January 31, 2013

Mr. Pedro Salas, Manager
U.S. EPR New Plants Regulatory Affairs
AREVA NP Inc.
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SUBJECT: AUDIT REPORT FOR GENERIC SAFETY ISSUE 191 RELATED TO U.S. EPR FINAL SAFETY ANALYSIS REPORT CHAPTER 6 SAFETY EVALUATION FEBRUARY 22-27, MARCH 10, MARCH 31, AND APRIL 16, 2010

Dear Mr. Salas:

AREVA NP, Inc., (AREVA) has submitted by a letter dated December 11, 2007, to the U.S. Nuclear Regulatory Commission (NRC) a Final Safety Analysis Report (FSAR) for its application of the U.S. EPR design, accessible by Agencywide Documents Access and Management System (ADAMS) Accession No. ML073520305. In order to address Generic Safety Issue (GSI)-191, AREVA submitted ANP-10293, "U.S. EPR Design Features to Address GSI-191 Technical Report," on February 11, 2008. Several requests for additional information (RAIs) were submitted by the staff in Chapter 6 concerning sump strainer performance. A public meeting was held to discuss these issues in detail on July 8, 2009. Several audits have been performed by the staff in order to review testing protocols and procedures, and to witness chemical effects, downstream effects, and strainer head loss testing at respective test facilities.

The audits performed on downstream effects testing and head loss testing protocols relating the planned Revision to ANP-10293 identified the need for additional information to cover important review areas handled by the Office of New Reactors (NRO), Containment and Ventilation Branch and the Component Integrity Branch. In order to address these concerns, the staff held an audit extension at test facilities in Holden, MA on February 22–27, 2010, and at the AREVA office in Rockville, MD, on March 10, March 31, and April 16, 2010.

The review of additional technical documents was facilitated by the presence of AREVA personnel at the audit. The audit report is contained in the enclosure to this letter. If you have any questions regarding this matter, I may be reached at 301-415-6822 or amy.snyder@nrc.gov.

Sincerely,

/RA/

Amy Snyder
Senior Project Manager
EPR Projects Branch
Division of New Reactor Licensing
Office of New Reactors

Docket No.: 52-020

Enclosure:
Audit Report

cc: See next page

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Audit Extension Report

Emergency Core Cooling System Sump Strainer and Chemical Effects Related to Generic Safety Issue-191 for the U.S. EPR Design Certification Chapter 6 Safety Evaluation

February 22-27, March 10, March 31, and April 16, 2010

Background

AREVA NP, Inc., (AREVA) submitted to the U.S. Nuclear Regulatory Commission (NRC) a Final Safety Analysis Report (FSAR) for its application of the U.S. EPR in December 2007. The staff initiated the design certification review on March 19, 2008. In order to address Generic Safety Issue (GSI) -191, AREVA submitted ANP-10293, "U.S. EPR Design Features to Address GSI-191 Technical Report," on February 11, 2008. The staff issued several requests for additional information (RAIs) under Chapter 6 concerning sump strainer performance. A public meeting was held to address these issues in detail on July 8, 2009. As a result of the public meeting, the applicant and staff determined that frequent interactions would be necessary to support the review of these topics. The staff conducted an audit to inspect chemical effects testing facilities and obtain a status of related work on August 18, 2009, at AREVA facilities in Lynchburg, VA. The audit plan was issued on August 17, 2009 (Agency Documents And Management System (ADAMS) Accession No. ML092260322). The audit was extended on August 21, 2009, for review of the debris generation calculation. On October 7, 2009, the staff audited the chemical effects test specification document at the AREVA offices in Rockville, MD. On October 27, 2009, the staff audited the head loss test protocol and downstream effects test plan. On October 29–30, 2009, the staff witnessed the downstream effects testing in Ewing, NJ. On November 12–13, 2009, the staff witnessed the chemical effects autoclave testing in Lynchburg, VA. The staff witnessed the first set of strainer head loss testing in Holden, MA from November 30 to December 4, 2009.

In order to gather additional information for the review, staff from the Containment and Ventilation Branch and the Component Integrity Branch held an audit extension on strainer head loss testing and chemical effects testing that was carried out at Alden Labs (ARL) in Holden, MA. AREVA personnel were present at the audit to facilitate the review of additional technical documents. AREVA personnel provided necessary technical information in response to staff questions during testing and documentation review. The audit extension continued at the AREVA office in Rockville, Maryland, in order to review additional documents on the chemical effects analysis not available at ARL. The audit supported the resolution of long-standing issues and accomplishing the U.S. EPR review schedule in an efficient manner, particularly in reference to Standard Review Plan Sections 6.2.2.

Regulatory Basis

The regulatory bases for the audit were General Design Criterion (GDC) 35 ("Emergency core cooling"), GDC 38 ("Containment heat removal"), and 10 CFR 50.46(b)(5) ("Long-term cooling"). These regulations are related to the evaluation of water sources for long-term recirculation cooling following a loss-of-coolant accident (LOCA).

Audit Approach

The purpose of this audit was to review several issues identified by the staff regarding sump strainer performance and downstream effects. The topics covered in the audit included the downstream effects test report and the head loss testing and bypass testing plans. The audit agenda is provided in Attachment A. To achieve the review goals in an efficient manner, the staff assembled an interdisciplinary audit team. The audit team included experts from NRC and consulting organizations. To facilitate and expedite the work, the audit was attended by representatives from AREVA who introduced the audit topics and provided supporting documents and technical evidence to the reviewers. The attendee list is provided in Attachment B, and a detailed list of the documentation provided is in Attachment C.

Summary Of Topics Discussed

I. Chemical Effects Aspects of Strainer Head Loss Testing

Basis for Chemical Addition Amounts

The staff reviewed a data sheet that summarized the calculation of the amount of surrogate precipitates to be added during the head loss test. For the head loss flume, the strainer and retaining basket area is 9.37 percent of the actual U.S. EPR design. The chemical amounts were scaled to 9.37 percent of the predicted amount of chemical for the plant, plus a "bump-up" factor to account for losses of the chemical in the piping.

The chemicals added to the head loss test are calcium phosphate ($Ca_3(PO_4)_2$), and aluminum oxyhydroxide (AlOOH). AlOOH is a surrogate for other aluminum containing precipitates predicted by the chemical modeling performed for the U.S. EPR, while the $Ca_3(PO_4)_2$ may be an actual precipitate predicted to form in the U.S. EPR post–LOCA liquid. For example, the required amount of AlOOH for the U.S. EPR design is approximately 169 pounds (lbs). Therefore, 16.3 lbs equals the scaling factor of 9.37 percent plus an additional 0.266 percent.

The flume volume is not scaled from the actual U.S. EPR design but is approximately one percent of the actual in-containment refueling water storage tank (IRWST) volume. Therefore, the concentration of the chemicals would be much higher than the predicted concentration of the precipitates in the U.S. EPR if all the chemicals were added at once. Therefore, the chemicals are added incrementally in 40 steps. Chemicals were added at 15-minute intervals until the full amount of each chemical was in the flume, with the AlOOH and $Ca_3(PO_4)_2$ being added alternately. The first three chemical additions are sufficient to bring the precipitate concentrations up to the predicted levels for the U.S. EPR, providing a data point at the design basis concentrations. For example, 1.6 pounds-mass (lbm) of AlOOH brings the flume up to the U.S. EPR design basis concentration. This is achieved by three additions of 0.53 lbm each. The additional chemical additions increased the chemical concentrations to much higher levels, providing a conservative test.

Preparation of Surrogate Precipitates

The staff observed the preparation of the surrogate precipitates. The AREVA chemist followed, "Chemical Preparation Plan for U.S. EPR Strainer Test," U.S. EPR Engineering Information Record Document No. 51-7001869-000. The procedure included the mass of each chemical required for the test, the equivalent concentration in the solution for each, the volume of solution to be added in liters and gallons (gal), and the number of 100-gram units of each product. The AlOOH was prepared by reacting aluminum nitrate Al $(NO_3)_3$ and sodium hydroxide (NaOH). The $Ca_3(PO_4)_2$ was prepared by reacting calcium acetate and trisodium phosphate (TSP). The procedure contained the masses required for each reactant and also the mass required for each 100-gram unit of product. The 100-gram unit amounts were not used because the entire required amount of each chemical was prepared in one batch.

The surrogate precipitates were prepared in large plastic batching tanks. The batching tanks are equipped with a motorized stirrer to keep the precipitates in suspension. The chemicals were weighed on an industrial top-loading balance and added to large plastic batching tanks. The aluminum nitrate and calcium acetate were each added separately to each tank. The AREVA chemist ensured that the initial chemicals added were completely dissolved before proceeding to add the precipitating agents. The respective precipitating agent (NaOH or TSP) was then added to each tank separately while stirring. For the AlOOH, the precipitate was observed to form immediately, as evidenced by the solution becoming milky. The staff observed that there was some splashing of liquid out of the AlOOH batching tank due to the positioning of the stirrer, which may have caused a small amount of the solution to be lost. However, based on the tank volume and the amount of liquid observed on the floor, this was much less than one percent of the total tank volume.

One hour after mixing each chemical in the batching tank, samples were drawn for a settling test. The test method and the acceptance criterion are standardized in WCAP-16530-NP-A, "Evaluation of Post-Accident Chemical Effects in Containment Sump Fluids to Support GSI-191." In the settling test, two milliliters (mL) of each suspension is added to a 10-mL graduated cylinder. Eight mL of water is added to bring the volume up to 10 mL. The suspension is shaken, put aside, and allowed to settle for one hour. Settling is visually measured by the clarification of the liquid from the surface of the liquid down to the top level of cloudiness of the solution. The acceptance criteria are different for each precipitate. For the AlOOH, the acceptance criterion is ≤ 1 mL settling or ≤ 10 percent. For the $Ca_3(PO_4)_2$, 50 percent settling is allowed. The staff observed that both settling tests were acceptable.

Addition of Chemicals

The two different precipitates were added to the flume using separate pumps and hoses. The staff verified this by walking down the hoses back to the source. The first chemicals were added between 9:00 A.M. and 10:00 A.M. on February 24 (9:12 A.M.). First, the pumps were discharged into a plastic container to clear out the flush water. When milky precipitate was observed, the pump was stopped. The precipitate suspension was then pumped into a different plastic container (the one marked for the appropriate volume). The volumes had been previously marked on the plastic containers by weighing the equivalent volume of water (8.34 pounds per gallon). The time to fill the marked plastic container to the line was recorded. A small electric pump was then used to pump the precipitate suspension from the plastic container into the flume downstream of the retaining basket. The plastic container with the flush water, which also contained a small amount of precipitate, was also introduced into the flume. After the first two additions, the chemicals were pumped directly into the flume for the appropriate amount of time.

There was no detectable change in head loss during the first several hours of chemical additions. No observable changes to the color or appearance of the liquid in the flume were observed with the first few additions of chemicals.

Sampling of Liquid

Liquid samples were taken downstream of the strainer on an hourly basis to measure the fiber bypass of the strainer. The samples will be sent to a lab in Ohio for a scanning electron microscope examination.

Conclusion

The staff's preliminary conclusion from test observations of the chemical preparation is that the preparation, testing of the surrogate precipitates, and delivery to the head loss test flume of the surrogate precipitates was consistent with the guidance of WCAP-16530-NP-A. The staff will review the applicant's pending submission for completeness and technical sufficiency before arriving at a final conclusion.

II. Strainer Head Loss Testing

Purpose

The purpose of the audit was to evaluate qualification testing for the U.S. EPR containment sump retaining basket and strainer. The audit report documents the staff observations of testing conducted at ARL. The audit does not include a review of the test report. All data listed in this audit report is approximate and has not been verified against the final test report.

Overview

AREVA conducted testing to qualify their containment sump debris filtration design consisting of a retaining basket and strainer. The preliminary test results indicate that the measured strainer head loss was very low and close to the clean strainer head loss condition. AREVA was asked to provide additional information to justify how their testing identified the limiting or worst-case strainer head loss condition due to concerns with their thin bed testing approach. Questions raised during the audit were to be addressed through the normal RAI process.

The staff visited ARL on February 22–27, 2010, to observe U.S. EPR strainer and retaining basket qualification testing. The primary objective of the testing was to address concerns identified in GSI-191, including chemical effects. U.S. EPR employs a first-of-a-kind design in comparison to U.S. operating plant experience and, as such, it required design and development of a unique test flume. The U.S. EPR has four independent strainers and four independent retaining baskets. The strainers and baskets are located in the bottom of containment inside the IRWST. The tested retaining basket and strainer were prototypes that represented 9.37 percent of the screen area proposed for the U.S. EPR. Before the visit the staff had the benefit of reviewing AREVA document 51-9125267-000, Revision 1, “U.S. EPR Strainer Test Protocol.”

The staff observed two head loss tests for U.S. EPR. The apparatus used for testing included a test flume, pumps, prototype strainer, prototype retaining basket, instrumentation and controls, associated piping and valves for the recirculation loop, debris introduction system, and flume level control. There was also the ability to heat the tank water. The flume dimensions were about 14 feet (ft) long, 5 ft wide, and 10 ft high. The main pump was driven by a variable-speed motor to assist in controlling flow rate. Some of the instrumentation was connected to a desktop computer for trending and data collection. The test loop had sample probes for taking samples to determine the amount of debris that bypasses the strainer.

As debris and chemicals were added to the flume, water in the flume was displaced. To maintain a steady water level in the flume an overflow weir was installed at the end of the test flume. Debris which may be transported past the overflow weir was captured by bag filters located downstream of the weir. Debris from these filters was returned to the flume periodically. In addition, as debris blocked the basket screen area and basket water level increased, water in the flume was again displaced. To maintain a steady water level in the flume, an automatic water makeup system was used to add water to the test flume.

Chemicals and the equipment needed for generating precipitates were available at ARL. An evaluation of the preparation and addition of chemical debris was reviewed during the audit. The methods of preparation and addition of the surrogate precipitates to the head loss test flume were consistent with the guidance of WCAP-16530-NP-A.

Test Setup

The test tank contained one model strainer and one model retaining basket. The strainer was connected to an outlet plenum. The outlet plenum was connected to the suction header for the test loop recirculation pump. The recirculation pump directed most of the recirculation flow into the retaining basket with a small portion of recirculation pump flow returned to the test flume to simulate U.S. EPR pump mini-flow. Mini-flow was introduced at the tank bottom in the region between the strainer and basket to agitate the flow stream and minimize the potential for near-field settlement of debris.

All non-chemical debris introductions into the retaining basket occurred by two independent methods. One method had technicians, using buckets, manually pouring a mixture of water and debris into the basket’s interior. The other method had technicians using remote debris mixing tank and operating a trash pump and associated hoses to transport debris from the remote mixing tank into the retaining basket interior. All chemical debris introductions occurred between the basket and strainer. The technicians used visual inspection techniques to ensure debris was not hiding out in hoses, pumps or buckets and to confirm debris additions were complete.

The scaling factor used for water flow rates, screen area, and debris quantities was 9.37 percent. The scaling factor for the water depth was one-to-one. Debris was weighed dry and placed into buckets and partially filled and mixed with water to remove air in the debris. The debris was mixed to also prevent debris agglomeration. Debris additions were sequenced from the most transportable to the least transportable debris in the following order: (1) Particulate; (2) fiber; and (3) coating chips.

To support testing, the flume was filled to the post-accident minimum water level. The primary measurements taken were system water flow rate, water temperature, clean strainer head loss, debris loaded head loss, and retaining basket level. A general layout of the test facility equipment and piping, specific dimensional information and test conditions, and the types and quantities of debris were reviewed during the audit (see Attachment D, E, F, respectively).

Test Performance (Full Load)

On February 23–24, 2010, the staff observed the Design Basis Debris Loaded Strainer Head Loss Test, also called a full load test. This test modeled the debris generated from a postulated design basis LOCA. The full load test was run to determine the head losses associated with the full debris load for U.S. EPR.

At the beginning of the test, the water temperature was around 120 degrees Fahrenheit (°F), the recirculation pump was running, and recirculation flow was set to just over 300 gallons per minute (gpm). Strainer differential pressure was approximately 0.38 ft. First, all of the particulate debris was added starting with Microtherm, then coatings, and followed by latent debris. The particulate addition took about 3 hours to complete due, in part, to a broken trash pump that required the ARL staff to locally add latent debris and tin powder (inorganic zinc coating surrogate) into the retaining basket rather than remotely using the pump. There was no change in head loss associated with the particulate addition, as expected. Second, the fiber was added using the trash pump. A portion of the fiber was added between the basket and strainer to account for drains to the IRWST that are not routed to the basket. It took roughly 5 minutes, about one-third of a flume turnover, to complete the fiber addition to the basket. After roughly five flume turnovers, the retaining basket level was steady and had risen approximately 1.3 ft above the normal flume level. (It took about 25 minutes for the basket to rise 1.0 ft and another 45 minutes to level out at 1.3 ft.) The water make-up system operated to maintain test tank water level steady as basket water level increased. The strainer head loss showed no change and was reading about 0.38 ft.

After the fiber addition was complete and the basket level was steady, 12 lbm of coating chips were added to the basket. The basket level rose about 6 ft over a period of 15 minutes and overflowed the top of the basket. The basket level at overflow is about 7.3 ft above the flume level. It took approximately 10 minutes to add coating chips. Strainer head loss did not change. The test ran through the evening of February 23 and into the morning of February 24 without any more debris additions. On the morning of February 24, the strainer head loss was steady at 0.38 ft and the basket was overflowing.

Chemical precipitates were added on the morning of February 24. The first chemical precipitates added were aluminum oxyhydroxide followed by calcium phosphate. At the conclusion of the chemical additions, the strainer head loss was essentially unchanged at 0.38 ft and the basket continued to overflow. The test continued to run overnight into the early hours of February 25, when the water make-up system failed and the test was terminated. Test personnel indicated the test termination criteria were met before system failure and will provide this information in the test report. The strainer head loss was reported as steady and unchanged, reading approximately 0.38 ft.

The flume was drained on the morning of February 25. The strainer screen was essentially clean screen and was consistent with the steady head loss readings that remained essentially unchanged throughout the full load test. The test flume was cleaned before close-up (hands on) inspection of the debris bed or debris sampling occurred.

Full Load Test Results

The full load test results and physical observations are summarized as follows:

- The strainer head loss associated with the full debris load was 0.38 ft, an insignificant change in comparison to the clean strainer.
- No filtering bed was built up on the strainer surfaces.
- The retaining basket level rose around 1.3 ft after the particulate and fiber additions.
- The retaining basket overflowed when coatings were introduced in chip form (i.e., a level change of around 6 ft). No chips were observed in the basket overflow.
- Chemical additions did not impact strainer head loss.
- No vortex formation was observed at the strainer.
- Retaining basket debris bed close-up inspection was not performed. However, it was evident from visual observations that coating chips blocked the majority of the basket screen (about 6 ft) above the normal flume water level.
- Debris settlement inspection did not occur due to flume clean-up activities.

Test Performance (Thin Bed)

On February 26, the staff observed the U.S. EPR Debris Loaded Strainer Head Loss Thin Bed Test. This test modeled the debris generated from a postulated design basis LOCA. The thin bed test was run because testing experience has frequently demonstrated that thin debris beds can create a limiting condition for head loss. Additionally, Nuclear Energy Institute (NEI) 04-07 Volumes 1 and 2 direct applicants to perform a thin bed test. At the beginning of the test, the water temperature was approximately 120 F, the recirculation pump was running, and recirculation flow was set to just over 300 gpm. Strainer head loss was approximately 0.37 ft. First, all of the particulate debris was added starting with Microtherm, then coatings, and followed by latent debris (same as the full load test, except without a long delay in the particulate addition). There was no change in head loss associated with the particulate addition, as expected. Second, the fiber was added. As in the full load case, a portion of the fiber was added between the basket and strainer to account for drains to the IRWST that are not routed to the basket. The fiber additions for the thin bed case were completed in two batches

The first fiber addition was based on creating a ⅛-inch thin bed on an area equal to the combined strainer and basket area in the test flume. The amount added in the first batch was around 3.0 lbm. It took roughly 7 minutes, about one-half of a flume turnover, to complete the first fiber batch addition. The level in the basket rose about 2.2 ft. (It took about 20 minutes for the basket to rise 1.6 ft and another 40 minutes to level out at 2.2 ft). The water make-up system operated to maintain test tank water level steady as basket water level increased.

The second fiber addition was 1.6 lbm. It took roughly 3 minutes, about one-fifth of a flume turnover, to complete the second fiber batch addition. Basket level rose an additional four feet. (It took about 10 minutes for the basket to rise 3.7 ft and another 20 minutes to level out at 4.0 ft). The water make-up system operated to maintain test tank water level steady as basket water level increased. Strainer head loss was approximately 0.37 ft after all fiber additions and steady.

After the fiber addition was complete and the basket level was steady, 12 lbm of coating chips were added, and these quickly (i.e., within seconds) clogged the remaining several inches of basket clean screen, causing water to overflow the basket. It took roughly 10 minutes to complete the addition of all the coating chips. Coating chips were observed in the overflow water leaving the top of the basket and entering the strainer region of the test flume. After waiting several flume turnovers, strainer head loss was steady at approximately 0.37 ft and the basket was overflowing.

The chemical precipitates were added starting in the afternoon of February 26. The first chemical precipitates added were aluminum oxyhydroxide followed by calcium phosphate. At the conclusion of the chemical additions, the strainer head loss was unchanged at 0.37 ft and the basket continued to overflow. The test continued to run overnight into the early morning hours of February 27, and the strainer head loss remained unchanged at approximately 0.37 ft.

The flume was drained on the morning of February 27. The strainer screen was essentially clean screen, consistent with the measured head loss readings. It was evident from the testing (i.e., from the overflowing basket) that the retaining basket screen was blocked with debris. ARL staff removed two of the retaining basket screens for close-up inspection. These screens were representative of the basket area above the normal flume water level. Close-up inspection revealed that the debris bed completely covered the basket screened surfaces. There was no open area. The outer debris layer was light grey in color and was predominantly made up of what appeared to be chemical precipitates with a consistency that can be best described as pudding. Under the apparent chemical layer was a dark layer that was comprised of fibers and non-chemical particulates. In the uppermost screen section, the top several inches of debris were predominantly comprised of coating chips and chemicals. The debris bed was adhered to the vertical basket screen mesh in such a manner that it did not fall off during drain-down. Coating chips were also stuck to the basket's topmost overhead seams and corners (non-prototypical test configuration) across from the overflow area. The staff visually observed debris settled in the test tank between the strainer and retaining basket

Thin Bed Results

The thin bed test results and physical observations are summarized as follows:

- The strainer head loss associated with the thin bed test was 0.37 ft, an insignificant change in comparison to the clean strainer.
- No filtering bed was built up on the strainer surfaces.
- The retaining basket level rose around 2.2 ft after the particulate and first fiber additions.
- The retaining basket level rose around 4.0 additional ft after the second fiber addition.
- The retaining basket overflowed when coatings were introduced in chip form. Many chips were observed in the overflow water.
- Chemical additions did not impact strainer head loss.
- No vortex formation was observed at the strainer.
- Basket inspection indicated that a filtering bed was covered with a layer of chemical.
- Debris settling was identified on the flume bottom between the strainer and the retaining basket.

Discussion

This section of the audit report discusses three items: (1) Coatings; (2) debris settling; and (3) thin bed testing.

In a public meeting on January 27, 2010, AREVA summarized changes to the debris generation analysis and test facility to support head loss testing. These changes were developed in response to aborted strainer testing in December 2009. In the presentation, the debris generation analysis considered all qualified and unqualified coatings as particulate. During the full load test and thin bed test, coatings were added in particulate and chip form. Coatings in chip form were not part of the design basis analysis and represent material additions over and above the design analysis. The addition of chips did result in the basket overflowing but did not result in a change to strainer head loss. The treatment of coatings as both particulate and chips during testing seemed reasonable to the staff. One of the staff conclusions in the Safety Evaluation on NEI 04-07 regarding failed coatings is that for plants that can substantiate a thin bed, use of the basic material constituent to size coating debris is acceptable. As observed during the thin bed testing, it appears that U.S. EPR can substantiate the formation of a thin bed in the basket and that treatment of coatings as particulate is reasonable.

Debris settling was identified in the bottom of the test flume between the strainer and retaining basket. During a follow-up phone call held on March 11, 2010, AREVA personnel indicated that the settled debris observed during the thin bed test was predominantly coating chips based on visual inspection. Given that U.S. EPR flume testing was understood to inhibit or prevent near-field debris settlement, the staff seeks information that the settled/collected debris in the test flume would be prototypical or conservative in comparison to plant conditions. The staff requested additional information on this debris settling issue.

The staff guidance documents for strainer head loss testing were developed to provide guidance for licensee and vendor evaluations of upgraded strainers being installed in

Pressurized Water Reactors (PWRs). Licensees typically used a single strainer to filter the water being drawn into the emergency core cooling systems (ECCS) and core spray (CS) pumps. The design of the U.S. EPR basically includes two strainers in series. Therefore, when applying the testing guidance, this design difference must be considered when assessing whether testing was conservative or prototypical.

Guidance indicates that an acceptable thin bed test should sequence the debris by adding 100 percent of the plant particulate load to the test flume and subsequently adding fibrous debris in incremental batches of an appropriate size to form a thin bed. Even if the plant has enough fiber to form a thick fibrous bed, the accumulation process should pass from zero accumulation to bed thicknesses greater than the typical thin bed thickness incrementally to ensure that the peak response is determined. A thin bed can be more challenging than thicker beds because a relatively small amount of fibrous debris can capture a relatively large amount of particulate debris resulting in a debris bed with relatively low porosity.

For U.S. EPR, the first screen encountered by the fiber debris is the retaining basket. Therefore, it seems reasonable that the thin bed test should attempt to form a thin bed in the basket, by incremental addition of fibrous debris, to conservatively determine the peak level rise in the basket. However, the U.S. EPR testing basis used the total screen area in the flume, basket area plus strainer area, to calculate the fiber addition needed for a one-eighth-inch thin bed. This ignores the fact that the fiber debris first encounters the basket screen, which AREVA claims to be a very efficient fiber filter and has an identical mesh size as the strainer. Using the total screen area (basket and strainer) results in a large fiber quantity being added in the first batch - potentially much more than is needed to develop a thin bed. Increasing the amount of fiber that is initially available allows a thicker bed to form on the available screen. Thicker beds tend to be more porous and typically result in less head loss. A comparison of test results, discussed in more detail below, indicates this phenomenon was likely experienced in the retaining basket.

Using the guidance documents, the staff would use the submerged basket area to calculate the initial fiber addition. This is the wetted screen area first encountered by the fiber and is the area available to develop a thin bed. The submerged basket area is much less than the combined strainer and basket area and represents roughly 60 percent of the total basket area. The submerged basket would require less fiber debris to form a thin bed than what was added as part of the first batch addition of fiber. As an example, the scaled strainer area is around 70 square feet (sq ft) and the scaled basket area (full height) is around 60 sq ft (less is initially submerged). The combined area equals 130 sq ft. An inexact but good rule of thumb is to divide the screen area (sq ft) by 100 to determine the volume (cubic feet [cu ft]) of fiber necessary to form a one-eighth-inch-thick bed, which is one measure of a thin bed. (Note: Thin beds can occur with less fiber thickness). The alternative is to multiply the fiber volume (cu ft) by 100 to determine the area (sq ft) necessary to form a one-eighth-inch-thick fiber bed. Using the above rule of thumb and a fiber density of 2.4 lbm per cu ft, 130 sq ft requires 1.3 cu ft of fiber (area/100 = volume) to form a ⅛-inch-thick debris bed and equals 3.12 lbm of fiber (volume * density).

The initial fiber amount added to the basket was around 3.0 lbm (with a small portion having been added between the basket and strainer), which equals about 1.25 cu ft of fiber

(3 lbm / 2.4 lbm per cu ft). The fiber volume of 1.25 cu ft can cover 125 sq ft of screen to a one-eighth -inch thickness (a nominal thin bed). The submerged basket area is approximately 60 percent of the total basket area, which equals about 36 sq ft. Therefore, only 0.36 cu ft, or 0.86 lbm, is needed to initially form a thin bed in the basket. The thin bed test added more than three times the amount of fibrous debris needed to form a one-eighth-inch thin bed on the basket (3.0 lbm vs. 0.86 lbm).

Comparing the full load test results to the thin bed test results demonstrates that lesser amounts of debris can result in a greater effect. In the full load test, the basket level rose 1.3 ft with the full load of fiber. In the thin bed test, the basket rose 2.2 ft with the first batch of fiber. With all else being equal (i.e., flow rates, initial water levels, particulate debris load, and screen area), approximately 33 percent less fiber resulted in a 70 percent increase in level.

Similarly, the comparison between the full load test results and thin bed test results after all fiber additions were complete further demonstrates that incremental additions of the same total amount can also result in a greater effect. Under the full load test, the basket level rose about 1.3 ft. For the thin bed test (after all the fiber was added) the level rose about 6.2 ft. With all else being equal (i.e., flow rates, initial water levels, particulate debris load, and screen area), incremental additions of the same amount of fiber resulted in a 470 percent increase in level. For the full load test, the fiber collected on roughly 65 percent of the screen area. For the thin bed test, using the same amount of total fiber as the full load test, the fiber collected on over 90 percent of the screen area.

Given that the first thin bed fiber addition caused level to increase more than the full load, it seems reasonable that even smaller amounts of fiber, which would be consistent with operating experience for thin bed development, may actually cause even greater level increases. Using smaller amounts and waiting an appropriate number of flume turnovers may cause basket level to rise and overflow before all fiber additions were complete. This, in turn, would allow remaining fiber additions to potentially bypass the basket and possibly develop a filtering bed on the strainer.

Overall, the staff has concerns with the applicant’s approach to thin bed testing. It is not clear that the completed tests established the strainer and basket limiting performance for the plant-specific conditions. Before testing there were several opportunities for the applicant and staff to discuss this type of information through public meetings and audits. However, the information provided by the applicant was limited to the overall test protocol and scope of activities. The test procedure that provided thin bed testing details was not made available for review.

Potential Requests for Additional Information

The staff considered the results of the two observed tests to be of significant interest. Two specific points illustrated by the tests are important for strainer and retaining basket qualification. These are:

1. The thin bed test used about 33 percent less fiber (first batch) than the full load test and resulted in a 70 percent increase in basket level. This demonstrated that incremental

fiber additions have a significant impact on basket level. However, the fiber amounts calculated for thin bed testing appear non-conservative given that they were based on the total screen area in the test flume and not on the screen area first encountered by the debris. Using the screen area first encountered by the debris indicates the first fiber batch addition amount may have been three times greater than what was needed to form a thin bed. AREVA should justify the selection of the total screen area as the basis for calculating the thin bed fiber batch amounts. In addition, AREVA should justify how the completed thin bed test would develop the worst-case (limiting-condition) strainer head loss. (Subsequently issued as RAI 378-4513, Question 06.02.02-45).

2. After drain-down of the test flume following the thin-bed test, the staff visually observed debris settled on the test tank floor between the strainer and the basket. The staff also noted debris collected in overhead seams (i.e., where walls met ceiling area) in the retaining basket. AREVA should justify how the debris that settled/collected during the test was prototypical or representative of plant conditions. AREVA should include in the response a description of the settled/collected debris and its impact on test results. (Subsequently issued as RAI 378-4513, Question 06.02.02-46)

Summary

The staff observed U.S. EPR containment sump GSI-191 testing at ARL from February 22–27, 2010. This testing is considered first-of-a-kind in comparison to U.S. operating plant strainer tests due, in part, to the U.S. EPR retaining basket design. Simulated plant debris in the test observed by the staff were representative of a break location that produced a limiting fiber, particulate, and chemical loading expected following a loss-of-coolant accident (LOCA). Neither the full load test nor the thin bed test developed a filtering bed on the strainer and, as a result, strainer head loss due to debris was insignificant. The thin bed test demonstrated that fibrous debris combined with particulate debris can result in a significant level increase in the retaining basket. Overall, the staff has concerns with the applicant's approach to thin bed testing and any use of the test results to establish the strainer and basket worst-case performance until items discussed above are addressed. The staff subsequently issued RAI 378-4513 to request additional information about two issues.

III. <u>Chemical Effects Testing and Modeling Documents</u>

Purpose

The audit discussed above was extended further to allow the staff to review additional AREVA internal documentation on chemistry modeling and chemistry validation testing performed to support the GSI-191 analysis for the U.S. EPR. The staff performed these activities on March 10, March 31, and April 16, 2010. The audit provided details to the staff about how AREVA validated material release rates through laboratory testing and calculated the amount of chemical precipitate using commercially available thermochemistry software.

Documents Examined

- 32-7002848-000, "Sump Chemistry Modeling for U.S. EPR," Rev. 0, February 4, 2010

- 51-7003241-001, “Chemical Validation Testing Final Report,” Rev. 1, March 12 2010
- AREVA Condition Report 2009-8266-CR (Synopsis)

Results

The intent of the validation testing was to validate published release rates for the insulation and structural materials in containment that may release chemicals that form precipitates. The intent of the themochemistry modeling was to use the material release rates and environmental conditions (pH, temperature, water chemistry) as inputs to calculate the type and amount of chemical precipitates. The calculated precipitate load was then used as an input for strainer and fuel assembly testing and analysis. The purpose of the condition report was to evaluate the effect of preparing some of the Nukon insulation for the autoclave validation testing differently than planned.

As a result of the audit extension, the staff identified 17 potential RAI questions and discussed them in a phone call with the applicant. During the call, AREVA explained that ANP-10293, Rev. 1, would be submitted in May 2010 and would introduce Appendix D on chemical effects. The applicant indicated that Appendix D would include most of the autoclave testing and chemistry modeling information in the audited documents. After ANP-10293, Rev. 1, was submitted, the staff confirmed that Appendix D answered most, but not all, of the audit questions. Subsequently, the staff issued RAI 401-4685, Questions 06.02.02-53, -54, -56, -58, -59, -63, and -66. These questions were all related to clarification and justification of the release rates AREVA determined, as summarized in the table below.

RAI 401-4685 Questions

Question	Topic
06.02.02-53	Some Nukon fiberglass insulation was prepared for autoclave testing differently than planned
06.02.02-54	pH dependence of the concrete release rate
06.02.02-56	Methodology for determining Nukon release rates
06.02.02-58	Justification for the assumed Microtherm insulation composition
06.02.02-63	Role of carbon in the chemical analysis of Microtherm
06.02.02-66	Inclusion of initial conditions (low-pH, high-temperature) in the chemistry modeling

Conclusion

After issuing the RAI, the staff ended the audit extension. Since the applicant had formally submitted the audited information in ANP-10293, Rev.1, the staff continued its review of chemistry testing and modeling based on docketed information, using the RAI process as needed. Details of the RAI resulting from this audit extension (RAI 401-4685) and subsequent RAIs are discussed in the staff’s Safety Evaluation Report in Section 6.2.2.4.13.

ACTION ITEMS

Following the audit, the staff issued two RAIs to obtain information necessary to support the safety evaluation of the U.S. EPR FSAR Chapter 6. RAI 378-4513 addresses two issues related to strainer and retaining basket qualification. RAI 401-4685 addresses six issues related to the chemical effects source term.

AUDIT SUMMARY

The February 22–27, 2010, strainer head loss test and chemical test report audit was performed successfully at ARL in Holden, MA. The staff continued the audit at the AREVA office in Rockville, MD, on March 10, March 31, and April 16, 2010, to examine additional documentation on chemical effects testing and modeling. The information presented by the applicant provided the staff with a better understanding of the testing and analysis performed to support the U.S. EPR strainer design, and this information will support the safety evaluation of U.S. EPR FSAR Chapter 6 and associated technical reports.

This audit identified the need for more information to support the safety evaluation of the U.S. EPR FSAR Chapter 6. The staff subsequently issued requests for additional information about both the strainer head loss testing and chemical effects testing and analysis.

Table 1: Audit Agenda (as performed on the week of February 22, 2010)

Timeframe	Item	Responsible Party
	February 22, 2010	
Afternoon	1. Fiber only testing, facility review	1. C. Ashley 2. J. Poehler
	February 23, 2010	
Morning	1. Preparation for Design Basis Strainer Head Loss Test 2. Chemical Effects Test Report Documentation Review	1. C. Ashley 2. J. Poehler
Afternoon	1. Beginning of Design Basis Strainer Head Loss Test 2. Chemical Preparation for Design Basis Strainer Head Loss Test	1. C. Ashley 2. J. Poehler
	February 24, 2010	
Morning	1. Chemical Addition, Design Basis Strainer Head Loss Test	1. C. Ashley 2. J. Poehler
Afternoon	1. Chemical Addition, Design Basis Strainer Head Loss Test 2. Chemical Test Report and Chemical Preparation Audit Exit	1. C. Ashley 2. J. Poehler
	February 25, 2010	
Morning	1. Design Basis Test Termination 2. Facility Drain / Cleanup	C. Ashley
Afternoon	1. Facility Drain / Cleanup 2. Thin Bed Test Start	C. Ashley
	February 26, 2010	
Morning	1. Chemical Addition: Thin Bed Test	C. Ashley
Afternoon	1. Chemical Addition: Thin Bed Test	C. Ashley
	February 27, 2010	
Morning	1. Thin Bed Test Termination	C. Ashley

Attendee List
AUDIT TO REVIEW SELECTED AREAS RELATED TO U.S. EPR FSAR CHAPTER 6 SAFETY EVALUATION
February 22–27, 2010, AREVA NP, Inc., Rockville, MD

Name	Affiliation
Clint Ashley	NRC
Jason Carneal	NRC
Jeffrey Poehler	NRC
Robert Litman	Chemstaff (NRC contractor)
Fred Maass	AREVA NP, Inc.
Fariba Gartland	AREVA NP, Inc.
Larry Peterson	AREVA NP, Inc.
Len Gucwa	AREVA NP, Inc.
Ludwig Haber	Alden Labs
Stuart Cain	Alden Labs

Attachment B

List of Audit Documentation Provided

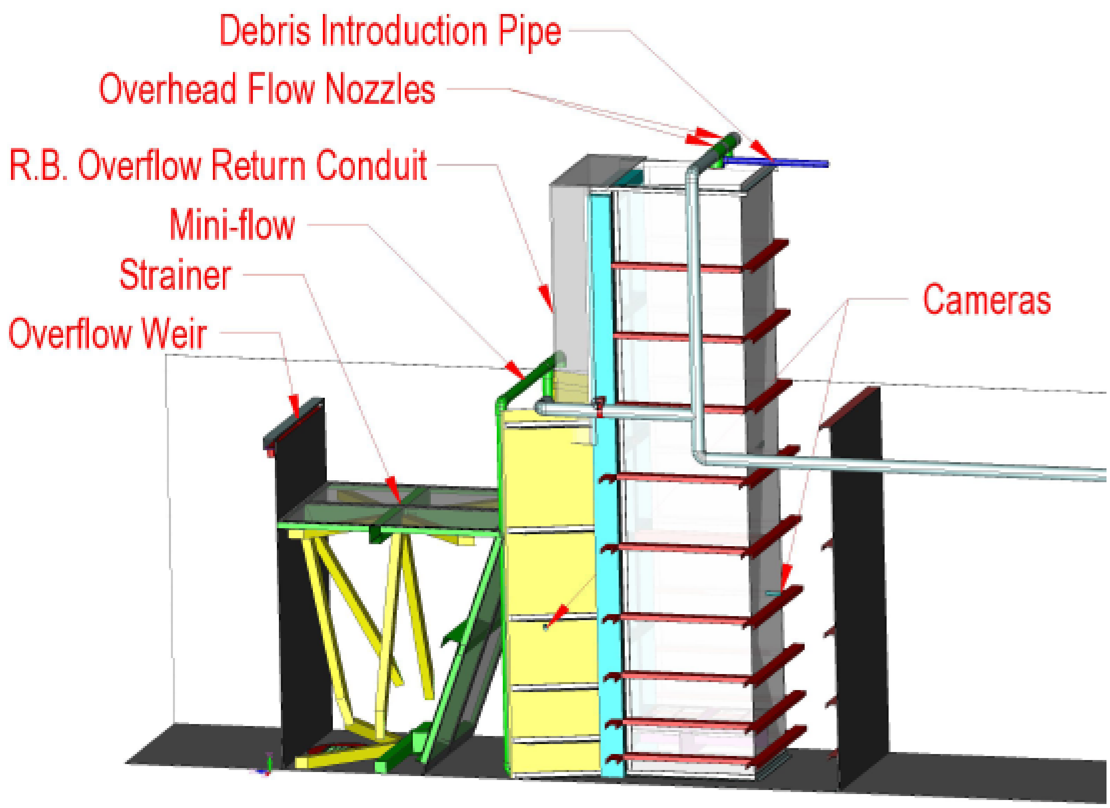
Testing Audit, February 22–27, 2010
Alden Labs
Holden, MA

Documentation Audit, March 10, March 31, April 16, 2010
AREVA Rockville Office
Rockville, MD

Applicant Document Number	Title
63-7003461-000	U.S. EPR Strainer Performance Test Plan
51-7001869-000	Chemical Preparation Plan for U.S. EPR Strainer Test
51-7003241-001	Chemical Validation Testing Final Report, Rev. 1, March 12, 2010
32-7002848-000	Sump Chemistry Modeling for U.S. EPR, Rev. 0, February 4, 2010

AREVA Condition Report 2009-8255-CR (Synopsis)

FIGURE 1



Debris Introduction Pipe
Overhead Flow Nozzles
R.B. Overflow Return Conduit
Mini-flow
Strainer
Overflow Weir
Cameras

TABLE 2		
Flume/Strainer Width	5	feet
Water Depth in Flume	9.25	feet
Strainer Length in Flume	6.6	feet
Overhang Length in Flume	2.6	feet
Strainer Height	7.1	feet
Strainer Screened Height	7.5	feet
Test Strainer Area	70.6	square feet
Total Active Strainer Area	753.5	square feet
Scale Factor	9.37%	
Total Active Strainer Flow Rate	3284	gpm
Heavy Floor Flow Rate	2997	gpm
Total Test Flume Flow Rate	307.8	gpm
Test Flume Heavy Floor Flow	280.9	gpm
Double Retaining Basket Area	642	square feet
Test Flume RB area	60.17	square feet
Test Flume RB width	3.1	feet
Double RB Volume in Plant	2024	cubic feet
RB Volume in Flume	187.9	cubic feet
Basket Length	3.7	feet
Test Flume Volume (w/o piping)	3885	gallons
Test Flume Piping Volume	236.4	gallons
Total Flume Volume	4122	gallons
Flume Turnover Time	14	minutes
Mini-Flow Flow Rate	26.9	gpm

TABLE 3

Type	Quantity	Weight Conversion	Scaled	Form
Nukon	6.62 ft3	2.4 lbm/ft3	1.49 lbm	Nukon Fines
Latent Fibers	37.50 lbm	n/a	3.51 lbm	Nukon Fines
Latent Particulates	212.50 lbm	N/A	19.92 lbm	PCI Dirt Mix
Microtherm	1 ft3	15 lbm/ft3	1.41 lbm	Microtherm Powder
Qualified Coatings*	126.5 lbm	94 lbm/ft3	11.86 lbm	Acrylic Powder [epoxy surrogate]
	958.7 lbm	457 lbm/ft3	89.86 lbm	Tin Powder [IOZ surrogate]
Unqualified Coatings	250 lbm	94 lbm/ft3	23.43 lbm	Acrylic Powder
Chemical Debris	158 kg	2.2 lbm/kg	32.65 lbm	15.91 lbm of AlOOH 16.74 lbm of CA3(PO4)2 (precipitate)

* Coatings in chip form also added: Epoxy 12 lbm, 5/8”, 4-12 mils thick