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

U.S. EPR Containment Sump

July 8th Public Meeting

U.S.NRC

Topics

- NRO Review Update
- Baseline Evaluation
  - Generation
  - Transport
- Head Loss Testing
- Upstream Effects

NRO Update

- Phase One review is complete
  - over 100 questions generated
- Phase Two review in progress
  - 95% of Phase One questions have responses, remainder due in December 2009
    - All responses have been reviewed and the NRC estimates half of the responses require additional justification to support a reasonable assurance conclusion
  - Audit raised questions with head loss testing
  - Follow-up questions issued on baseline evaluation and head loss testing
  - Awaiting chemical and downstream effects plan and schedule

Generation

Additional information required in the following areas:

- Break Selection
  - Describe and provide basis for break selection criteria
  - Provide basis for break location that presents greatest challenge
    - Consider variations in amount, type, transport and combinations
- Debris Generation and ZOI
  - Justify ZOI selection for U.S. EPR
  - Demonstrate that spherical ZOI is appropriately applied
    - Assess if fragile materials are installed just outside the spherical boundary that would likely be damaged in LOCA
  - Provide destruction ZOIs and basis for ZOIs for each source
  - Discuss types and amounts of insulation used in containment, especially in and around postulated break locations

Generation (cont.)

- Debris Source Term
  - Specify types and amounts of debris
    - insulation (fiber, particulate, RMI)
    - latent
    - coating
    - chemical
- Debris Characteristics
  - Define size distribution for each type of debris
  - Provide bulk and material densities
  - Provide specific surface areas

Generation (cont.)

- Latent Debris
  - Justify methodology used to estimate quantity, composition
  - Provide basis for assumptions used in evaluation
  - Provide amounts and physical data (density, surface area)
  - Discuss treatment and/or controls in place for miscellaneous debris i.e. signs, labels and placards
  - Discuss performance criteria within COL Item on containment cleanliness program
- Coatings Debris
  - Specify and justify the coatings ZOI and amount of coatings
  - Provide debris characteristics of coating material
  - Discuss use of unqualified coatings (anywhere in containment)
  - Discuss treatment of equipment coatings

Transport

Apparent discrepancies in docketed correspondence

- FSAR states all dislodged material is transported to IRWST and is assumed to accumulate on one strainer
- RAI responses appear to indicate that all debris transports to one strainer, except that which is captured by the retaining basket or settles out in the tank
  - Reconcile potential conflict between FSAR and RAI responses
  - Justify credit taken for debris settling

Head Loss Testing

- Justification required for the following items (for all-inclusive listing see RAI 06.02.02-30)
  - Particulate amounts appear non-conservative (microporous and coatings)
  - Fiber amount is very large – non prototypical
  - Latent debris amount, type and sizing inconsistent with guidance
  - Scaled flow during testing is non-conservative (too low)
  - Weir height during testing is non-conservative (too high)
  - Chemical debris not tested

Head Loss Testing (cont.)

- Debris sequencing appears to be inconsistent with guidance – homogenous mixture versus incremental batches
- Head loss not extrapolated out to mission time
- Demonstrate retaining basket filtration performance over mission time and with varying load combinations
- Demonstrate flow conditions (velocities and turbulence) simulated in the strainer head loss test flume are prototypical or conservative with respect to the plant conditions

Upstream Effects

- Limited discussion in FSAR
- Document evaluation approach and provide hold-up volumes in FSAR
- Provide basis for concluding that the water inventory required to ensure adequate ECCS recirculation would not be held up or diverted by debris blockage at chokepoints in sump return flowpaths
- Describe how drain paths such as refueling and reactor cavity drain lines are protected from potential debris blockage


AREVA

AREVA

U.S. EPR Sump Performance Strategy

Sandra Sloan
Manager, Regulatory Affairs
New Plants
AREVA NP Inc.

Rockville, MD
July 8, 2009

EPR

Introduction

- **Objective:**
  - Continue a series of interactions to keep NRC apprised of AREVA's approach and progress toward addressing RAIs related to GSI-191
- **Background:**
  - Technical Report ANP-10293, "U.S. EPR Design Features to Address GSI-191"
  - RAIs:
    - Batches 32, 90, 111, 191, 233, 242
    - Related RAIs
  - Audits:
    - April 22-23, 2009
    - June 10 and 23, 2009

U.S. EPR Sump Performance Strategy

Fred Maass
Manager
AREVA NP Inc.

EPR

Meeting Agenda

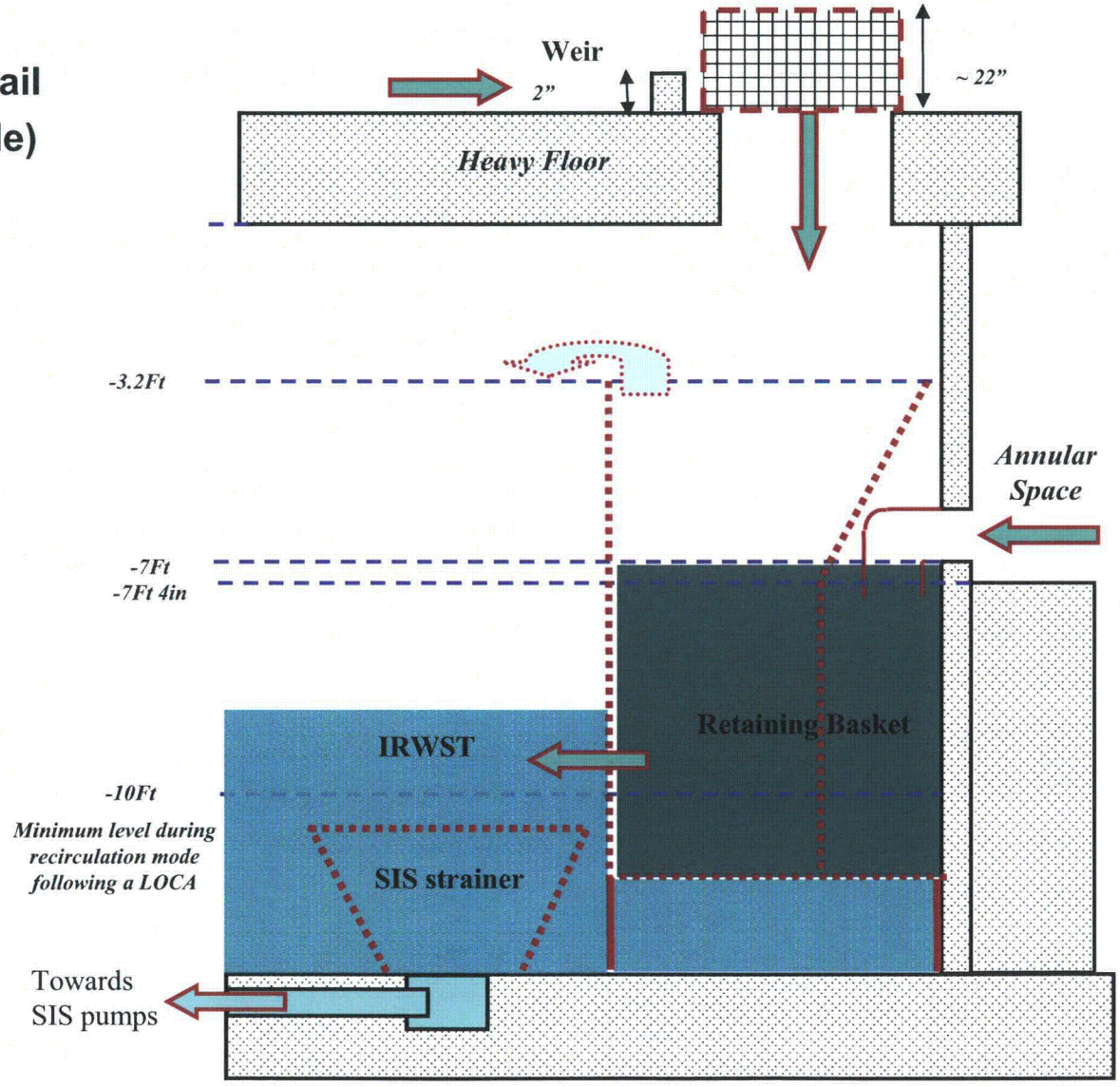
- > Overview: approach to GSI-191 for U.S. EPR design
- > Debris generation methodology
- > Strainer head loss testing
- > Chemical and upstream effects
- > Downstream effects external / in vessel

Introduction

- Overview: approach to GSI-191
  - Plant sump performance strategy
  - Testing performed
  - Plant design features that improve performance

Sump Performance Strategy

Design Detail
(not to scale)



Sump Performance Strategy

- Insulation material
- Four protective weir / trash rack structures
- Four retaining baskets in the IRWST
- Large area, low flow velocity region within the IRWST
- Four large surface area three-dimensional flat screen sump strainers in the IRWST
- The key to the defense-in-depth strategy is the retaining basket
  - Key barrier that collects debris
  - Large surface area

Defense in depth

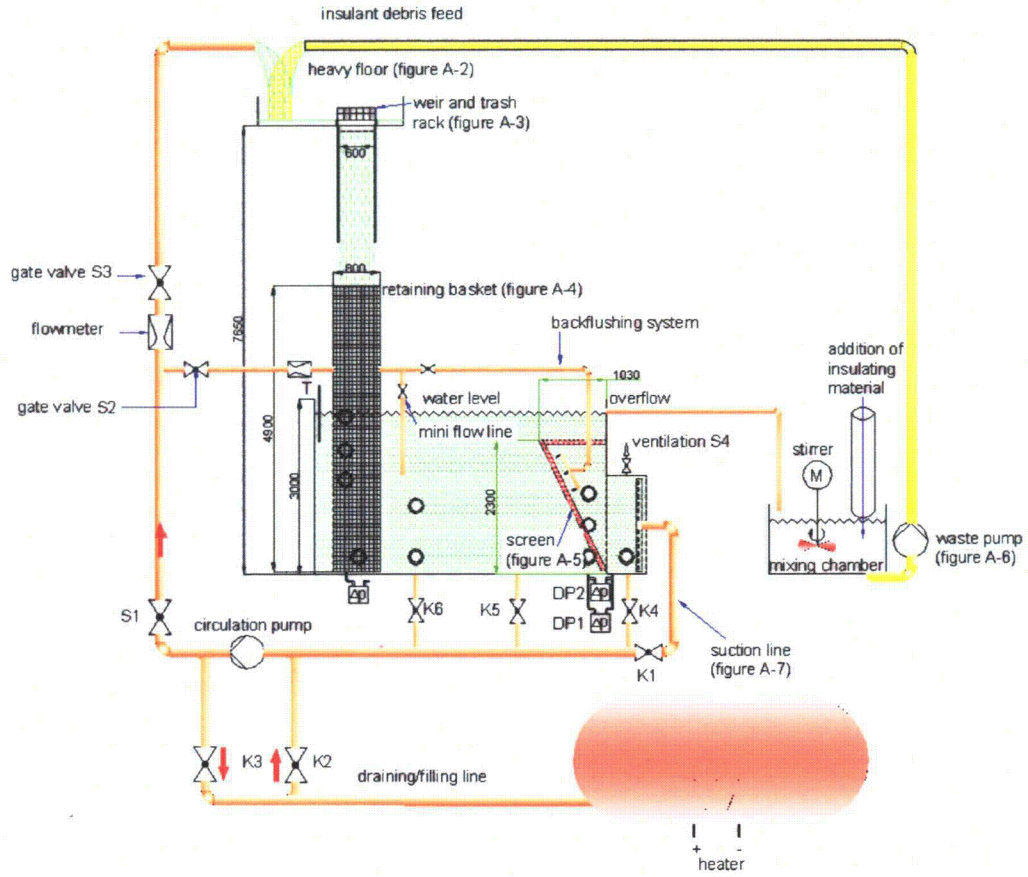
Testing Performed

- **ECCS strainer testing**
  - **Head loss testing performed at AREVA NP's Erlangen (Germany) test facility**
  - **Scaling was 1:1 vertically and 1:20 for all other parameters**
  - **Thirteen tests performed to characterize design performance**

Testing Performed

> ECCS strainer testing

- Test facility



Testing Performed

- **ECCS strainer testing**
  - **Test results demonstrated system is highly effective (95% retention in basket)**
  - **Retaining basket limited debris migration to strainer**

ECCS strainer testing demonstrates effectiveness of three-tiered design

Design Features

- > Predominant use of reflective metal insulation (RMI) vs mineral wool (used in testing)
- > Exclusion of calcium silicate insulations from containment
- > Large settling areas
- > Low approach velocities
- > Large screen areas
- > Three tiered design
- > Containment spray for severe accident only

Design features enhance effectiveness

GSI-191 Debris Generation Methodology

Paul Hannes
Advisory Engineer
AREVA NP Inc.

EPR

Debris Generation Methodology

- Development of the U.S. EPR debris source term employs the guidance of NEI 04-07 and associated NRC safety evaluation
- The U.S. EPR GSI-191 design results in a low fiber plant
- The debris generation evaluation performed consistent with methods used for operating plants

Debris Generation Methodology

- The debris generation evaluation process includes the following and is based on NEI 04-07 and associated NRC safety evaluation:
  - Insulation Inventory (types, locations, amounts)
    - Insulation inventory is obtained by review of plant drawings for piping database and equipment information
  - Pipe Break Location Selection
    - Break locations selected

Debris Generation Methodology

- Break Jet Destruction Model Zones of Influence (ZOIs)
  - ZOIs are determined for each postulated break location and insulation type
- Insulation Debris Quantities (targeted and destroyed)
  - Insulation debris quantities within each ZOI are totaled for each break location
- Non-insulation Debris Types and Quantities Generated
  - Non-insulation debris types and quantities generated such as latent debris, miscellaneous debris and coatings are identified and totaled
- Debris Characteristics of Debris Generated
  - Debris characteristics are evaluated for size distribution, size, shape, and density

Debris Generation Methodology

- After the debris source term is determined, the debris source term will be applied to the debris transport methodology provided in NEI 04-07
  - The debris source term will undergo debris transport
  - A 100% debris transport to the trash racks on the heavy floor is used for the U.S. EPR design
  - No credit is taken for intervening structures

Debris Generation Methodology

- The debris source term for the U.S. EPR GSI-191 design is impacted by two concepts:
  - Design control
  - Design conservatism
- Being a new design, the U.S EPR design can:
  - Control the insulation debris source term
    - Extensive use of RMI in containment
    - No cal-sil insulation used in containment
  - Control and limit the use of zinc and aluminum in containment to minimize chemical effects

Debris Generation Methodology

By controlling the debris source term and adopting conservative debris mitigation design features with inherent margin, the U.S. EPR GSI-191 design results in a low fiber plant

Methodology consistent with NEI 04-07 and the associated NRC safety evaluation

GSI-191 Testing

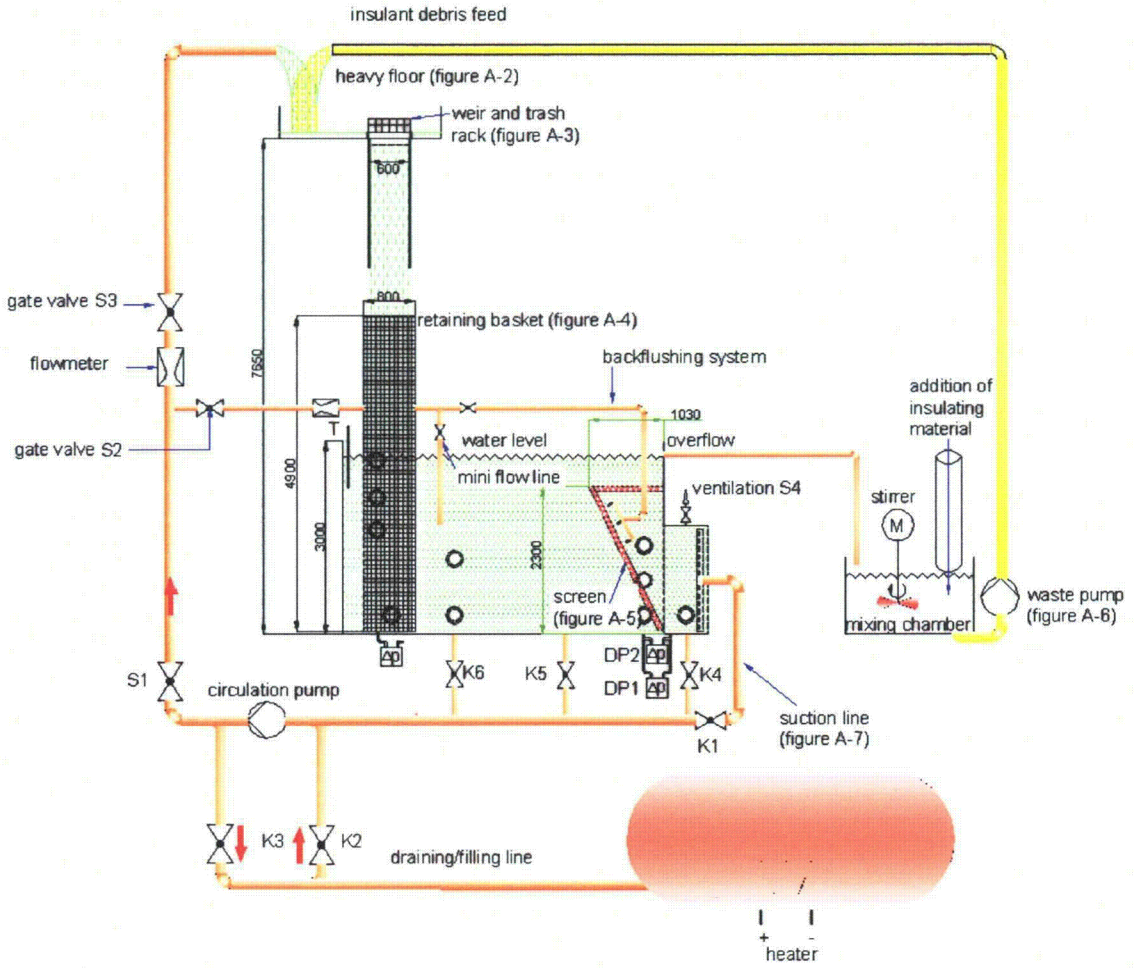
Fariba Gartland
Project Manager
AREVA NP Inc.

EPR

Strainer Head Loss Testing

- Testing performed to date to support design of ECCS Trash rack, Retaining Basket and Strainer
- Testing was performed for much higher fiber load than that in U.S. EPR containment
- Debris Generation analysis is in progress to identify the U.S. EPR specific debris source term (fiber and particulate)
- Assume 100% debris transport to trash racks
- Upon completion of analysis, head loss testing will be performed based on U.S. EPR specific debris source term and in accordance with the NRC March 2008 guidance

Strainer Head loss Testing Test Facility



Test Loop Description

- The test loop:
  - Flume tank16.4 ft long x 9.8 ft high x 3.3 ft wide
  - Suction chamber at one end with a slanted strainer
  - Recirculation pump (max flow ~ 553 gpm)
  - Piping with valves connecting the pump to the suction chamber and the simulated break above the heavy floor
  - Simulation of a part of the heavy floor with opening including removable weir and trash rack
  - Retaining basket (RB) with a screen (identical in mesh size to the sump strainer), top of RB at ≈ 6.6 ft above water level, top open to limit head loss by possible overflow
  - Instrumentations for measuring differential pressures, flow rates, and temperature
  - System to inject a defined amount of debris

Retaining Basket Test

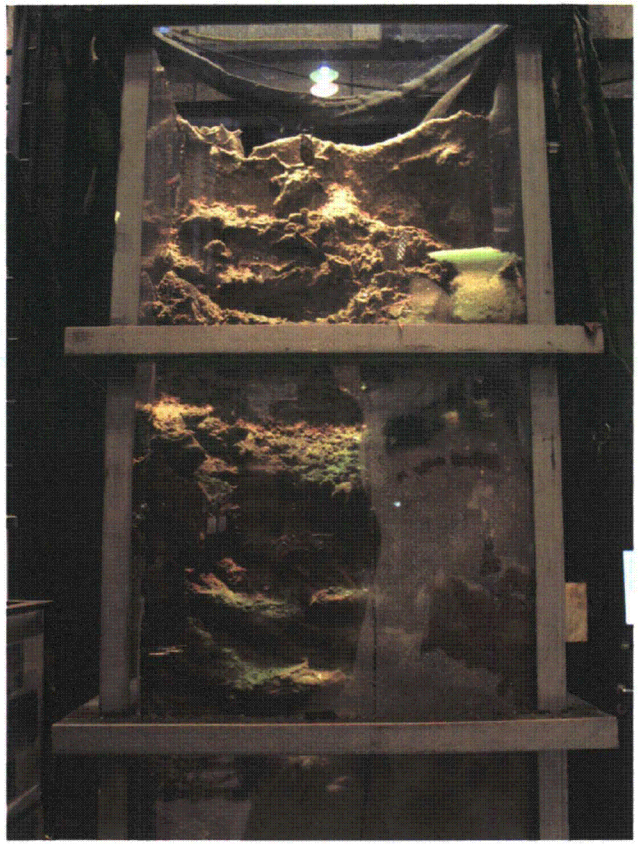
- Retaining basket (RB)
- Relevant phenomena
  - The RB was able to take the recirculation flow with the entrained debris without any problem.
  - The water falling from the heavy floor induced significant turbulences. The pressure fluctuations apparently caused material deposited in the upper region of the screen to slip down into deeper regions of the RB. Therefore, overflow will only happen when the RB is essentially filled.
  - The amount of fibrous debris bypassing the RB was limited to < 5% of the total amount of debris introduced in the test loop.
  - Due to the phenomenon of the self-cleaning effect in the upper part of the RB, there also seems to be no significant influence of a thin bed effect. The total amount of fibrous debris was more important with respect to the water level than the ratio of particulates to fibers.
  - No metal debris pieces or paint chips were able to pass the RB.

Retaining Baskets Flume Tank

Strainer Test

- Sump strainers
- Relevant phenomena
  - In all tests the debris layer on the screen of the sump strainer seemed to have a fairly even thickness.
  - The layers on the inverted part of the screen were fairly unstable for tests with mainly fibrous debris. They tended to fall off the screen, when the pump was shut off.
  - Reducing the amount of fibrous debris in tests with RB did not lead to a significant thin bed effect. In test where the ratio of particulate to fibrous debris was highest the head loss over the sump screen increased at first, but then slowly decreased again. This behavior can be explained by the fact that only very fine fibrous debris penetrates the screen of the RB resulting in a thin layer on the sump screen that is not sufficiently stable.
  - Only without weir and RB was it possible to create a sufficiently stable layer. However, even then the head loss remained below the design value.

Debris Sedimentation in Retaining Baskets



Trash Rack Test

- Heavy floor, weir, trash rack
- Relevant phenomena
  - Water level on the heavy floor is limited by the height of the weir.
  - In the region where the break flow drops on the heavy floor the water flow is turbulent pushing away some debris. With increasing distance, flow velocities decreases causing the heavier parts of the debris to settle.
  - The deposited debris acts as additional obstacle in the flow path retaining smaller debris. Generally, only smaller and lighter parts of the debris reach the weir. Because of the small size of the debris transported up to the weir, no built up of "debris dams" and no increase of the water level higher than the weir is encountered.
  - Because of the low water level on the heavy floor, no rotating flow patterns are induced which could cause debris material to be transported back to the region of the break and lead to further fragmentation of the debris to finer sizes.

Trash Rack Test

Strainer Head Loss Testing

- **Test loop will address:**
  - **Debris introduction system will accommodate debris sequencing**
  - **Chemical precipitant addition will be performed**
  - **Bypass sampling will be performed**

Strainer Head Loss Testing

- Testing protocol is currently under development
- AREVA will schedule a meeting with the NRC staff to review the test methodology and protocols prior to testing

Chemical Effect

- AREVA will utilize the NRC sponsored ICET results along with additional testing to determine the chemical precipitants for U.S. EPR containment specific design
- Analysis is in progress and will be completed after performance of debris generation analysis
- Chemical effect anticipated to be minimal due to limits placed on use of reactive materials such as:
  - Zinc and Aluminum in U.S. EPR containment (controlled)
  - No Cal-Sil insulation used in U.S. EPR containment
  - RCS piping insulation is RMI to the extent practicable

Upstream Effect

- Open heavy floor arrangement
- Low amount of fibrous debris generated (primarily RMI insulation)
- Four heavy floor openings to IRWST are protected by trash racks
- Only two of four ECCS trains required to maintain core cooling during LOCA

GSI-191 In-Vessel/Ex-Vessel

Gordon Wissinger
Principal Engineer
AREVA NP Inc.

EPR

In-Vessel Evaluation

- Debris that reaches the RCS will be determined conservatively
- U.S. EPR design minimizes downstream effects
  - Low fiber plant
  - Retaining basket/strainer combination
  - No design basis safety related containment spray
- Screen debris bypass testing will be performed to determine the in-core source term
- Insights from operating plant bypass testing will be used to ensure a conservative source term
  - Fiber introduction
  - Particulate introduction

In-Vessel Evaluation

- The assessment of the effect of debris on the fuel will be done in a similar manner to the current operating plants
- The following areas will be addressed
  - Debris accumulation at the core inlet
  - Debris accumulation at the intermediate spacer grids
  - Debris adherence to heated fuel rods
  - Chemical effects in the RV and core
  - Debris introduced during HLI
- The evaluation will be consistent with the operating plant methodology
  - Design differences between the current operating plants and the U.S. EPR design will be taken into consideration
- Evaluation will include results from tests of AREVA fuel designs

In-Vessel Evaluation

- > **The NRC is currently reviewing the proposed industry methodology as part of the operating plants efforts to resolve GSI-191 issues**
- > **AREVA is involved in this process and will continue to monitor the situation with regard to the U.S. EPR design and licensing**

AREVA will be consistent with the final NRC generic safety evaluation and applicable conditions and limitations

Ex-Vessel Evaluation

- **Downstream effects to ex-core components will be addressed by:**
  - **Strainer bypass sampling to provide input to vendor specifications**
  - **Specifying materials in equipment specifications for fluid debris and mission time that must be qualified by vendors**

Ex-vessel effects will be addressed by equipment specifications

U.S. EPR Sump Performance Plan

Fred Maass
Manager
AREVA NP Inc.

EPR

Path Forward

- **Debris generation methodology**
  - **Currently developing break selection and debris generation for low fiber plant design**
  - **Performed using guidance in NEI 04-07 and associated NRC safety evaluation**

Path Forward

- Strainer head loss testing
  - Scheduled for late September
  - Preliminary test plan prepared
  - Planned tests
    - Clean strainer head loss test
    - Bypass testing – fiber only
    - Bypass testing – particulate only
    - Design basis debris loading test
  - Review test methodology with NRC prior to testing

Path Forward

- Chemical and upstream effects
  - AREVA will perform analysis and specific validation testing to identify chemical precipitants
  - Chemistry Analysis Plan
    - Test plan and procurement
    - Perform material leaching test
    - Perform calculations
    - Final validation test
    - Synthetic precipitate generation
  - Resulting chemical effects will be included in strainer head loss testing

Path Forward

- **Downstream effects**
  - **Ex-vessel**
    - Determine bypass debris and identify mission time
    - Requirements included in equipment specifications
    - Addressed during component procurement and testing
  - **In-vessel**
    - Perform evaluation using current industry guidance

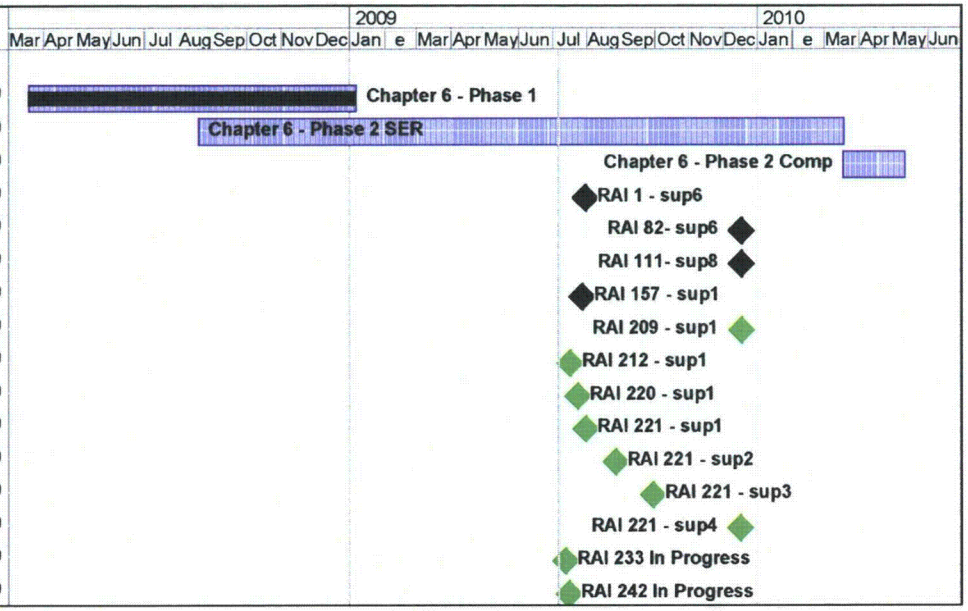
Schedule

- > Break selection/debris generation in progress (6/1/22009 - 7/31/2009)
- > Chemical analysis (7/1/2009 - 9/15/2009)
- > Testing preparation (8/15/2009 - 9/30/2009)
- > Downstream effects (8/15/2009 - 11/20/2009)
- > Preparation of technical report and submittal to NRC (12/18/2009)

Supports NRC review schedule

Chapter 6 RAI Schedule

Task Name	Start	Finish
Chapter 6 - Phase 1	Thu 3/20/08	Tue 1/6/09
Chapter 6 - Phase 2 SER	Tue 8/19/08	Thu 3/18/10
Chapter 6 - Phase 2 Comp	Thu 3/18/10	Tue 5/11/10
RAI 1 - sup6	Fri 7/31/09	Fri 7/31/09
RAI 82- sup6	Fri 12/18/09	Fri 12/18/09
RAI 111- sup8	Fri 12/18/09	Fri 12/18/09
RAI 157 - sup1	Tue 7/28/09	Tue 7/28/09
RAI 209 - sup1	Fri 12/18/09	Fri 12/18/09
RAI 212 - sup1	Fri 7/17/09	Fri 7/17/09
RAI 220 - sup1	Fri 7/24/09	Fri 7/24/09
RAI 221 - sup1	Fri 7/31/09	Fri 7/31/09
RAI 221 - sup2	Thu 8/27/09	Thu 8/27/09
RAI 221 - sup3	Wed 9/30/09	Wed 9/30/09
RAI 221 - sup4	Thu 12/17/09	Thu 12/17/09
RAI 233	Mon 7/13/09	Mon 7/13/09
RAI 242	Thu 7/16/09	Thu 7/16/09



Summary and Next Steps

- Develop methodologies and protocols consistent with industry and NRC-accepted practices
- Set specific test dates (NRC welcome to observe)
- NRC interactions:
  - Periodic (July, August, September)
  - Break selection and debris generation (August)
  - Strainer head loss testing methodology, including chemical effects (August)
  - Testing (September)
  - Report outline (October)
- Respond to RAIs
- ANP-10293 revision and to address outstanding RAIs (December 18)