U.S. NUCLEAR REGULATORY COMMISSION MEETING WITH THE PRESSURIZED WATER REACTOR OWNERS GROUP TO DISCUSS THE PWROG BORIC ACID PRECIPITATION PROGRAM

Wednesday May 11th, 2011

Introductions

- Thomas Heng, OPPD, PWROG Analysis Subcommittee Chairman
- Kurt Flaig, Dominion, PWROG Analysis Subcommittee Vice Chairman
- Kathleen Parrish, APS, PWROG Analysis Subcommittee Past Chairman
- Bob Schomaker, Areva, PWROG Project Office
- David Fink, Westinghouse, PWROG Project Manager
- John Ghergurovich, Westinghouse, ASC Management Sponsor
- Brett Kellerman, Westinghouse, LOCA Group
- Yongjae Song, Westinghouse, Nuclear Power Plants
- Dana Knee, Dominion
- Jim Andrachek, Westinghouse Licensing
- Michael Scarpello, AEP
- Salauddin Ahmed, Exelon Corporation

Agenda

1:00 - 1:05 pm	Introductory Remarks / Meeting Purpose and Objectives (All)
1:05 - 1:30 pm	Discussion of Boric Acid Precipitation Safety Significance (David Fink)
1:30 - 1:45 pm	PWROG Boric Acid Precipitation Program Status (David Fink)
1:45 - 2:15 pm	Technical Discussion of Completed Testing / PIRT Activities (Brett Kellerman) (Portions May be Closed)
2:15- 2:25 pm	Break
2:25 - 2:55 pm	Future Testing (Yongjae Song)
2:55 - 3:15 pm	Boric Acid Precipitation and GSI-191 Interfaces (David Fink)
3:15 - 3:50 pm	Licensee Perspective (Thomas Heng, OPPD)
3:50 - 4:00 pm	Closing Remarks and Opportunity for Public Comment

Meeting Purpose and Objectives

- Show basis for position that Post-LOCA boric acid precipitation is low safety significance
- Review project status toward development of an NRC-approved Evaluation Model for Long Term Core Cooling
- Update NRC staff on new technical insights
- Provide preview of Full Height Integrated Precipitation/ Transport/ Mixing Tests
- GSI-191 / Boric Acid Precipitation Interfaces
- Provide licensee feedback on recent LAR submittals

DISCUSSION OF BORIC ACID PRECIPITATION SAFETY SIGNIFICANCE

DAVID FINK, WESTINGHOUSE

Boric Acid Precipitation Safety Significance

- After a number of PIRT exercises that reviewed phenomena and current state-of-knowledge, no boric acid precipitation safety concerns were identified provided dilution measures are initiated in accordance with current plant operating procedures
- No significant safety issues were uncovered in previous or current testing
  - 1975 CE tests
  - MHI BACCHUS tests
  - Single Rod Boiling / Heat Transfer Tests
  - 3x3 Rod Bundle Boiling / Heat Transfer Tests

Safety Significance - 1975 CE Test

- Documented in report LOCA-75-127-P/NP (OG-11-136)
- Small scale facility studied post-LOCA buildup of boric acid in the reactor vessel
- Tests indicated *"no catastrophic effect associated with the post LOCA initiation of boric acid precipitation"*. The test report states the while the initial appearance of boric acid precipitation occurred 8 hours into the test, the heater rod cooling was not impaired even after 38 hours (the termination of the test). The test report also states that at the completion of the test (38 hours), *"Boron precipitation had completely enclosed the lower annulus, flow skirt and support plate regions and two-thirds of the heater core region. Boric acid buildup did occur in the steam venting pathway but at no time was venting impaired."*

Safety Significance - MHI BACCHUS Tests

- Summarized in WCAP-16317-P and further summarized in the Waterford EPU LAR (ML050400463)
- Large scale test facility studied post-LOCA buildup of boric acid in the reactor vessel
- Test facility representative of a typical Westinghouse 3-loop PWR
- Tests indicated that significant boric acid precipitation in the core would not occur for at least 24 hours after a large break LOCA

Safety Significance - Single Rod Boiling / HT Tests

- Documented in WCAP-17040-P/NP (OG-11-139)
- Considered boric acid and buffered boric acid
- Conclusions

  "Boiling channel tests further show that boric acid solutions and boric acid solutions buffered with sodium hydroxide, tri-sodium phosphate, or sodium tetraborate are capable of adequately cooling fuel rod at post-LOCA decay heat levels without precipitation in the boiling region . . ."

Safety Significance - 3x3 Rod Bundle Boiling / HT Tests

- Documented in WCAP-17360-P/NP (07/31/11)
- 3x3 reduced length bundle
- Considered boric acid and buffered boric acid with debris
- Conclusions/Observations support the position that boric acid precipitation is not a significant safety concern

Safety Significance - 3x3 Rod Bundle Boiling / HT Tests

Conclusions/Observations

- Unbuffered boric acid precipitates on cool surfaces in lower plenum at 5 hours in, but coolant flow to heated region is not impeded even at end of test (10 hours)
- Nucleate boiling heat transfer minimally impacted
- Bulk precipitation was not observed
- Early precipitation due to sump debris (impact on solubility) is not observed
- Debris deposition on fuel cladding is not observed
- Deposition (on unheated structures) above two phase mixture level was not observed
- Heat transport (and likely solute transport) to lower plenum was enhanced (occurs earlier) with the presence of debris

Boric Acid Precipitation Safety Significance - Summary

- At this point in the program, no boric acid precipitation safety concerns were identified provided dilution measures are initiated in accordance with current plant operating procedures

- Based on limited testing thus far, using debris loading limits from the GSI-191 program, sump debris does not appear to introduce new decay heat removal or precipitation concerns for post-LOCA boric acid buildup scenarios

PWROG BORIC ACID PRECIPITATION PROGRAM STATUS

DAVID FINK, WESTINGHOUSE

PWROG BAP Methodology Strategic Plan

- Objective - Use guidance in Reg Guide 1.203 to develop NRC-approved Evaluation Model
- Phase 1 - Evaluation Model Requirements and Assessment Base
  - ✓ Determine requirements for the evaluation model
  - ✓ Develop an assessment base consistent with the determined requirements
- Phase 2 - Evaluation Model Development and Adequacy Assessment
  - ✓ Develop the evaluation model
  - ✓ Assess the adequacy of the evaluation model
  - ✓ Follow an appropriate quality assurance protocol during the EMDAP
  - ✓ Provide comprehensive, accurate, up-to-date documentation

PWROG Boric Acid Precipitation Program Status

- Following Reg Guide 1.203 guidance, OG efforts are focused on identifying the important phenomena related to boric acid precipitation, and more fundamentally, identifying the nature of boric acid and other precipitates. This includes questions like. . .

Original Knowledge Gaps Regarding In-Vessel Precipitates Being Addressed by this Program

- ✓ What are the precipitation modes and mechanisms?
- ✓ Where are precipitates likely to form?
- ✓ What are the characteristics of the precipitates?
- ✓ How quickly do precipitates form and/or re-dissolve?
- ✓ What are the heat removal characteristics of concentrated solutions (prior to precipitation)?
- ✓ What are the consequences of precipitation in the various regions of the vessel?
- ✓ What is the effect of sump debris on the above?

Phase 1 - Evaluation Model Requirements and Assessment Base

- Includes PIRTs to identify significant phenomena
  - Boric Acid Solution PIRT
  - Buffered Boric Acid Solution PIRT
  - Buffered Boric Acid Solutions w/Debris PIRT
  - NRC Research Chemistry PIRT Review
- Includes Heat Transfer / Physical Properties Tests to increase state-of-knowledge and assessment base for highly concentrated solutions
- "Evaluation Model Requirements" Report ready to be submitted to NRC 3Q2011

Evaluation Model Development and Adequacy Assessment

- Includes full-height scaled mixing tests concurrent with NRC review of Phase 1 report. A PWROG project authorization is in progress to fund the development of test objectives, preliminary test apparatus design
- Design-specific evaluation model development to begin after NRC approval of Evaluation Model Requirements and Assessment Base
- Need for large-scale validation testing will not be determined until full-height scaled mixing tests are complete

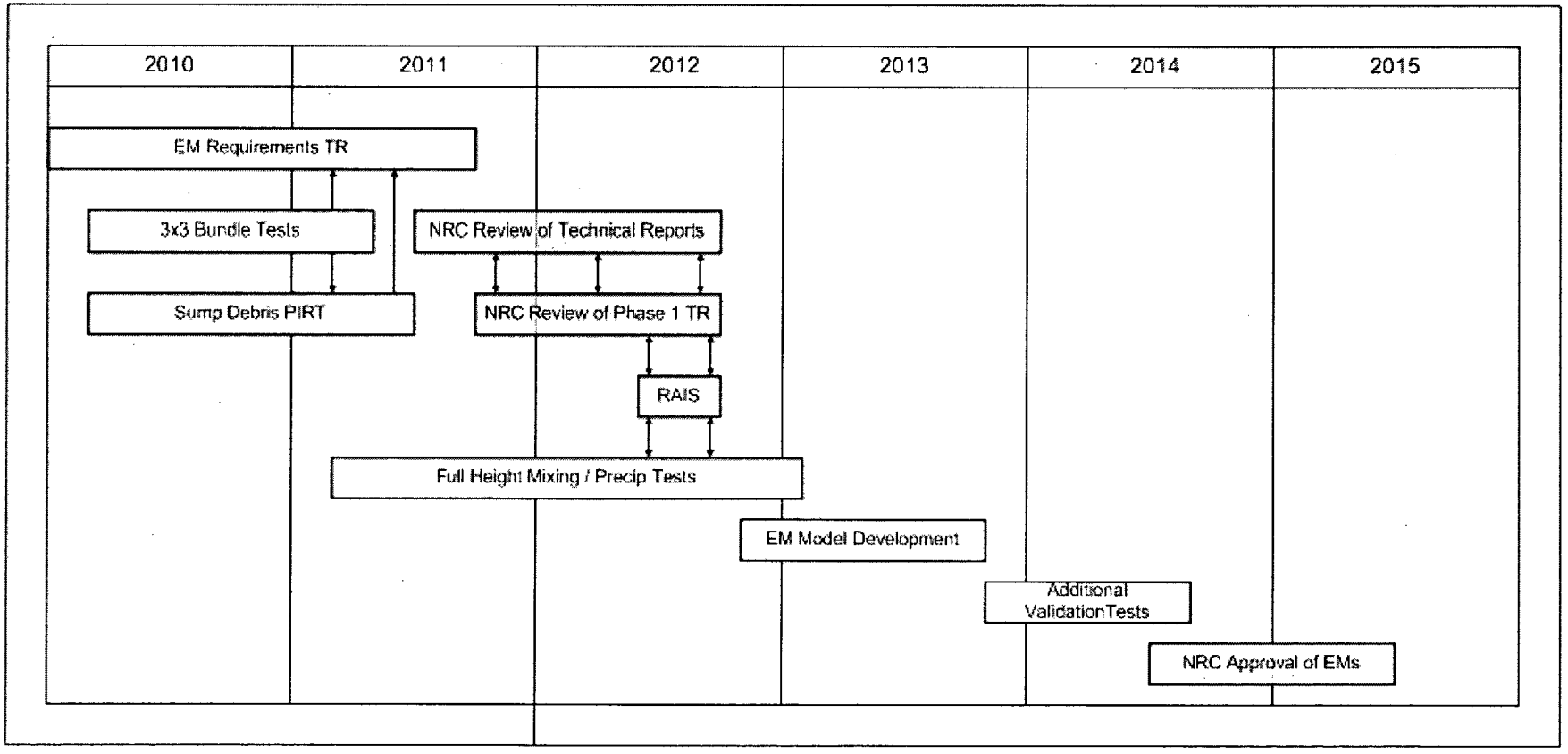
Supporting PWROG Technical Reports

1. WCAP-17047-NP PIRT, Buffered Boric Acid Solutions (OG-09-279)
2. WCAP-17040-P/NP, Single Rod, BA Boiling/Heat Transfer Tests (OG-11-139)
3. WCAP-17211-P/NP, Chemistry Issues and NRC Research PIRT Review (OG-11-140)
4. WCAP-17021-NP, BA Physical Properties Tests (OG-11-149)
5. WCAP-17360-P/NP, 3x3 Bundle, BA w/Debris Boiling / Heat Transfer and Physical Properties Tests (07-31-11)
6. WCAP-17272-NP PIRT, Boric Acid Solutions w/Debris (09-30-11)

Other Supporting Technical Reports

- LOCA-75-127-P/NP, 1975 CE Test Report (OG-11-136)
- MHI BACCHUS PWR Vessel Mixing Tests
- REWET-II
- VEERA
- Modified VEERA
- IVO Hydraulic Laboratory

PWROG BAP Methodology Strategic Plan



TECHNICAL DISCUSSION OF COMPLETED TESTING / PIRT ACTIVITIES

BRETT KELLERMAN, WESTINGHOUSE

PROPRIETARY PORTION OF THE MEETING

FUTURE TESTING

YONGJAE SONG, WESTINGHOUSE

Objectives

- Increase state-of-knowledge of the mixing / transport phenomena in the core and lower plenum in the presence of solutes and debris
- Increase state-of-knowledge of two-phase flow phenomena (instability, entrainment) in the presence of solutes and debris
- Determine the ability of sump solutions to provide adequate boiling heat transfer from a simulated fuel rod without irreversible precipitation /deposition in a boiling channel configuration

Design Features (Highly Ranked Phenomena)

- Mixing and Transport
  - Lower plenum and core transport
  - Lower plenum mixing process
  - Entrainment and de-entrainment (upper plenum)
  - Upper plenum and downcomer transport (via RVVV and or nozzle gaps?)
  - Lower plenum and downcomer mixing
- Precipitation and Debris
  - Boric acid and debris in core region, lower and upper plenum
- Core Region Phenomena
  - Core mixture level
  - Instability of core mixture level and flow
  - Sump debris behavior at core inlet and in the core
  - Power distribution effects
- Two-phase flow phenomena (flow regime, instability, entrainment)

Design Features (Test Section)

- General Features
  - Full height axial
  - 12 ft heated length
  - Power to be scaled based on decay heat
  - Capability to simulate loop pressure drop
  - Windows / sight glass where appropriate
  - Closed loop for mass and energy balance
  - Samples will be taken to analyze boric acid and debris concentration
- Makeup Feed
  - Gravity driven (natural circulation) flow to replace core boiloff
  - Downcomer makeup feed to simulate full downcomer and CL break
  - HL makeup feed to simulate hot leg/UPI injection
- Fuel Assembly (Bundle)
  - 4 x 34 rod array or similar arrangement (slab geometry)
  - Radial power distribution required
  - Axial power distribution will be considered

Other Considerations

- Test objectives to be fine-tuned after PIRT exercise is complete
- Currently potential vendors and capabilities are being evaluated
- Scaling study to be performed as part of preliminary design
- NRC staff will be have a chance to comment on the final design
- NRC staff will be invited to observe testing
- Eventually results from this test will be used to validate or modify PIRT rankings

GSI-191 / BORIC ACID PRECIPITATION INTERFACES

DAVID FINK, WESTINGHOUSE

GSI-191 / Boric Acid Precipitation Interfaces

	Boric Acid Precip Control		GSI-191	
	CL Break	HL Break	CL Break	HL Break
CORE REGION				
In-Core Precipitation	✓	NA	NA	NA
Fuel Rod Plate Out (<24 hours)	✓	NA	NA	NA
Fuel Rod Plate Out (>24 hours)	NA	NA	✓	✓
Heat Transfer Coefficient Degradation (<24 hours)	✓	NA	NA	NA
Heat Transfer Coefficient Degradation (>24 hours)	NA	NA	✓	✓
2-Phase Flow Regime Effects	✓	NA	NA	NA
In-Core Debris Accumulation Effect on Core Cooling	NA	NA	✓	✓
In-Core Debris Accumulation Effect on In-Core Mixing	✓	NA	NA	NA
Core Inlet Blockage Effect on Core Cooling	NA	NA	NL	✓
Core Inlet Blockage Effect on In-Core Mixing	✓	NA	NA	NA
LOWER PLENUM REGION				
LP Precipitation	✓	NA	NA	NA
LP Debris Accumulation	✓	NA	NA	NA
UPPER PLENUM REGION				
UP Precipitation	✓	NA	NA	NA
UP Debris Accumulation (with HL injection)	NA	NA	✓	✓

LICENSEE PERSPECTIVE

THOMAS HENG, OPPD

Licensee Perspective - Current Basis

- Assessments done in 2006 indicate current analyses (Duke responded separately) have margin to address NRC's significant methodology concerns (OG-06-200)
- Subsequent submittals have used interim methodology described in ML062690032 (Beaver Valley EPU, Waterford EPU, Crystal River)
- Current PWROG program schedule commensurate with perceived level of safety significance
- GSI-191 resolution is being addressed by in-vessel debris loading limits

Licensee Perspective - NRC Review Support

NRC Review Support

- Evaluation Model Requirements Topical Report target submittal in 3rd quarter 2011
- Supporting technical reports will be submitted prior to Evaluation Model Requirements Topical Report
- Appropriate technical disciplines (chemistry, PIRT, testing) are required to support proposed schedule (a multi-discipline approach)
- OG plans to pursue Fee Waiver for all Phase 1 reports

Licensee Perspective - NRC Expectations for Recent/Current Submittals

- Interpretation of interim methodology is not consistent
  - Varying interpretation of 50% of lower plenum contribution to mixing volume
  - Inconsistent results from NRC confirmatory analyses
- Analysis-of-Record Confusion
- Recent RAIs go beyond scope of interim methodologies
  - Containment condensation factor (2 recent submittals)
  - Core axial power shape
  - 1 hour extra margin for operator action
- LOCA long term cooling boric acid precipitation analyses being reviewed on unrelated submittals
  - BE LBLOCA Submittals
  - PWROG assessments (OG-06-200) are considered still valid for plants that have not changed their post-LOCA long term cooling analyses

Review of Meeting Purpose and Objectives

- Show basis for position that Post-LOCA boric acid precipitation is low safety significance
- Review project status toward development of an NRC-approved Evaluation Model for Long Term Core Cooling (Slide 21)
- Update NRC staff on new technical insights
- Provide preview of Full Height Integrated Precipitation/ Transport/ Mixing Tests
- GSI-191 / Boric Acid Precipitation Interfaces
- Provide licensee perspective on recent LAR submittals