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

Thursday November 18th, 2010

Westinghouse

U.S.NRC
UNITED STATES NUCLEAR REGULATORY COMMISSION
Protecting People and the Environment

AREVA

PWROG
PWR Owners Group

Introductions

- Peipei Chen, Westinghouse, LOCA Group
- David Fink, Westinghouse, Project Manager
- Rob Fournier, Westinghouse Windsor Systems Group
- John Ghergurovich, Manager, Westinghouse Windsor LOCA Group
- Brett Kellerman, Westinghouse, LOCA Group
- Kathleen Parrish, APS, PWROG Analysis Subcommittee Chairman
- Michael Scarpello, AEP, PWROG Licensing Subcommittee Rep
- Bob Schomaker, Areva, PWROG Project Office

Agenda

8:00 - 8:15 am	Introductory Remarks • PWROG Introductory Remarks • NRC Introductory Remarks • Meeting Purpose and Objectives
8:15 - 9:00 am	Program Status (David Fink) • Program Overview • Review of Progress toward developing Evaluation Model Requirements (Consistent with Reg Guide 1.204) • Schedule for Submitting an Evaluation Model Requirements TR
9:00 - 9:45 am	Technical Discussion • Review of Chemistry Issues/PIRT (Rob Fournier)
9:45 - 10:00 am	Break
10:00 - 10:45 am	Technical Discussion • Review of Recent Testing (Peipei Chen) • Sump Debris Solution Precipitation/PIRT (Brett Kellerman)
10:45 - 11:00 am	Open Discussion/Opportunity for Public Comment

Meeting Purpose and Objectives

- Reinforce PWROG commitment to develop post-LOCA boric acid precipitation control analysis methodology
- Review long term plans to achieve an NRC approved methodology(s)
- Review status of short term activities including schedule for TR submittal
- Update NRC staff on new technical insights
  - Debris solution Heat/Transfer and Boiling Tests
  - Concentrated Sump Debris Solution Chemistry Issues/PIRT
  - Sump Debris Solution Precipitation/PIRT
- Gain further NRC perspectives on interfaces between post-LOCA boric acid precipitation methodology development and GSI-191 resolution
- Fulfill commitment to meet regularly with the NRC staff

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PROGRAM OVERVIEW AND STATUS

DAVID FINK, WESTINGHOUSE

Background

- PWROG Boric Acid Precipitation Program began in 2004 as an initiative to address long-running NRC concerns over the various methodologies used to analyze post-LOCA boric acid buildup in the core for cold leg break scenarios.
- Issues were expanded with the issuance of an August 2005 NRC letter withdrawing approval of virtually all PWR boric acid precipitation methodologies.
- A follow-up letter was sent to the PWROG requesting licensees justify licensing basis analyses. PWROG provided the NRC a summary of the assessments that showed participating PWROG members' methodologies adequately address NRC main concerns

Background (cont'd)

- In August 2006, the staff agreed with plan to use interim methodologies until more definitive methods are developed
  - CE Plants to use Waterford EPU Approach
  - Westinghouse to use Beaver Valley / Ginna EPU Approach
  - B&W Plants to use CR3/DB Approach
- GSI-191 boric acid precipitation issues will be deferred to the PWROG boric acid precipitation methodology program

Regulatory Drivers

- August 2005 NRC letter withdrawing approval of virtually all PWR boric acid precipitation methodologies
- August 2006 NRC/PWROG agreement on interim methodologies pending PWROG development of a new evaluation model
- Unresolved GSI-191 boric acid precipitation issues

PWROG BAP Methodology Strategic Plan

- Objective - Use guidance in Reg Guide 1.203 to develop NRC-approved Evaluation Model
- Basic Principles of Reg Guide 1.203 (Evaluation Model Development and Assessment Process)
  - ✓ Determine requirements for the evaluation model
  - ✓ Develop an assessment base consistent with the determined requirements
  - ✓ 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 BAP Methodology Strategic Plan (cont'd)

- 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

Phase 1 (In Progress)

- Includes PIRTs to identify significant phenomena
  - Boric Acid Solution PIRT (Complete)
  - Buffered Boric Acid Solution PIRT (Complete)
  - Buffered Boric Acid Solutions w/Debris PIRT (In Progress)
  - NRC Research Chemistry PIRT Review (Pending)
- 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 2Q2011

Phase 2 (Planned)

- Support NRC approval of "Evaluation Model Requirements" Report
- 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 Phase 1
- Need for large-scale validation testing will not be determined until after Phase 1 report is submitted for approval and full-height scaled mixing tests are complete

Phase 1 Report

PHASE 1 REPORT REFERENCES AND TECHNICAL BASIS

PIRTs

- Unbuffered/Buffered BA Mixing/Transport (WCAP-17047-NP)
- Unbuffered/Buffered BA Precip Mode (WCAP-17047-NP)
- Buffered BA w/ Debris (WCAP-17272-NP)
- Sump Debris Chemistry Effects (WCAP-17211)

PWROG TESTS

- Concentrated Buffered BA Physical Prop Tests (WCAP-17021-NP)
- Unbuffered / Buffered BA Boiling HT Tests (WCAP-17040-P)
- Buffered BA w/ Debris Boiling HT Tests (WCAP-xxxxx)
- Concentrated BA/Debris Physical Prop Tests (WCAP-xxxxx)

OUTSIDE TESTS

- CE Tests (1976) — VEERA
- MHI BACCHUS — Modified VEERA
- REWET-II — IVO Hydraulic Laboratory

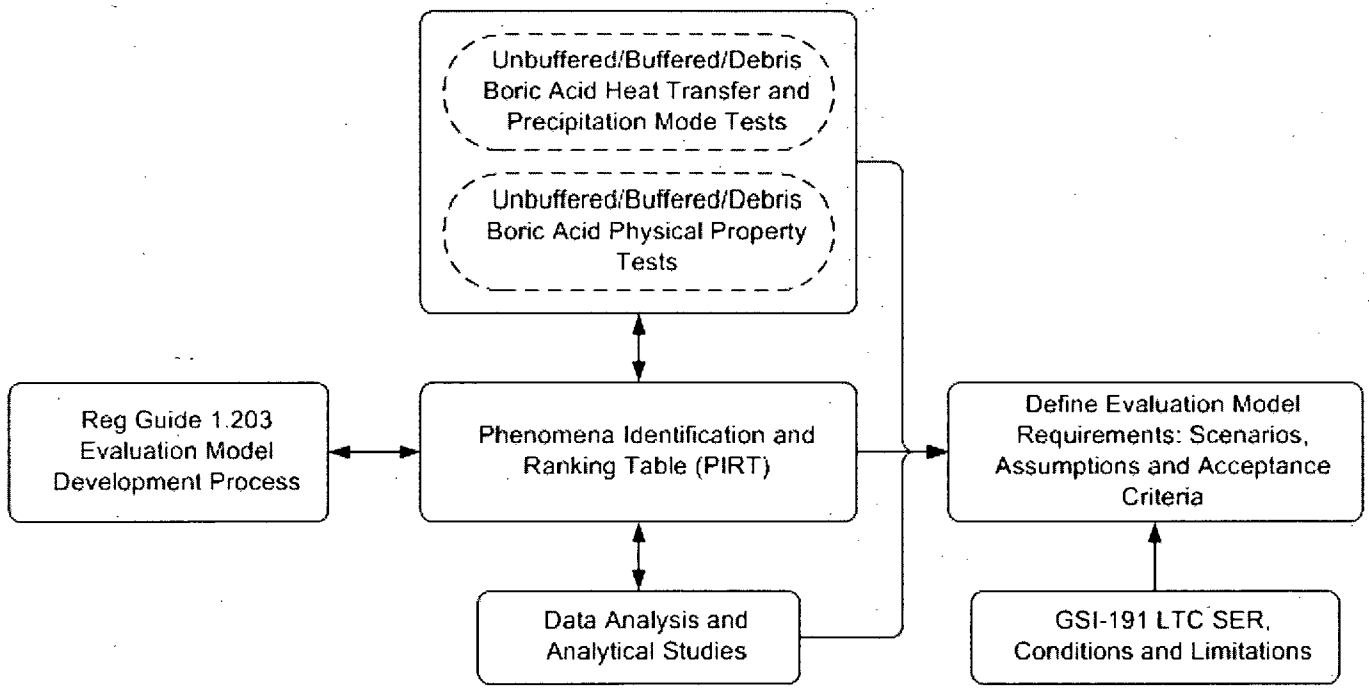
OTHER

- CFD Analytical Studies
- Misc Assessments/Evaluations

PHASE 1 REPORT

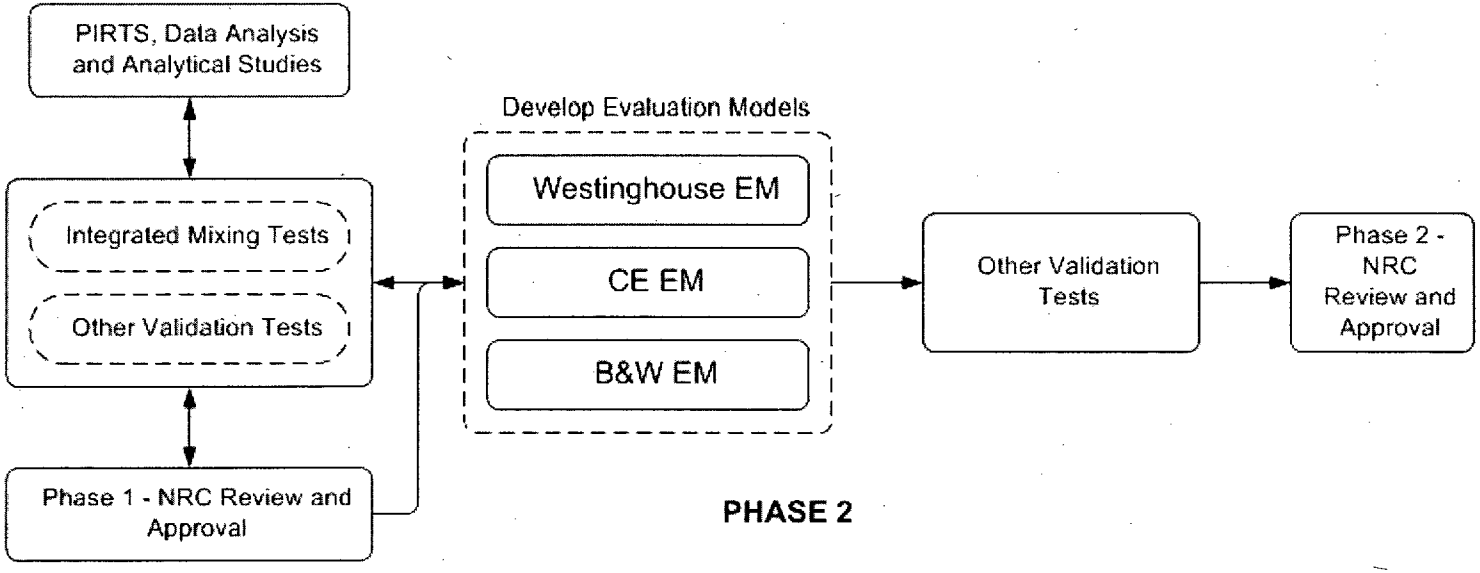
Post-LOCA Long Term Cooling Boric Acid Control Analyses - Evaluation Model Requirements: Scenarios, Assumptions and Acceptance Criteria (WCAP-16910)

PHASE 1 Scope

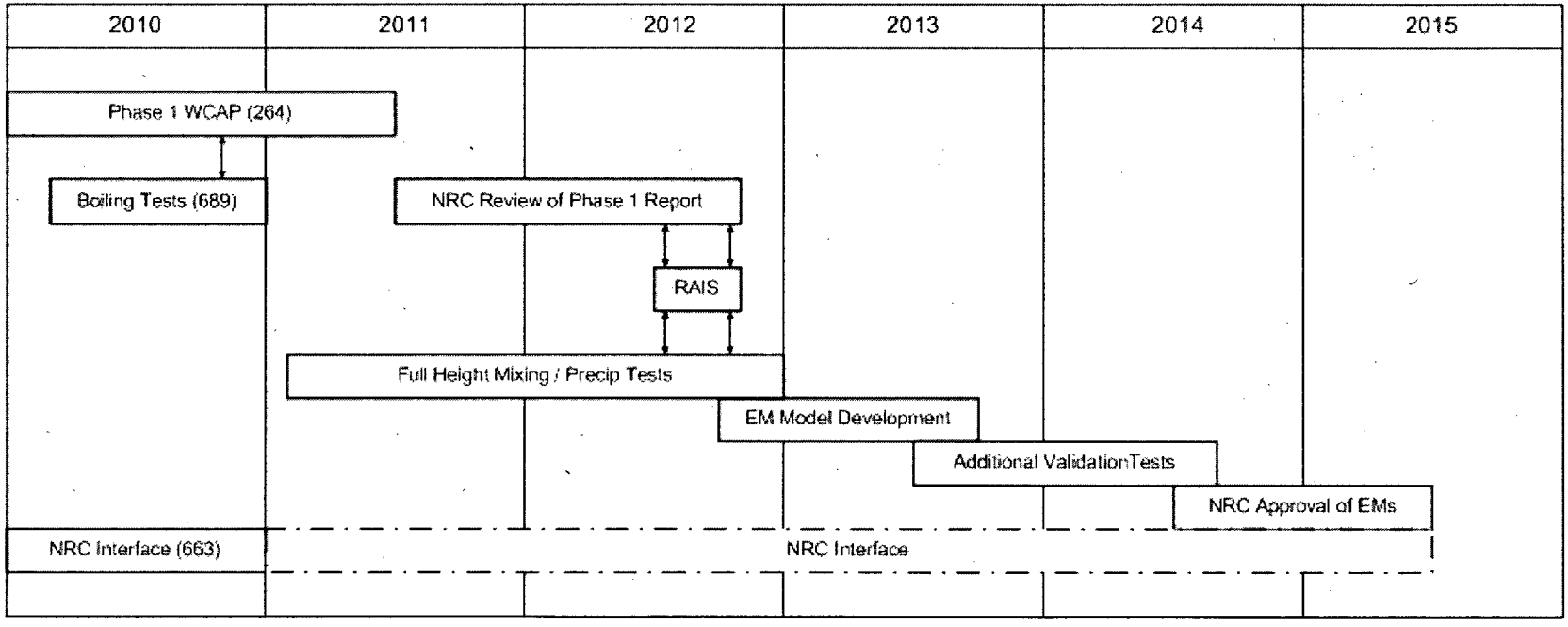


PHASE 1

PHASE 2 Schedule



PWROG BAP Methodology Strategic Plan



Implementation of New Methodologies

- The implementation plan for new methodologies will likely be determined by the results of demonstration analyses that will be included in the design-specific evaluation model reports
- If the demonstration analyses indicate the interim methods currently in place are conservative as compared to the new methodologies, implementation would be on a forward-fit basis, driven by plant changes that affect boric acid precipitation control (Upratings, Tech Spec RWST/Accumulator boron increases, etc.)
- If the demonstration analyses indicate the interim methods currently in place are not conservative as compared to the new methodologies, the scheduled reanalysis may be required

In-Vessel Precipitation and Chemical Effects

Downstream impact of chemical effects associated with GSI-191 on boric acid precipitation methodology development.

Highlights from WCAP-17211

Presented by: Robert Fournier

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Purpose

- Review NUREG-1918
  - Precipitation Perspective
    - Time frame
    - Concentration
- Establish State of Knowledge
  - WEC / PWROG testing
  - GSI 191 research
- Evaluate Deltas
  - Relevance
  - Importance
- Reconcile
  - Next steps
  - Additional testing

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Chemical Sources

- Identify contributors
- Containment
  - Debris
  - Corrosion products
  - Atmospheric gases
- Reactor Coolant
  - Boric Acid
  - Buffering Agent

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Recirculating Coolant Makeup

- Dissolution
  - Aluminum, Calcium and Silicon
- Debris (GSI 191)
  - Chemical, particulate, fibrous
- High concentration species
  - Boric acid
  - Sodium borates
  - Sodium phosphates (for TSP plants)

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Reactions

- Reaction Types
  - Precipitation
  - Deposition
  - Complexation
  - Degradation
  - Corrosion
  - Biological Growth

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Precipitation

- Solubility limit
  - Temperature
  - Flow
  - pH ((Un-buffered vs. Buffered)
- Locations
  - Lower plenum
  - Collapsed two-phase water level
  - Heat exchange sites

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Deposition

- Impact
  - Fuel Coolability
    - Flow
    - Fuel geometry
  - Corrosion
  - Deposition rate

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Coolant Properties

- Concentrated solution
  - Un-buffered and buffered boric acid
  - Current property testing shows solutions are neutral or improved as compared to water for heat removal
- Other chemical contributions
  - Low concentration and no impact on analysis model
- Existing boric acid solubility limits, based on existing test data, are conservative

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Modeling Concerns

- Thermal Hydraulic Effects
  - Thermal Gradients
  - Coolant Characteristics
  - Decay Heat Removal
  - Flow Geometries
- Precipitation/Deposition
  - Limiting Deposition
  - Input from GSI-191
  - Limiting Boric Acid and Sodium Borate Solubility

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Parameters

- Applicable time period
- Limiting sump debris and chemical loads
- Buffering agent
- Post-accident concentrations
- Temperature and pH data
- Vessel mixing profiles

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Conclusions

- Boric acid and buffering agents predominate
- GSI 191 derived chemical loadings may provide limited secondary effects
  - Low concentration
    - Deposition or maintained solubility (tests)
- Existing test data indicates no degradation in coolant heat removal capability for chemical effects

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Recommendations

- Full height vessel mixing tests (as planned)
- Parallel testing
  - Effects of sump chemical and particulate debris
- Limiting loading (critical assumption) per GSI-191 considering this comes from an expanded time frame

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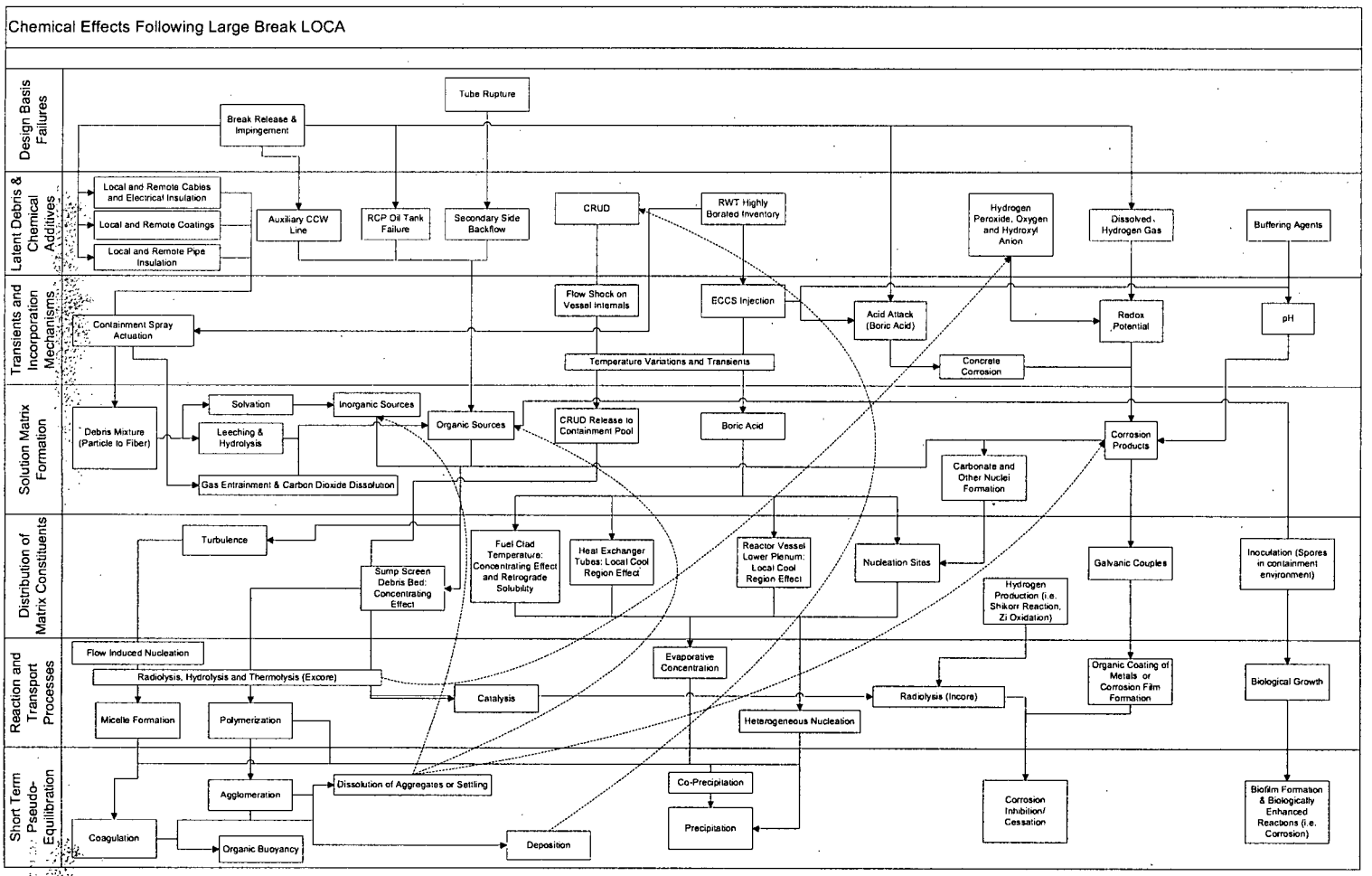
Chemical Effects Following Large Break LOCA
Design Basis Failures
Latent Debris & Chemical Additives
Transients and Incorporation Mechanisms
Solution Matrix Formation
Distribution of Matrix Constituents
Reaction and Transport Processes
Short Term Pseudo-Equilibration
Tube Rupture
Break Release & Impingement
Local and Remote Cables and Electrical Insulation
Local and Remote Coatings
Local and Remote Pipe Insulation
Auxiliary CCW Line
RCP Oil Tank Failure
Secondary Side Backflow
CRUD
RWT Highly Borated Inventory
Hydrogen Peroxide, Oxygen and Hydroxyl Anion
Dissolved Hydrogen Gas
Buffering Agents
Flow Shock on Vessel Internals
ECCS Injection
Acid Attack (Boric Acid)
Redox Potential
pH
Containment Spray Actuation
Temperature Variations and Transients
Concrete Corrosion
Solvation
Inorganic Sources
Debris Mixture (Particle to Fiber)
Leeching & Hydrolysis
Organic Sources
CRUD Release to Containment Pool
Boric Acid
Corrosion Products
Carbonate and Other Nuclei Formation
Gas Entrainment & Carbon Dioxide Dissolution
Turbulence
Sump Screen Debris Bed: Concentrating Effect
Fuel Clad Temperature: Concentrating Effect and Retrograde Solubility
Heat Exchanger Tubes: Local Cool Region Effect
Reactor Vessel Lower Plenum: Local Cool Region Effect
Nucleation Sites
Hydrogen Production (i.e. Shikorr Reaction, Zi Oxidation)
Galvanic Couples
Inoculation (Spores in containment environment)
Flow Induced Nucleation
Radiolysis, Hydrolysis and Thermolysis (Excore)
Evaporative Concentration
Catalysis
Radiolysis (Incore)
Organic Coating of Metals or Corrosion Film Formation
Biological Growth
Micelle Formation
Polymerization
Heterogeneous Nucleation
Agglomeration
Dissolution of Aggregates or Settling
Co-Precipitation
Coagulation
Organic Buoyancy
Deposition
Precipitation
Corrosion Inhibition/ Cessation
Biofilm Formation & Biologically Enhanced Reactions (i.e. Corrosion)

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Boric Acid Precipitation Analysis Methodology: Phenomena Identification and Ranking Tables with Consideration of Moderate to High Levels of Debris

Technical Update
November 18, 2010

Topics

- PIRT Roadmap
- Impact of Debris on Existing Figures of Merit
- New/Revised Phenomena Related to Debris
- Additional Figure of Merit

PIRT Roadmap

- WCAP-16745-NP, "Phenomena Identification and Ranking Table (PIRT) for Unbuffered Boric Acid Mixing/Transport in Reactor Vessel During Post-LOCA Conditions"
- 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"
- WCAP-17272-NP (In Progress), "Phenomena Identification and Ranking Tables (PIRT) for Un Buffered/Buffered Boric Acid Mixing/Transport and Precipitation Modes in a Reactor Vessel in the Presence of Fibrous, Particulate, and Chemical Debris during Post-LOCA Conditions"

PIRT Roadmap

WCAP-16745-NP
- Boric acid only

WCAP-17047-NP
- Boric acid
- Boric acid + buffer
- Low debris (normal impurities)
- Supercedes* WCAP-16745-NP

WCAP-17272-NP (In Progress)
- Boric acid + debris
- Boric acid + buffer + debris
- High level of debris (GSI-191)
- Supercedes* WCAP-16745-NP
- Likely will supercede* WCAP-17047-NP

* Supercedes but does not invalidate

Impact of Debris on Existing Figures of Merit

- Transport and Mixing PIRT
  - Debris 'bed' could be equivalent to increased hydraulic resistance
  - Separate effect tests suggest 'bed' may not be continuous if formed at all
- Precipitation Modes PIRT
  - Relative importance of precipitation modes not expected to change
  - No observation of 'bulk' type precipitation at high debris level

New/Revised Phenomena Related to Debris

- Transport and Mixing PIRT
  - Transport/mixing due to static/dynamic instabilities in two-phase natural circulation
  - Secondary circulation due to two-phase flow regime transition
- Precipitation Modes PIRT
  - No new phenomena

Additional Figure of Merit

- Two-Phase Mixture Level in the Inner Reactor Vessel

  Impacted by system effects

  Impacted by fluid properties

  Sustained core uncovery at high boric acid/chemical debris concentrations may lead to problematic deposition/precipitation effects (to be considered in full height testing)