RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

APR1400 Design Certification

Korea Electric Power Corporation / Korea Hydro & Nuclear Power Co., LTD

Docket No. 52-046

RAI No.:	**63-7983**
SRP Section:	**06.02.02 – Containment Heat Removal Systems**
Application Section:	**6.2.2**
Date of RAI Issue:	**07/07/2015**

Question No. 06.02.02-14

Review procedure #9 of SRP 6.2.2, “Containment Heat Removal Systems,” addresses performance evaluations for equipment downstream of the IRWST sump strainer with regard to debris ingestion. To complete this review, additional information is needed. Technical Report APR1400-E-N-NR-14001-P, Section 4.2.2.4, “Post-LOCA Fluid Constituents,” describes the total amount of debris generated during an LBLOCA and the methodology to determine the amount of debris that passes through the IRWST sump strainer. For reflective metal insulation (RMI), the applicant states the following:

> Results of the NRC debris generation test documented in NUREG/CR-6808, “Knowledge Base for the Effect of Debris on Pressurized Water Reactor Emergency Core Cooling Sump performance”, show that RMI debris size distribution ranges from 6.35 mm (0.25 inch) to 152.4 mm (6 inch). RMI debris will not bypass the sump screens and enter the ECCS because the size of the RMI debris is greater than the perforated plate hole diameter of the sump strainer. As a result, this evaluation assumes no RMI passes through the sump strainer.

The NRC staff requests that the applicant describe and provide technical justification in the technical report that the RMI testing referenced in NUREG/CR-6808 is applicable to the APR1400 reactor and provides reasonable assurance that RMI in the APR1400 reactor will not pass through the IRWST sump strainer. Also, the applicant is requested to describe in the technical report any specific RMI testing in addition to that referenced in NUREG/CR-6808.

Response

One of the tested RMIs in NUREG/CR-6808 will be selected. The DCD will be revised to include a COL information item which requires the COL applicant to confirm the RMI is one of the types tested in NUREG/CR-6808. In addition, the APR1400 has similar NSSS layout and plant operating conditions as US PWRs. Therefore, it is reasonable to apply NUREG/CR-6808 information to the APR1400.

Following the SE for NEI 04-07, RMI is sufficiently dense and the flow rate toward the strainers is sufficiently slow, such that RMI debris will not reach the strainers. Moreover, the minimum RMI foil size suggested in NUREG/CR-6808 is between 0.25 and 1 inch; therefore, even if RMI debris reached the strainers, it could not bypass the strainers.

There is no specific RMI test information because the APR1400 uses NUREG/CR-6808.

Impact on DCD

DCD, Table 1.8-2, Subsection 6.8.4.5.3, 6.8.6, and 6.8.7 will be revised, as shown in the attachment associated with this response.

Impact on PRA

There is no impact on the PRA.

Impact on Technical Specifications

There is no impact on the Technical Specifications.

Impact on Technical/Topical/Environmental Reports

There is no impact on any Technical, Topical, or Environmental Report.

Table 1.8-2 (9 of 29)

Item No.	Description
COL 6.1(1)	The COL applicant is to identify the implementation milestones for the coatings program.
COL 6.2(1)	The COL applicant is to identify the implementation milestone for the CILRT program.
COL 6.3(1)	The COL applicant is to prepare operational procedures and maintenance programs as related to leak detection and contamination control.
COL 6.3(2)	The COL applicant is to maintain complete documentation of system design, construction, design modifications, field changes, and operations.
COL 6.4(1)	The COL applicant is to provide automatic and manual operating procedures for the control room HVAC system, which are required in the event of a postulated toxic gas release.
COL 6.4(2)	The COL applicant is to provide the details of specific toxic chemicals of mobile and stationary sources and evaluate the MCR habitability based on the recommendations in NRC RG 1.78 to meet the requirements of TMI Action Plan Item III.D.3.4 and GDC 19.
COL 6.4(3)	The COL applicant is to identify and develop toxic gas detection requirements to protect the operators and provide reasonable assurance of the MCR habitability. The number, locations, sensitivity, range, type, and design of the toxic gas detectors are to be developed by the COL applicant.
COL 6.5(1)	The COL applicant is to provide the operational procedures and maintenance program as related to leak detection and contamination control.
COL 6.5(2)	The COL applicant is to maintain the complete documentation of system design, construction, design modifications, field changes, and operations.
COL 6.6(1)	The COL applicant is to identify the implementation milestones for ASME Section XI inservice inspection program for ASME Code Section III Class 2 and 3 components.
COL 6.6(2)	The COL applicant is to identify the implementation milestone for the augmented inservice inspection program.
COL 6.8(1)	The COL applicant is to provide the operational procedures and maintenance program for leak detection and contamination control.
COL 6.8(2)	The COL applicant is to provide the preparation of cleanliness, housekeeping, and foreign materials exclusion program.
COL 6.8(3)	The COL applicant is to maintain the complete documentation of system design, construction, design modifications, field changes, and operations.
COL 6.8(4)	The COL applicant is responsible for the establishment and implementation of the Maintenance Rule program in accordance with 10 CFR 50.65.
COL 7.5(1)	The COL applicant is to provide a description of the site-specific AMI variables such as wind speed, and atmosphere stability temperature difference.
COL 7.5(2)	The COL applicant is to provide a description of the site-specific EOF.

COL 6.8(5)
The COL applicant is to confirm that the RMI is one of the tested RMIs in NUREG/CR-6808.

and coating debris, the diameter of the ZOI is defined as 2 and 4 (10 for IOZ) times of diameter of the broken pipe respectively.

For latent debris, 90.72 kg (200 lbs) of latent debris with a 7.5 percent / 92.5 percent (fiber to particulate) spilled is assumed as latent debris loads. To deal with the quantity of miscellaneous debris, a 9.29 m^2 (100 ft^2) penalty of sacrificial strainer surface area per sump is applied.

Total amount of debris generated during an LBLOCA are provided in Table 6.8-3.

6.8.4.5.3 Debris Characteristics

Three potential sources of debris are evaluated for their impacts on the APR1400 recirculation flow path and LTCC.

All fibrous latent debris within containment is assumed as fines easily remains suspended in water (even relatively quiescent water) and collected in the sumps following the SE for Nuclear Energy Institute (NEI) 04-07 (reference 8).

For RMI, it is assumed to consist of 75 percent for small fines and 25 percent for large pieces as the size distribution of any type of RMI inside a pipe break ZOI in accordance with NEI 04-07 guideline (Reference 7). RMI is sufficiently dense and the flow rates are also sufficiently small so that the RMI debris is considered as non-suspended and is not transported to the strainer.

In addition, because the size of the RMI debris is greater than the perforated plate hole diameter of the strainer, based on the results of the NRC debris generation test in NUREG/CR-6808 (Reference 16), it is assumed that no RMI passes through the strainers. The COL applicant is to confirm that the RMI is one of the tested RMIs in NUREG/CR-6808 (COL 6.8(5)).

For coatings, all qualified coatings within the ZOI are considered small fine particles based on Section 3.4.3.2 of NEI 04-07 (Reference 7). All coating debris will be suspended and transported in the recirculating water along with the latent debris to the strainers.

For chemical precipitates, detail information is provided in Subsection 6.8.4.5.7.

The size range of the debris materials is based on (i) the assumption that 100 percent of particulates will bypass the ECCS strainers, and (ii) guidance from NEI 04-07 Volume 2 Appendix V (Reference 7). The concentration of the post-LOCA fluid constituents is

The COL applicant is responsible for the establishment and implementation of the Maintenance Rule program in accordance with 10 CFR 50.65 (COL 6.8(4)).

d. A containment coating monitoring program is implemented in accordance with the requirements of NRC RG 1.54, Rev. 2 (Reference 15). The coatings program is described in Subsection 6.1.2.

6.8.5 Testing and Inspection

Inservice inspection and testing of ASME Section III Class 2 and 3 components are conducted in accordance with the programs described in Subsection 3.9.6 and Section 6.6.

6.8.6 Combined License Information

COL 6.8(1) The COL applicant is to provide the operational procedures and maintenance program for leak detection and contamination control.

COL 6.8(2) The COL applicant is to provide the preparation of cleanliness, housekeeping, and foreign materials exclusion program.

COL 6.8(3) The COL applicant is to maintain the complete documentation of system design, construction, design modifications, field changes, and operations.

COL 6.8(4) The COL applicant is responsible for the establishment and implementation of the Maintenance Rule program in accordance with 10 CFR 50.65.

COL 6.8(5)
The COL applicant is to confirm that the RMI is one of the tested RMIs in NUREG/CR-6808.

6.8.7 References

1. 10 CFR 20.1406, "Radiological Criteria for Unrestricted Use," U.S. Nuclear Regulatory Commission.

2. Regulatory Guide 4.21, "Minimization of Contamination and Radioactive Waste Generation: Life-Cycle Planning," Rev. 0, U.S. Nuclear Regulatory Commission, June 2008.

15. Regulatory Guide 1.54, "Service Level I, II, and III Protective Coatings Applied to Nuclear Power Plants," Rev. 2, U.S. Nuclear Regulatory Commission, December 2010.

16. NUREG/CR-6808, "Knowledge Base for the Effects of Debris on Pressurized Water Reactor Emergency Core Cooling Sump Performance," U.S. Nuclear Regulatory Commission, February 2003.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

APR1400 Design Certification

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Docket No. 52-046

RAI No.:	**63-7983**
SRP Section:	**06.02.02 – Containment Heat Removal Systems**
Application Section:	**6.2.2**
Date of RAI Issued:	**07/07/2015**

Question No. 06.02.02-21

Review procedure #9 of SRP 6.2.2, "Containment Heat Removal Systems," addresses performance evaluations for equipment downstream of the IRWST sump strainer with regard to debris ingestion. To complete this review, additional information is needed. Technical Report APR1400-E-N-NR-14001-P, Section 4.2.3.3.1, states that the containment main spray nozzles and auxiliary spray nozzles have an orifice diameter of 13.1 millimeter [mm] (0.516 inch) and 5.6 mm (0.22 inch), respectively. The orifice is the smallest portion of spray nozzle. The strainer hole size is 2.38 mm (0.094 inch). Containment spray nozzles are significantly larger than the strainer hole size. Their one-piece design provides a large, unobstructed flow passage that resists clogging by particles. Therefore, the applicant states that the potential of spray nozzle plugging is very low. The NRC staff has the following requests regarding the spray nozzles:

a. The performance of the spray nozzles in accomplishing their necessary safety functions may be affected by changes to the CSS fluid physical or chemical properties, even though the flow rate through the nozzles is not restricted. The staff requests that the applicant describe in the technical report the evaluation of the effects of entrained debris, chemicals, and gases on the performance of the CSS spray nozzles, especially regarding the effects on spray droplet size distribution for containment pressure suppression and removal of fission products from the containment atmosphere.

b. The staff requests that the applicant provide a drawing of the main and auxiliary spray nozzles to confirm the large, unobstructed flow passage that resists clogging by particles.

Response

a. The diametric wear and flow rate increase for the containment spray nozzles are listed in Table 4.2-7. The flow rate increase caused by entrained debris is very low and will not affect the spray pattern, coverage, or spray function. The containment spray nozzle orientation, nozzle spray profiles, and sprayed regions are shown in Figures 6.2.2-3, 6.2.2-4, and 6.2.2-5 of the DCD. Subsection 4.2.3.3.2 will be revised to describe the evaluation of wear rate for the containment spray nozzles.

For chemical effects on the containment spray nozzles, only chemical precipitates smaller than (or equal to) the perforated plate hole size of the IRWST sump strainers are ingested by the CSS. The diameter of the containment spray nozzles is significantly larger than the size of the ingested chemical precipitates, and the velocity of the post-LOCA fluid is expected to be sufficient to avoid settling. Therefore, the nozzles downstream of the sump strainers are not expected to be clogged with chemical precipitates to such an extent that blockage of flow occurs. The chemical effects evaluation for the CSS, including containment spray nozzles, is incorporated through the response to RAI 63-7983, Question No. 06.02.02-29.

The expanded nozzle orifice size due to wear reduces the nozzle orifice pressure drop slightly, which allows entrained gas to be retained in the sprayed water. This effect creates a more even flow of sprayed water through the nozzle orifice.

b. Drawings of the main and auxiliary spray nozzles for the reference plants, Shin Kori NPPs Unit 3&4, are provided in Attachment 2.

Impact on DCD

There is no impact on the DCD.

Impact on PRA

There is no impact on the PRA.

Impact on Technical Specifications

There is no impact on the Technical Specifications.

Impact on Technical/Topical/Environmental Reports

Technical Report APR1400-E-N-NR-14001-NP, subsection 4.2.3.3.2 will be revised as shown in Attachment 1.

through the sump strainer. Therefore the valves do not clog due to post-LOCA insulation debris.

4) Orifice

ECCS and CSS flow is controlled though a combination of orifices and throttled valves. Orifices are used for throttling system flow. ECCS and CSS pressure and flow are monitored in the MCR. The orifice sizes are above 20.3 mm (0.8 inch). Flow velocities in all cases are above the settling velocities of the post-LOCA fluid (Table 4.2-6). Therefore, the potential of orifice plugging is very low.

5) Spray Nozzles

The containment main spray nozzles and auxiliary spray nozzles has an orifice of 13.1 mm (0.516 inch) and 5.6 mm (0.22 inch) diameter, respectively. This orifice is the smallest portion of spray nozzle. The strainer hole size is 2.38 mm (0.094 inch). Containment spray nozzles are significantly larger than the strainer hole size. Their one-piece design provides a large, unobstructed flow passage that resists clogging by particles. Therefore, the potential of spray nozzle plugging is very low.

4.2.3.3.2 Wear Rate Evaluation for Valves, Orifices and Pipes

, Spray Nozzles,

Erosive wear is caused by particles that impinge on a component surface and remove material from the surface because of momentum effects. The wear rate of a material depends on the debris type, debris concentration, material hardness, flow velocity, and valve position.

Flow rates of 6,057 L/min (1,600 gpm) and 26,963 L/min (7,123 gpm)) for SIS and CSS, respectively, are conservatively assumed for the wear rate evaluation of the components listed in Table 4.2-1. The ECCS design flow rates listed in Table 4.2-1 include the maximum flow rate of the SI pump, CS pump, and the sum of the SIS and CSS flows based on system configuration.

, spray nozzles,

Table 4.2-7 contains a summary of the piping and orifice wear calculation. Based upon the results of wear evaluation for piping and orifice, it is concluded that the system piping and component flow resistances will change minimally during the course of the LOCA. Therefore, flow balances and system performance are not affected in an appreciable manner. The resulting flows and pressures are consistent or conservative with respect to the accident analysis. The minor resistance changes do not affect the system flow calculations and design basis analysis.

The wear rate of ECCS valves will be provided by the vendor. The vendor will qualify the ECCS valves to operate with the post-LOCA fluids for at least 30 days, using the qualification guidance of ASME QME-1-2007 endorsed by RG1.100 Revision 3. As part of the qualification process, the vendor will provide data and/or analyses to support acceptable wear rates during operation in post-LOCA fluids (Table 4.2-5) at the associated flow velocities listed in Table 4.2-6.

Vendor(s) will also provide tests and/or analyses to support acceptable wear rates of pipes and orifices. In addition, an analysis will be provided to confirm that the overall system resistance/pressure drop across the ECCS is consistent with the safety analysis results for the 30 day mission time.

For conservatism, vendors will perform component wear evaluations at the assumed flow rates/velocities.

The expanded nozzle orifice size due to wear reduces the nozzle orifice pressure drop slightly, which allows entrained gas to be retained in the sprayed water. This effect creates a more even flow of sprayed water through the nozzle orifice.

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SRP Section:	**06.02.02 – Containment Heat Removal Systems**
Application Section:	**6.2.2**
Date of RAI Issue:	**07/07/2015**

Question No. 06.02.02-26

Review procedure #9 of SRP 6.2.2, "Containment Heat Removal Systems," addresses performance evaluations for equipment downstream of the IRWST sump strainer with regard to debris ingestion. To complete this review, additional information is needed. Technical Report APR1400-E-N-NR-14001-P, Section 4.2.3.3.2, "Wear Rate Evaluation for Valves, Orifices and Pipes," describes the wear rate evaluation for valves, orifices, and pipes during operation with post-LOCA fluids and states that the vendor will provide tests and/or analysis to support acceptable wear rates of valves, pipes and orifices. The wear rate evaluation is performed using the post-LOCA fluid constituents listed in Technical Report APR1400-E-N-NR-14001-P, Table 4.2-5, and the flow velocities listed in Technical Report APR1400-E-N-NR-14001-P, Table 4.2-6. However, the technical report does not identify the material properties (e.g., abrasiveness) for the vendor to evaluate the wear rate. The NRC staff requests that the applicant describe in the technical report the material properties used to determine wear rate of the components.

Response

Wear rate information for different system materials will be added to Section 4.2.2.4 of the technical report. The wear rate data was obtained by using coarse sand as the wearing material, as described in ADS-Pipe Technical Note 2.116, "Abrasion Resistance of Piping Systems." The technical note is referenced by WCAP-16406-P-A.

Impact on DCD

There is no impact on the DCD.

Impact on PRA

There is no impact on the PRA.

Impact on Technical Specifications

There is no impact on the Technical Specifications.

Impact on Technical/Topical/Environmental Reports

Technical report APR1400-E-N-NR-14001-P/NP, Subsection 4.2.2.4 and Section 6 will be revised, and Table 4.2-8 will be added, as shown in the attachment associated with this response.

LIST OF TABLES

1) This evaluation conservatively assumes that 100% of the particulates will bypass the IRWST sump strainers. Therefore, it is reasonable to assert that the size of the particulate debris is less than (or equal to) the perforated plate hole size of the IRWST sump strainers, 2.38 mm (0.094 inch).

2) Fines are defined as debris materials that are less than 101.6 mm (4 inch) by 101.6 mm (4 inch), based on NEI 04-07 Volume 1, Subsection 3.6.3 (Reference [3-2]).

3) Large pieces are defined as debris materials that are greater than 101.6 mm (4 inch), based on NEI 04-07 Volume 1, Subsection 3.6.3 (Reference [3-2])..

The total amount of debris generated during an LBLOCA is estimated in Appendix B of this report and summarized in Table 4.2-3. The amount of reflective metallic insulation (RMI) listed in Table 4.2-3 is based on a size distribution of 75% of small fines and 25% for large pieces.

The amount of debris that passes through the IRWST sump strainer depends on the size of the strainer hole, ratio of open to closed area of the strainer, the fluid approach velocity to the strainer, and the strainer geometry. This evaluation assumes that LBLOCA debris materials that are less than or equal to the perforated plate hole size 2.38 mm (0.094 inch) of the IRWST sump strainers will bypass the sump strainer. As a result, the ECCS will ingest 100% of the coating particulates.

Miscellaneous debris materials are large pieces with a debris size range that is significantly greater than the perforated plate hole size sump strainer. As a result, the ECCS will not ingest miscellaneous debris materials.

Bypass testing of the latent debris yielded a fiber bypass percentage of less than 25% (see Appendix D). This evaluation uses bounding bypass percentages of 100% for latent particulates (i.e., dust and dirt). The bypass percentage for latent fiber uses a conservative of 100%. The actual bypass percent for latent fiber is evaluated by qualified test results conducted specific to the APR1400 plant conditions. The detail test plan is provided in Reference [4-1] and the test result is provided in Appendix D of this report. Based on the results of bypass testing, the actual bypass percentage for latent fiber is approximately 25%.

Results of the NRC debris generation test documented in NUREG/CR-6808 (Reference [4-2]) show that RMI debris size distribution ranges from 6.35 mm (0.25 inch) to 152.4 mm (6 inch). RMI debris will not bypass the sump screens and enter the ECCS because the size of the RMI debris is greater than the perforated plate hole size sump strainer. As a result, this evaluation assumes no RMI bypasses through the sump strainer.

Reference information (Reference [3-12]) on material properties to evaluate the wear rate of the components is provided in Table 4.2-8.

4.2.2.5 ECCS Flow Rate and Flow Velocity

The APR1400 is a fixed resistance system under valve wide-open conditions. Emergency Operating Procedures do allow for operator action to throttle flow based on main control room (MCR) indication. The range of operation is therefore assumed to be from shutoff head conditions to runout conditions.

To evaluate debris settlement and component wear during an LBLOCA, this evaluation conservatively assumes ECCS and CSS flow rates ranging from shutoff head conditions to runout conditions.

Table 4.2-8 Wear Rates of Material under Abrasive Slurries

Material	Wear Rates [mm/year (inches/year)]	
	Coarse Sand	
	2.13 m/sec (7 ft/sec)	4.58 m/sec (15 ft/sec)
Steel	0.65 (0.0256)	1.81 (0.0713)
Aluminum	1.81 (0.0713)	7.48 (0.2945)
Polyethylene	0.06 (0.0024)	0.46 (0.0181)
ABS	0.36 (0.0142)	2.07 (0.0815)
Acrylic	0.99 (0.0390)	4.10 (0.1614)
Geometric Average	4.6183	

Added

6 REFERENCES

1-1 Regulatory Guide 1.82, "Water Sources for Long-term Recirculation Cooling Following a Loss-of-Coolant Accident," Revision 4, U.S. Nuclear Regulatory Commission, March 2012.

1-2 SECY-12-0093, "Closure Options for Generic Safety Issue-191, Assessment of Debris Accumulation on Pressurized Water Reactor Sump Performance," U.S. Nuclear Regulatory Commission, July 9, 2012.

2-1 Regulatory Guide 1.54 Revision 2, "Service Level I, II, and III Protective Coatings Applied to Nuclear Power Plants," U.S. Nuclear Regulatory Commission, October 2010.

2-2 ASTM D 3911-08, "Standard Test Method for Evaluating Coatings Used in Light-Water Nuclear".

3-1 "Design Control Document for the APR1400," Rev.0, KEPCO & KHNP, December 2014.

3-2 NEI 04-07, "Pressurized Water Reactor Sump Performance Evaluation Methodology," Nuclear Energy Institute, May 2004.

3-3 Safety Evaluation by the Office of Nuclear Reactor Regulation Related to NRC Generic Letter 2004-02, Nuclear Energy Institute Guidance Report (Proposed Document Number NEI 04-07), "Pressurized Water Reactor Sump Performance Evaluation Methodology," Nuclear Energy Institute, December 2004.

3-4 NRC Staff Review Guidance regarding Generic Letter 2004-02, "Closure in the Area of Strainer Head Loss and Vortexing," U.S. Nuclear Regulatory Commission, March 2008.

3-5 APR1400-E-A-T(NR)-13002-NP, "APR1400 IRWST ECCS Sump Strainer Prototype Hydraulic Qualification Test Plan," Rev. 1, KHNP, August 2013.

3-6 Regulatory Guide 1.1, Revision 4, "Water Sources for Long-term Recirculation Cooling Following a Loss-of-Coolant Accident," Revision 4, U.S. Nuclear Regulatory Commission, March 2012.

3-7 APR1400-Z-A-NR-14007-P, "LOCA Mass and Energy Release Methodology for the APR1400," Rev.0, KHNP, December 2014.

3-8 EPRI, Advanced Light Water Reactor Utility Requirements Documents Vol. II, ALWR EVOLUTIONARY PLANT, Ch 5 "Engineered Safety System," Rev.7, December 1995.

3-9 CRANE , "Flow of Fluids through Valve, Fitting, and Pipe," Technical Paper No. 410, 2009.

3-10 SECY-11-0014, "Use of Containment Accident Pressure in Analyzing Emergency Core Cooling System and Containment Heat Removal System Pump Performance in Postulated Accidents," U.S. Nuclear Regulatory Commission, January 31, 2011.

3-11 WCAP-16530-NP-A, "Evaluation of post-Accident Chemical Effect in Containment Sump Fluid to Support GSI-191," Rev.0, Westinghouse Electric Corporation, April 2008.

4-1 APR1400-E-A-T(NR)-13003-P, "APR1400 IRWST ECCS Sump Strainer Bypass Test Plan," Rev. 1, KHNP, August 2013.

4-2 NUREG/CR-6808, "Knowledge Base for the Effects of Debris on Pressurized Water Reactor Emergency Core Cooling Sump Performance," U.S. Nuclear Regulatory Commission, February 2003.

4-3 WCAP-16406-P-A, "Evaluation of Downstream Sump Debris Effects in Support of GSI-191," Rev. 1, Westinghouse Electric Corporation, March 2008.

4-4 NUREG/CR-6902, "Effects of Insulation Debris on Throttle Valve Flow Performance," U.S. Nuclear Regulatory Commission, March 2006.

4-5 NUREG/CR-6913, "Chemical Effects Head-Loss Research in Support of Generic Safety Issue 191, Argonne National Laboratory," U.S. Nuclear Regulatory Commission, 2006.

4-6 NUREG/CR-6914, "Integrated Chemical Effects Test Project: Consolidated Data Report, Volume 1," U.S. Nuclear Regulatory Commission, 2006.

4-7 WCAP-16793-NP, "Evaluation of Long-Term Cooling Considering Particulate, Fibrous and Chemical Debris in the Recirculating Fluid," Revision 2, Westinghouse Electric Corporation, October 2011.

4-8 "Final Safety Evaluation by the Office of Nuclear Reactor Regulation: Topical Report WCAP-16793-NP, Revision 2," U.S. Nuclear Regulatory Commission, April 2013.

4-9 APR1400-F-A-NR-14003-P, Rev. 0, "Post-LOCA Long Term Cooling Evaluation Model," KHNP, September 2014.

3-12 ADS-Pipe Technical Note 2.116, "Abrasion Resistance of Piping Systems", Hillard, Ohio 43026, November 1994.