrium achieved (without moisture separator)
    - Similar to low quality steam venting through HL ADS flowpath

1. Precipitation occurred at boron concentration much greater than expected in AP1000

Post-LOCA Boric Acid Precipitation – APP-GW-GLR-110
Review of Existing Tests

VEERA

- Small-scale – 1 fuel assembly
  - Accurate simulation of core outlet structures
- Observations
  - Uniform concentration in core region
  - Stratified concentration profile (gradient) in lower plenum
    - Requires high core concentration not expected in AP1000
  - Precipitation(1) observed at top of mixture (constant pressure)
  - Precipitation(1) throughout top of core (depressurization)
  - Precipitation(1) in lower plenum (high concentration solution dropping from core chilled by feedwater)

1. Precipitation occurred at boron concentration much greater than expected in AP1000

Post-LOCA Boric Acid Precipitation – APP-GW-GLR-110
Review of Existing Tests

Modified VEERA

- Small-scale – 1 fuel assembly
  - Accurate simulation of core inlet and outlet structures
- Observations
  - Precipitation(1) observed at top of mixture (constant pressure)
  - Precipitation(1) throughout top of core (depressurization)
  - Precipitation(1) in lower plenum (high concentration solution dropping from core chilled by feedwater)

1. Precipitation occurred at boron concentration much greater than expected in AP1000

Post-LOCA Boric Acid Precipitation – APP-GW-GLR-110
Review of Existing Tests

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Post-LOCA Boric Acid Precipitation – APP-GW-GLR-110
Conclusions

- Bulk precipitation not observed in system tests
- Localized precipitation observed in nearly all tests
  - Precipitation due to rapid evaporation (boiling) on heated structures above two-phase mixture level (uncovery)
    - This type of precipitation easily / rapidly went back into solution when fuel mixture level was recovered
  - No precipitation observed in single-phase region within heated core region
- Precipitation observed only under conditions not expected for AP1000
  - Core uncovery
  - High concentration/low temperature

Long Term Core Cooling
APP-PXS-GLR-001

Long-Term Core Cooling Analysis (APP-PXS-GLR-001, Rev 4)

- Primary Changes
  - Added sensitivity case #11 to evaluate impact of debris in core exit where there is a steam water mix
  - Revised words justifying why a DEDVI break in the loop compartment is more limiting than a break in a PXS room (per RAI SRSB-38)
  - Revised words justifying min time (9 hr)
  - Corrected core DPs for cases 4 – 9
    - Cases 3 and 10 did not change
  - Changed core resistance units to K/A^2 to allow for easy comparisons

Case #11

- Similar to Case 10
  - Same time (8.6 hr), break location (DEDVI next to RV), containment conditions, no screen DP
- Difference is that debris resistance moved to core exit
  - Allowable K/A^2 smaller because of impact of steam/water mix on DP (large 2 phase multiplier used)
  - Case allows for debris DP of 2.0 psi at core exit
  - Water flow into core inlet is 214.5 lbm/sec and the ADS 4 vent quality is 10%
    - [

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Case #11 Compared With Other Cases

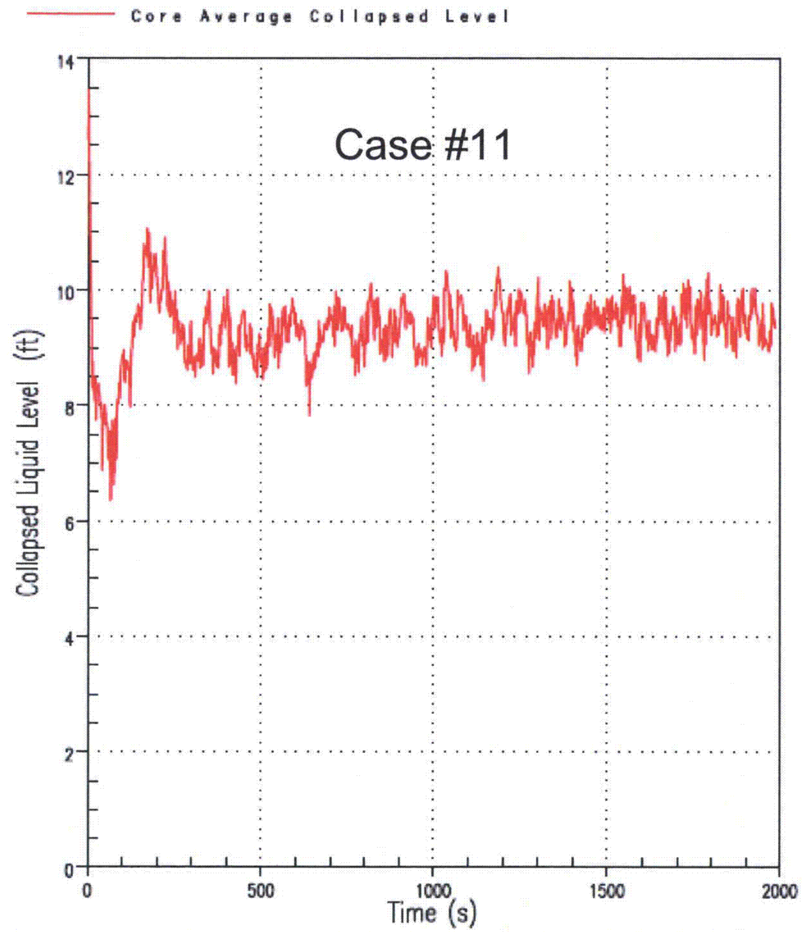
Table 4-1 AP1000 LTC Sensitivity Analysis With Added Debris Head Losses

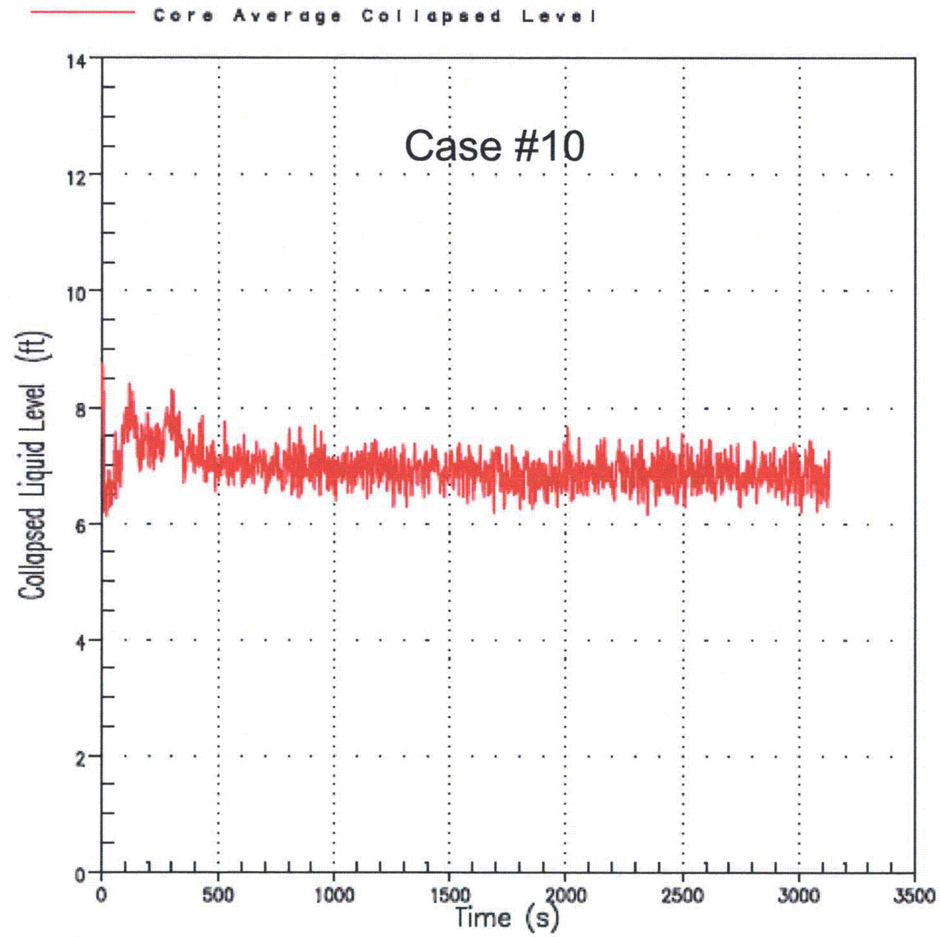
Case	LOCA	Time After LOCA (hr)	Added Resistance[1] Core (K/A²)	Added Resistance[1] Screen (K/A²)	Core Flow (lb/sec)	PXS A Flow (lb/sec)	PXS B Flow (lb/sec)	Core Debris DP (psi)	ADS 4 Quality	Max Core Boron Conc (ppm)
DCD	DEDVI PXS Rm	2.6	0.0	0.00	152.2	77.2	75.0	0.00	25%	4200
1	DEDVI PXS Rm	2.6	31.6	25.70	145.6	73.6	72.0	1.18	25%	4200
2	DEDVI PXS Rm	2.6	62.0	51.39	136.5	69.0	67.5	2.08	25%	4200
3	DEDVI PXS Rm	2.6	158.2	51.39	111.0	56.0	55.0	3.50	35%	4700
4	DEDVI PXS Rm	8.6	331.2	0.00	88.0	44.0	44.0	3.40	36%	4800
5	DEDVI PXS Rm	8.6	430.6	0.00	80.0	40.0	40.0	3.80	37%	4800
6	DEDVI RV	8.6	430.6	0.00	83.0	29.0	54.0	4.10	37%	4800
7	DEDVI PXS Rm	8.6	546.5	0.00	72.0	36.0	36.0	4.00	42%	5300
8	DEDVI RV	8.6	546.5	0.00	76.0	27.0	49.0	4.40	41%	5100
9	DEDVI RV	8.6	645.8	0.00	70.0	25.0	45.0	4.50	45%	5600
10	DEDVI RV	8.6	761.8	0.00	65.0	23.0	42.0	4.10	49%	6100
11	DEDVI RV	8.6	1.13	0.00	214.5	76.0	138.5	2.00	10%	3300

Notes:

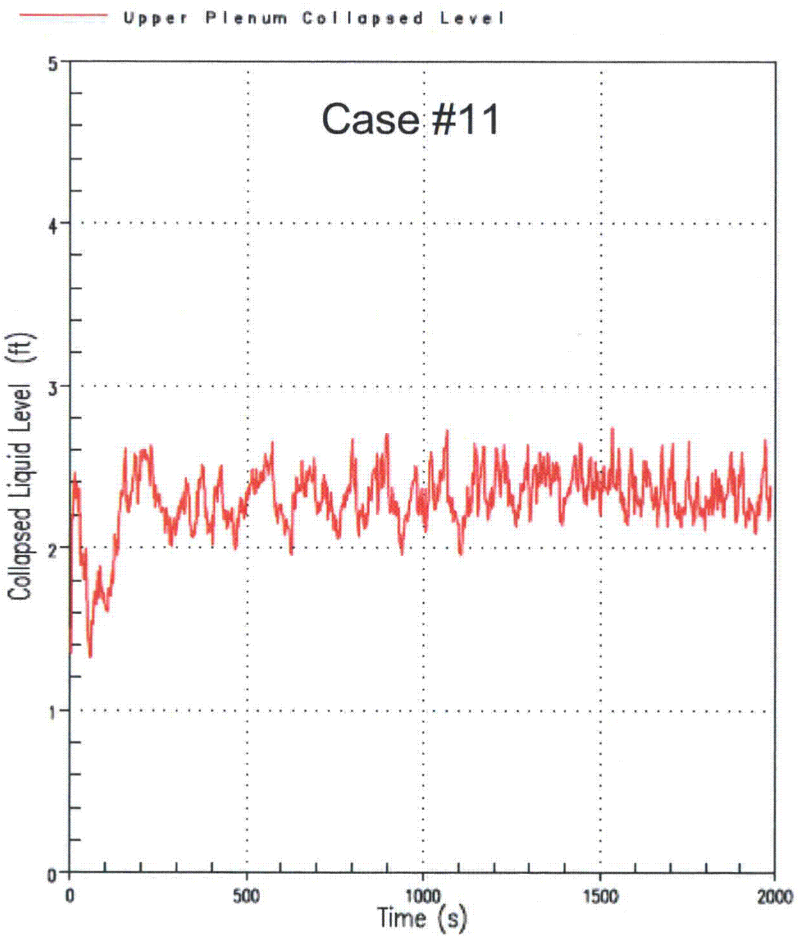
(1) The added flow resistances (K/A²) have units of ft⁻⁴.

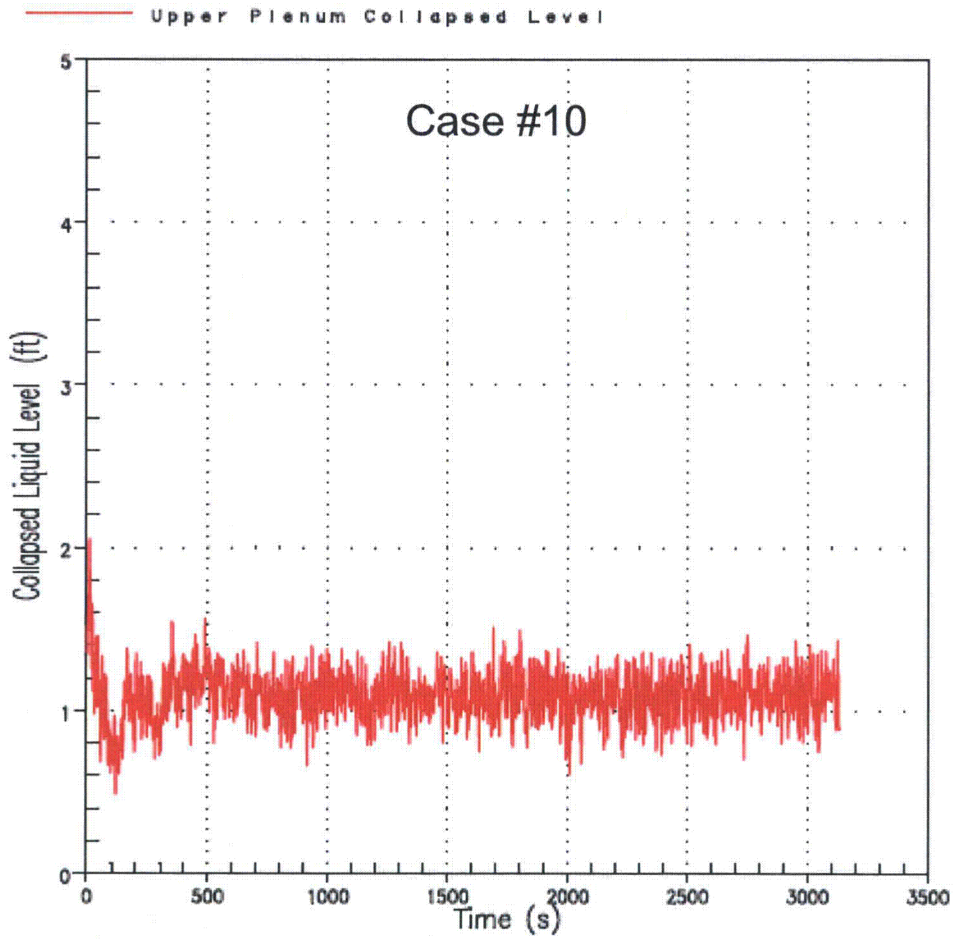
Collapsed Level of Liquid of Heated Length of Fuel (Case 11 vs 10)



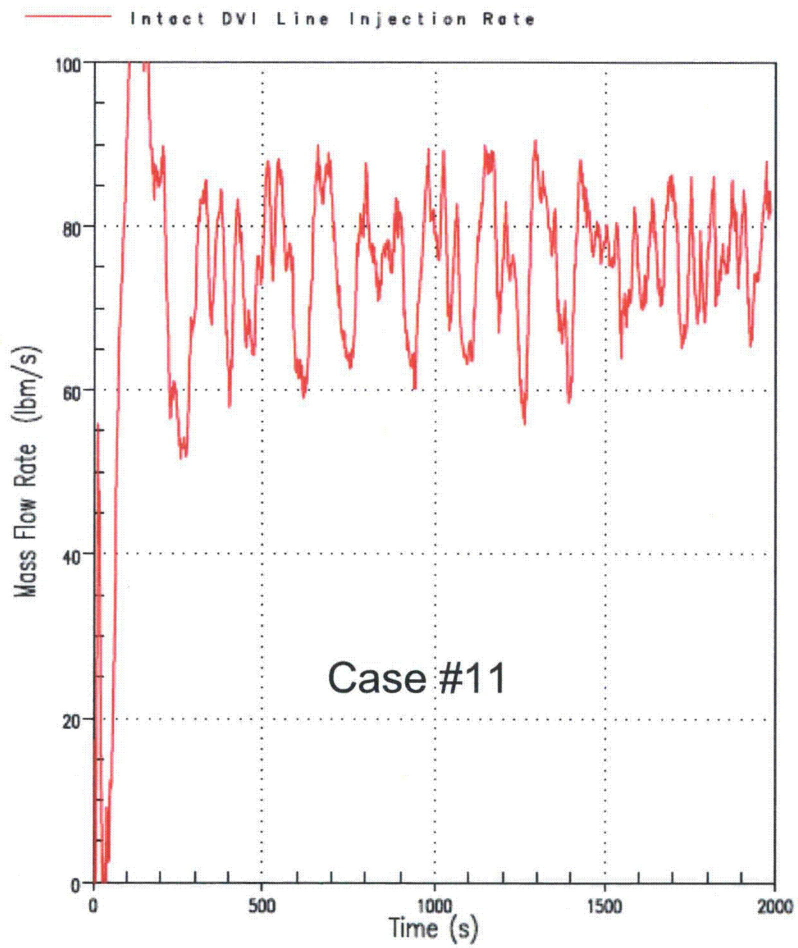


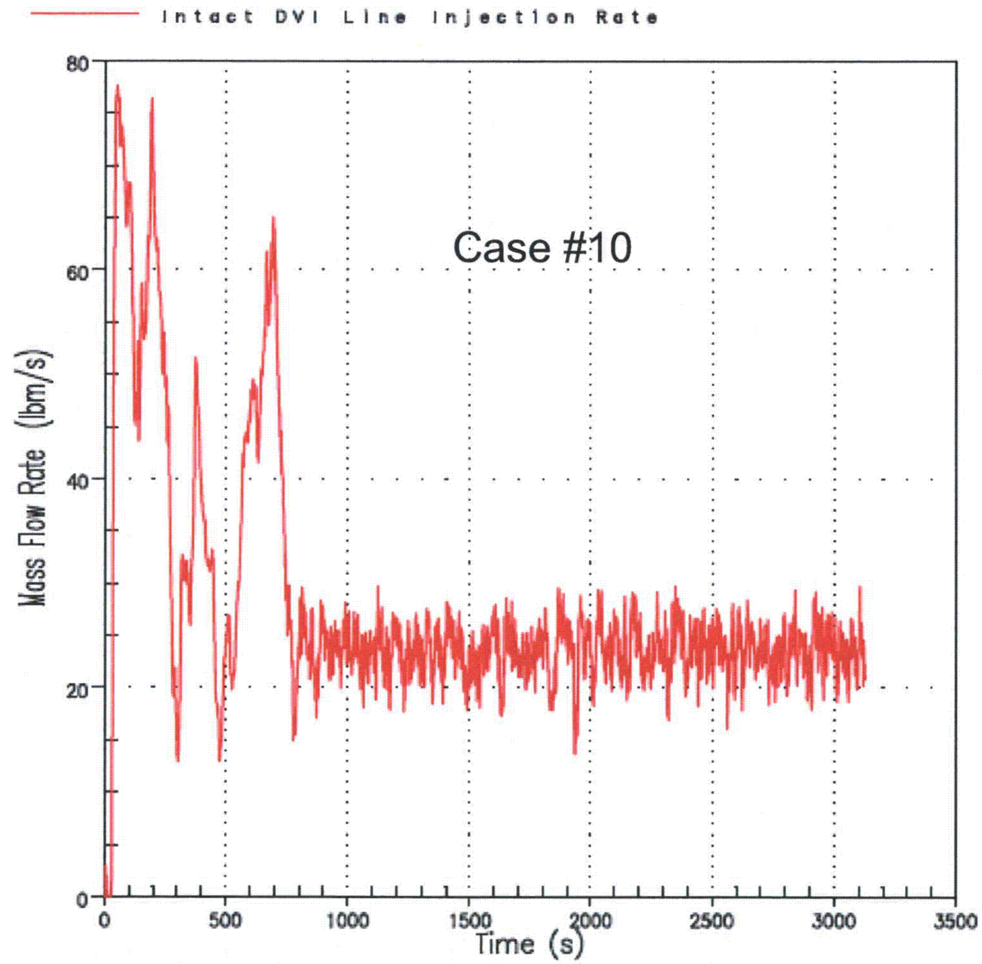
Collapsed Level of Liquid in Upper Plenum (Case 11 vs 10)



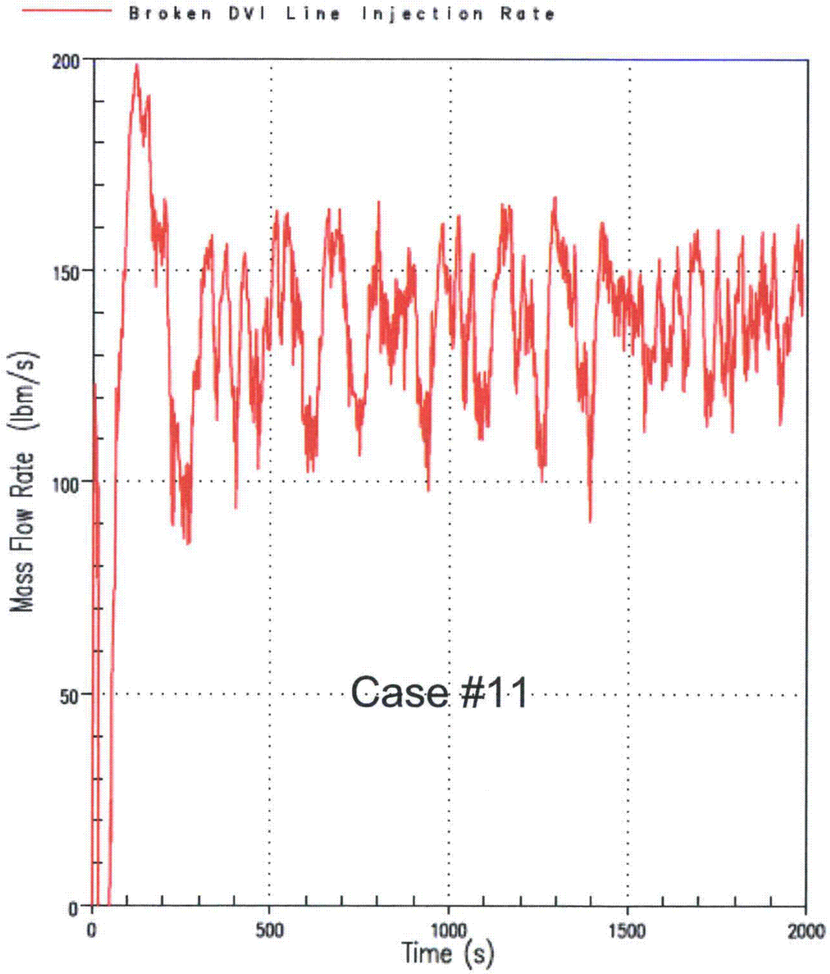


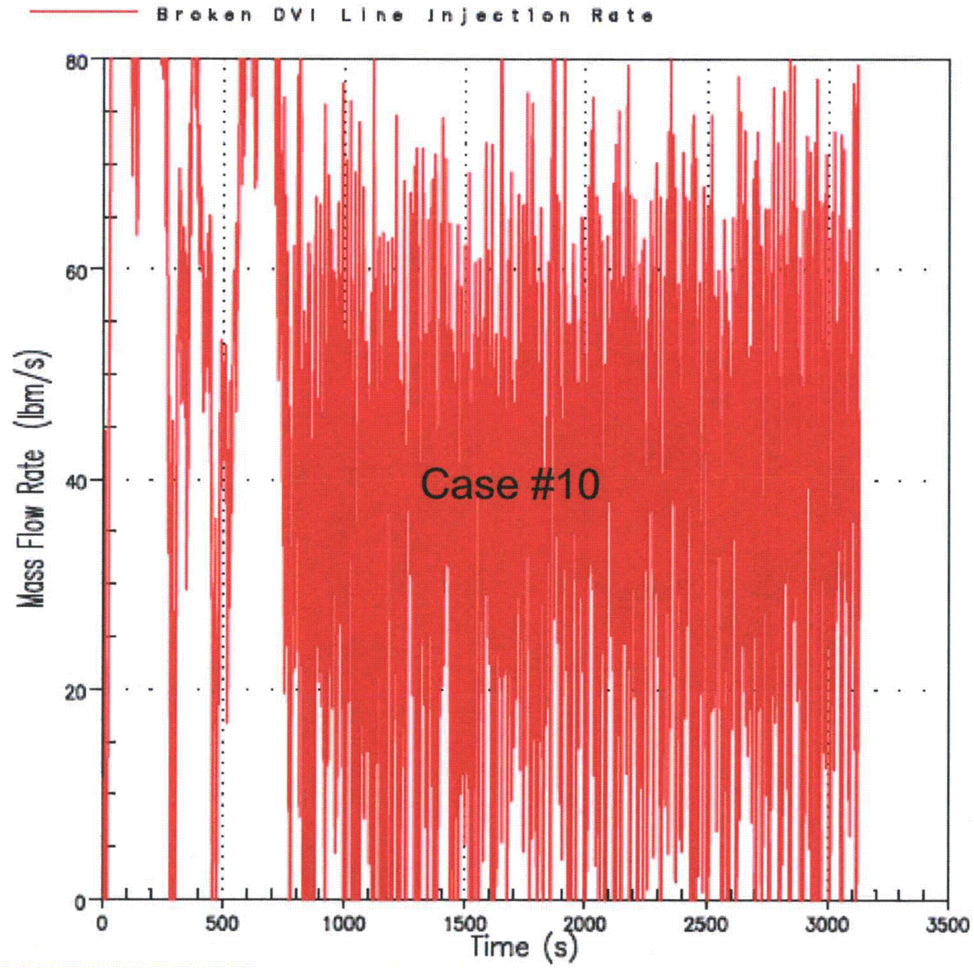
Flow Through DVI A Line, Intact (Case 11 vs 10)





Flow Through DVI B Line, Faulted (Case 11 vs 10)





Additional Technical Report Revisions

- WCAP-16914 – screen debris test report
- APP-GW-GLR-079 (TR-26) – summary overview
- APP-GW-GLE-002 – DCD/ITAAC changes

WCAP-16914-P, Revision 4
Screen Debris Test Report

- Screen flow rates were changed.
  - Maximum flow rate through IRWST and CR screens increased to 2320 gpm to account for maximum RNS flow rate.
  - Minimum flow rates changed:
    - IRWST screen minimum flow rate increased to 464 gpm [ ]a,c
    - CR screen minimum flow rate increased to 622 gpm [ ]a,c
  - Flow rates changed in:
    - Changes to Table 5-2 (max and min flow rates).
    - Discussed in Section 5.2 (max and min flow rates, as discussed in RAI-SRP6.2.2-SPCV-26, Rev. 1).
    - Changes to maximum flow rate in Appendix A Test Plan.
      - Updated in Section A.1.2.1, Table A-1, Table A-5.

WCAP-16914-P, Revision 4 Screen Debris Test Report (cont'd.)

- Head Loss Limit changed for screen tests WE213-4W and WE213-5W.
  - Changes to Table 6-1, Table 8-1.
  - Head loss limit related to increase in maximum screen design flow rates.
- Additional justification for the basis for the allowable DP across the screens.
  - Discussed in Section 5.2 (RAI-SRP6.2.2-SPCV-26).

WCAP-16914-P, Revision 4 Screen Debris Test Report (cont'd.)

- AlOOH Concentration Adjustment
  - Prior calculation error due to not accounting for mass of reaction byproducts. Prior values reported as concentration of AlOOH was actually concentration of total residual solids.
    - The concentration of AlOOH is 19.2% of this value. (responses to RAI-SRP6.2.2-CIB1-26 and RAI-SRP6.2.2-CIB1-27)
    - Changes to Table 7-2, Table 7-3, Table 7-6, Table 7-7.
    - Discussed in Section 7.2 and Section 7.4.
  - Added Appendix B "Boil-off Test Calibration" and Appendix C "Calculation of AlOOH Concentration from Boil-off Tests" to further explain how AlOOH concentrations were calculated. (response to RAI-SRP6.2.2-CIB1-26)
  - These changes were previously discussed with the NRC during several phone calls.

WCAP-16914-P, Revision 4
Screen Debris Test Report (cont'd.)

- Adjusted approach velocities for clean screen head loss tests based upon new maximum flow rates.
  - Changes to Appendix A Test Plan.
    - Discussed in Section A.1.2.1 and Table A-2.
- Typographical and editorial corrections.
  - Table 7-6: 81.12 g changed to 81.21 g (RAI-SRP6.2.2-SPCV-31)
  - Appendix B: 30.86 g changed to 300.86 g (RAI-SRP6.2.2-CIB1-26)
  - Total chemical debris intended for test WE213-2W and percentage of AlOOH added during the test corrected in Table 6-1 (RAI-SRP6.2.2-CIB1-27).

APP-GW-GLE-002, Revision 6 Summary of Changes

- Change to DCD Tier 1, Figure 2.2.3-1 to correct valve labels.
  - Valves on Train B immediately downstream of Containment Recirculation Sump B were incorrectly labeled in Revision 1 of APP-GW-GLE-002.
  - Valves labels are corrected in Revision 6.
- Change to DCD Tier 2, Section 6.1.3.2 in regards to Service Level II coatings (RAI-SRP6.1.2-CIB1-01).
  - COL Item added for Service Level II coatings.

APP-GW-GLE-002, Revision 6
Summary of Changes (cont'd.)

- Changes to DCD Tier 2, Section 6.3.2.2.7.1 related to:
  - Change to zone of influence (ZOI) for inorganic zinc coatings based upon discussions with NRC staff.
    - ZOI for inorganic zinc coatings changed from 5D to 10D.
    - ZOI for epoxy coatings remains at 4D.
    - ZOI coating debris remains at 50 lbm.
  - LOCA-generated coatings debris load (response RAI-SRP6.2.2-SPCV-25).
    - The basis of 50 lbm of coatings debris from within the ZOI is a DECL or DEDVI LOCA.
    - RAI response indicates that coatings debris load from with the ZOI of a DEHL LOCA could be higher, however screen head loss testing and fuel assembly head loss testing show that an increased particle load would not be limiting.

APP-GW-GLE-002, Revision 6 Summary of Changes (cont'd.)

- Changes to DCD Tier 2, Section 6.3.2.2.7.1 related to:
  - Chemical precipitate loading (response RAI-SRP6.2.2-SPCV-30).
    - Chemical precipitate loading was changed from ≤55 lbm to ≤57 lbm to agree with TR26 (APP-GW-GLR-079) and the chemical effects evaluation for the AP1000.
  - And discussion of screen design flows and RNS operation (responses RAI-SRP6.2.2-SPCV-26, Rev. 1 and RAI-SRP6.2.2-SPCV-28, Rev. 1).
    - Screen design flows updated to included maximum RNS flow needed to [ ][a,c] (explained in more detail in RAI responses).
    - Discussion in the paragraph following the design flows explains that the design flow rates account for both passive and active system operation.

APP-GW-GLR-079, Revision 7 (TR 26) Summary of Changes

- Document was reorganized and information added to make it a more complete AP1000 GSI-191 summary report.
- Three types of changes were made:
  - Editorial and re-arranging.
  - Addition of pre-existing information from documents submitted to NRC prior to January 2010.
  - Additions of newly developed information from GSI-191 documents submitted to the NRC in January-February 2010 .

APP-GW-GLR-079, Revision 7 (TR 26) Summary of Changes (cont'd.)

1. Document reorganization.
   - Sections organized by each area of GSI-191.
   - Wording modified and added for clarification.
2. Information added to report that was pre-existing information in other documents.
   - In order to present a complete summary of GSI-191 in TR26, pre-existing information from other documents (e.g. APP-PXS-GLR-001) was added.
   - This information is new as content in TR26 but it is not new in the AP1000 GSI-191 effort.

APP-GW-GLR-079, Revision 7 (TR 26) Summary of Changes (cont'd.)

3. Newly-developed information added to TR26.
   - New information developed in January-February 2010 to respond to NRC RAIs
   - For example:
     - Additional fuel assembly tests conducted (documented in WCAP-17028-P, Rev. 4).
     - Response RAI-SRP 6.2.2-SPCV-26, Rev. 1 regarding screen flow rates through CR and IRWST screens with RNS operating.
   - This type of new information will be discussed in more detail on the following slides.

APP-GW-GLR-079, Revision 7 (TR 26) Summary of Changes (cont'd.)

- Section 1 is a new introduction. None of the content is new to the GSI-191 effort.
- Section 2 – Debris Characterization
  - Section was reorganized.
  - Content was expanded with pre-existing information from other AP1000 GSI-191 documents.
  - Most significant changes are to Section 2.3.2 – Coatings Inside the LOCA Zone of Influence (ZOI).

APP-GW-GLR-079, Revision 7 (TR 26) Summary of Changes (cont'd.)

- Section 2.3.2 – Coatings Inside the LOCA ZOI
  - Diameter of the spherical ZOI for inorganic zinc coatings was changed from 5D to 10D to be consistent with NRC SER on NEI 04-07.
  - Discussion of LOCA ZOI debris from epoxy coatings was expanded to show conservatism in the calculation of debris from epoxy within the ZOI.
  - The inorganic zinc debris load from within the ZOI was increased from 10 lbm to 15 lbm, since the ZOI was changed to 10D.
  - The 50 lbm of total coatings debris generated within the ZOI is explained to be applicable to DECL and DEDVI LOCAs.
    - Additional particulate coatings debris could be generated from a DEHL LOCA.
    - However, an increased particulate loading has been shown to be not limiting in screen head loss testing and fuel assembly head loss testing.

APP-GW-GLR-079, Revision 7 (TR 26) Summary of Changes (cont'd.)

- Section 3 – Debris Transport
  - Minor changes made to discussion on debris transport to screens.
  - Most significant changes to Section 3.3 – Debris Transport to the Core.
    - The calculations for the flow split for a DEDVI LOCA were fine-tuned since the last revision of TR26. The ultimate percent flow split results remain the same.
    - The calculations for the flow split for a DECL LOCA are now shown in TR26. The assumption of 90% flow and debris from the flooded broken cold leg still stands and is bounding and conservative.
  - Also changed Section 3.3.4 – Minimum Time to Transport Debris to the Core.
    - Since additional fuel assembly testing was performed in January 2010, the results from testing are currently used to show that the time when the maximum resistance of the debris-bed is achieved, the time in the plant is much greater than the 9 hours assumed in long-term core cooling analyses.

APP-GW-GLR-079, Revision 7 (TR 26) Summary of Changes (cont'd.)

- Section 4 – Long-Term Core Cooling
  - This section was added to TR26 to show information and results from the long-term core cooling analyses.
  - Most of the information was pre-existing before January 2010 in APP-PXS-GLR-001, Revision 3.
  - New information includes:
    - Showing the resistances in the WCOBRA/TRAC model as K/A^2.
    - Showing results from Case 11, which include a debris-induced resistance and corresponding DP at the core exit.
    - A modified explanation of how the results of Case 3, Case 10, and Case 11 relate to acceptance criteria for long-term core cooling with debris-induced DP.

APP-GW-GLR-079, Revision 7 (TR 26) Summary of Changes (cont'd.)

- Section 5 – Ex-Vessel Downstream Effects
  - Reorganization of the screen testing and fuel assembly testing.
  - Ex-Vessel report section now encompasses the PXS and RNS component evaluations and the screen head loss testing.
  - New information added in two areas:
    - Section 5.1.2 – Screen Head Loss Testing.
    - Section 5.2.4 – AP1000 Refueling Cavity Drain Lines.

APP-GW-GLR-079, Revision 7 (TR 26) Summary of Changes (cont'd.)

- Section 5 – Ex-Vessel Downstream Effects
  - New information added in two areas:
    - Section 5.1.2 – Screen Head Loss Testing
      - This section now discusses the screen design flow rates with respect to a maximum RNS flow of 2320 gpm.
      - Detailed explanation provided in Response RAI-SRP 6.2.2-SPCV-26, Revision 1.
      - Explanation also included in WCAP-16914-P, Revision 4 and APP-GW-GLE-002, Revision 6.
    - Section 5.1.2 – Screen Head Loss Testing
      - Additional discussion on particulate debris load from coatings within the LOCA ZOI. A DEHL LOCA could generate more particulate than the 50 lbm assumed, however this is not limiting for screen head loss testing, since a fiber bed never formed.
    - Section 5.2.4 – AP1000 Refueling Cavity Drain Lines
      - Additional information added in response to RAI-SRP 6.2.2-SPCV-25 to explain why the plugging of these drain lines by MRI debris is not expected.

APP-GW-GLR-079, Revision 7 (TR 26) Summary of Changes (cont'd.)

- Section 6 – In-Vessel Downstream Effects
  - Reorganization of the screen testing and fuel assembly testing.
  - In-Vessel report section now encompasses fuel assembly head loss testing and fuel rod chemical deposition.
    - Major changes in Section 6.1 – Fuel Assembly Head Loss Testing.
    - Addition of Section 6.2.1 – Boric Acid and Trisodium Phosphate Evaluation.
    - Clarification of results in Section 6.2.2 – LOCADM Evaluation.

APP-GW-GLR-079, Revision 7 (TR 26) Summary of Changes (cont'd.)

- Section 6 – In-Vessel Downstream Effects
  - Section 6.1 – Fuel Assembly Head Loss Testing.
    - New discussion on January 2010 tests, which include a higher temperature test (with boric acid and TSP) and DEHL tests.
    - New discussion on non-uniform blockage of individual fuel assemblies and of the core.
    - New discussion that includes the results of the statistical evaluation of the tests (from APP-GW-GLR-092, Rev. 0).
    - As was added to Section 5.1.2 for screen testing, a discussion is shown explaining that the 50 lbm of particulate debris from coatings within the ZOI is acceptable, since the fuel test program showed that lower particulate loads are more limiting.
    - Please note that Table 6-1 (and Table 8-7 is a copy) includes values of the maximum adjusted DP at 9 hours in test time for the Maximum Adjusted DP (at 5.3 gpm). In WCAP-17028-P, Revision 4 (and response RAI-SRP 6.2.2-SRSB-29), the maximum adjusted DP values are calculated at 9 hours plant time. TR26 needs to be revised to reflect the appropriate values shown in the WCAP and the RAI response.

APP-GW-GLR-079, Revision 7 (TR 26) Summary of Changes (cont'd.)

- Section 6.1 – Fuel Assembly Head Loss Testing
  - The maximum adjusted DP shown in Table 6-1 and Table 8-7 related to LTC Case 3 acceptance criteria in TR26 needs to be updated.
  - Maximum adjusted DP values in Table 9-2 of WCAP-17028-P, Revision 4 are correct.

a,c

APP-GW-GLR-079, Revision 7 (TR 26) Summary of Changes (cont'd.)

- Section 6 – In-Vessel Downstream Effects (cont'd.)
  - Section 6.2.1 – Boric Acid and Trisodium Phosphate Evaluation.
    - New section added to summarize tests and results presented in APP-GW-GLR-110, Revision 0.
    - Ultimate conclusion is that deposition of boric acid on the fuel rods is not expected to occur post-LOCA in the AP1000.
  - Section 6.2.2 – LOCADM Evaluation.
    - Text added for clarification.
    - LOCADM results in Table 6-2 remain the same as they were in TR26, Revision 6.
    - Numerical results of LOCADM in the text preceding Table 6-2 were corrected, since they did not reflect Table 6-2 in TR26, Revision 6. The text and the table match in TR26, Revision 7.

APP-GW-GLR-079, Revision 7 (TR 26) Summary of Changes (cont'd.)

- Section 7 – Regulatory Impact. No change.
- Section 8 – Summary of Results.
  - New section with the objective of summarizing all GSI-191 evaluation results and showing acceptance criteria, where available.
  - Evaluations with acceptance criteria include:
    - Screen head loss testing. Passed.
    - PXS and RNS downstream effects evaluations. Passed.
    - Fuel assembly head loss testing. Passed.
    - Statistical analysis of core inlet debris-induced DP. Passed.
    - LOCADM fuel rod deposition. Passed.

APP-GW-GLR-079, Revision 7 (TR 26) Summary of Changes (cont'd.)

- Section 9 – References
  - Revision numbers of references were updated where appropriate.
  - New references added to support the content changes to TR26.

APP-GW-GLR-079, Revision 7 (TR 26) Roadmap of Licensing Basis

- Document was reorganized and information added to make it a more complete AP1000 GSI-191 summary report.
- The report is a comprehensive summary of the complete licensing basis for resolution of GSI-191 for AP1000.
- Provides a roadmap to detailed information contained in other documents.

Summary of WEC Recent Actions for Resolving GSI-191 for AP1000

- WEC provided responses to 24 RAIs issued by the NRC on 12/22/09.

- WEC submitted updates to five technical reports and generated two new reports which incorporate the RAI responses into the AP1000 containment debris design basis documents.

- Information that has been submitted is expected to provide the basis for the NRC to proceed with completing the Chapter 6 SER related to GSI-191.