REVISED 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. 06.02.02-24

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. Technical Report APR1400-E-N-NR-14001-P, 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, the report concludes 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. 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. The NRC staff requests that the applicant describe the analysis in the technical report to confirm that the overall system resistance/pressure drop across the SIS and CSS is consistent with the safety analysis results for the 30-day mission time. Also, the applicant is requested to describe in the technical report the analysis documentation that will provide verification of acceptable SIS and CSS operation.

Response – (Rev.2)

The individual component’s evaluation due to erosive wear is described in Technical Report, Section 4.2.3 and is supplemented in the responses to related RAIs.

In addition to this component’s evaluation, the wear evaluation of the heat exchangers will be added in Technical Report, Section 4.2.3.3.2 and the wear evaluation of the piping, spray nozzles, and orifices will be revised in Section 4.2.3.3.2. Finally, the overall system evaluation will be added in Technical Report, Section 4.2.4.

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, Sections 4.2.3.2.2, 4.2.3.3.2, and 4.2.4 will be revised as shown in the Attachment associated with this response.

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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(6))~~
~~The COL applicant is to evaluate the potential increase of flowrates in ECCS and CSS due to component wear and to verify that any increased flowrates in ECCS and CSS are within the maximum allowable flowrates for at least 30 days of post-LOCA operation.~~

This result also verifies that inadequate core or containment cooling does not occur because of debris blockage at flow restrictions, plugging or excessive wear of close-tolerance component (e.g., pumps, heat exchangers, piping, valves, spray nozzles) in the flow path. The component design parameter used in the evaluation of ex-vessel downstream effect is listed in ~~Table~~ Tables 6.2.2-2, 6.3.2-1, and 6.8-4. ~~The COL applicant is to evaluate the potential increase of flowrates in ECCS and CSS due to component wear and to verify that any increased flowrates in ECCS and CSS are within the maximum allowable flowrates for at least 30 days of post-LOCA operation (COL 6.8(6)).~~

As a result of strainer bypass test, the amount of bypass fiber per fuel assembly (FA) is less than the 15 gram limit. Based on this information, the evaluation result of in-vessel downstream effect is that the maximum total deposit thickness and the peak cladding temperature are maintained within the WCAP-16793-NP (Reference 10) LTCC criteria with enough margin, and the LTCC can be maintained.

6.8.4.5.10 Potential Debris Source Control

Programmatic controls are established to ensure that potential sources of debris introduced into containment (e.g., insulation, coatings, foreign material, aluminum), and plant modifications do not adversely impact the SI and CS/SC recirculation function.

Programmatic controls are established consistent with the guidance in NRC RG 1.82, Rev. 4 (Reference 3), which provides reasonable assurance that (1) potential quantities of post-accident debris are maintained within the bounds of the analyses and design bases that support the safety injection (SI), containment spray (CS), and shutdown cooling (SC) recirculation functions and (2) the long-term core cooling requirements of 10 CFR 50.46 (Reference 11) are met.

The following is a summary of the programmatic controls that are implemented to provide reasonable assurance of the proper operation of IRWST sump strainer and limits the quantities of latent debris (e,g., unintended dirt, dust, paint chips, fibers) and miscellaneous debris (e.g., tape, tags, stickers) are limited inside containment:

a. Preparation of a cleanliness, housekeeping, and foreign materials exclusion program. This program addresses latent and miscellaneous debris inside containment. An acceptance criterion below the conservative assumption of 90.72 kg (200 lb) for latent debris inside containment is consistent with Reference 4. The programs also ensure that the quantity of miscellaneous debris, such as signs, placards, tags or stickers in the containment is limited so that the 9.29 m^3

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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(6))~~
~~The COL applicant is to evaluate the potential increase of flowrates in ECCS and CSS due to component wear and to verify that any increased flowrates in ECCS and CSS are within the maximum allowable flowrates for at least 30 days of post-LOCA operation.~~

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.

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(Reference [4-3]).

The tube wear for the CS heat exchangers and CS pump miniflow heat exchangers is evaluated assuming a free-flowing wear model, the mission time of 30 days, and conservative mass concentration of debris of 1,000 ppm, which is larger than that in Table 4.2-5. The tube wear for the CS heat exchangers and CS pump miniflow heat exchangers is commonly calculated to 0.064 mm (0.00252 inch). The available thicknesses for erosion, i.e. the actual wall thickness minus the required wall thickness to retain pressure, are calculated to 0.381 mm (0.015 inch) for CS heat exchanger and 0.635 mm (0.025 inch) for CS pump miniflow exchanger. The total tube wear during the mission time (30 days) is very small comparing the available thickness for erosion. Therefore, the heat exchanger tubes have sufficient thickness to withstand the erosion effects of the debris particles.

4.2.3.2.2 Heat Exchanger Performance and Wear

The CS heat exchange is sized and designed with a fouling factor of 0.000088 m^2-K/W (0.0005 hr-ft^2-°F/Btu) to maximize heat transfer efficiency and performance. The post-LOCA fluid could potentially cause particulate fouling of the heat exchanger tubes if the fluid velocity is less than the terminal settling velocity of the debris. However, fouling is considered a long-term phenomenon. In addition, the heat load of the CS heat exchangers is greatest at the start of the event and decreases rapidly over the first 24 hours. Heat removal capacity is not degraded over this short period. Any potential reduction in capability over the 30 day mission time is gradual and well within the nominal heat exchanger design.

The CS heat exchanger tubes are specified to be constructed of 304 stainless steel. Stainless steel is appropriate for use as heat exchanger tubing and is standard for use in mildly abrasive applications. The tube material will not significantly degrade considering operation with post-LOCA fluid over an intended mission time of 30 days.

Therefore, the CS heat exchanges are fully capable of performing their intended function using post-LOCA fluid as the process fluid.

The vendor will also provide test and/or analysis to confirm that the heat exchanger tube material will not degrade significantly (i.e., “eroded” tube thickness > minimum tube thickness required to retain pressure) in post-LOCA fluid over the 30 day mission time.

4.2.3.3 Evaluation of Valves, Orifices and Pipes

4.2.3.3.1 Blockage and Debris Settling Evaluation for Valves, Orifices and Pipes

The strainer hole size is 2.38 mm (0.094 inch). Therefore, when the gap of the components is 2.38 mm (0.094 inch) + 0.238 mm (0.0094 inch) (10%) or 2.62 mm (0.103 inch) or less than this value, the flow-path or component may be blocked. This is consistent with Reference [4-3]. Components that are in the flow-paths during accidents are listed in Table 4.2-1.

Piping

Fluid velocity decreases with an increase in pipe diameter. Therefore, the lowest velocity in the ECCS occurs in the region with the largest pipe diameter/flow area. Flow velocities in all piping except several cases (24 inch, 20 inch, and 10 inch SI Pump suction lines and 12 inch SI pump discharge line) are above the settling velocities of the post-LOCA fluid. Refer to Table 4.2-6.

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 ab velocities of the post-L low.

The results show that the system piping and component flow resistances will be changed minimally during the course of the LOCA. 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.

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.

~~Vendor(s) will qualify the ECCS and CSS piping, nozzles, and orifices to support wear rates of piping, nozzles, and orifices in accordance with QME-1-2007 endorsed by RG 1.100 Revision 3.~~

4.2.3.3.2 Wear Rate Evaluation for Valves, Orifices and Pipes

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.

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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 potential increase of flowrates in ECCS and CSS due to component wear will be evaluated and any increased flow rates are within the maximum allowable flowrates for at least 30 days of post-LOCA operation will be verified.~~

4.2.3.4 Instrument Tubing Clogging Evaluation

According to WCAP-16406-P (Reference [4-3]), when the instrument tubing lines maintain a solid state prior to emergency core cooling operation, it is determined tubing integrity is not affected because there is almost no possibility of debris ingestion, and the evaluation shows there are no effects from flow blockage and wear because flow velocities in all cases are above the settling velocities of the post-LOCA fluid. Also, all instrument connections used in the APR1400 are located either at the horizontal or above.

4.2.3.5 Chemical Effects Evaluation

Chemical precipitates (aluminum oxy-hydroxide, sodium aluminum silicate and calcium phosphate) are formed when concrete and LOCA-generated debris materials are exposed to the buffering materials in the IRWST. This reaction forms additional solid species that could potentially pass through the sump screen and degrade the performance of the ECCS.

In-vessel fuel blockage tests performed using particulate, fiber and aluminum oxy-hydroxide precipitate demonstrate that the flow resistance created by the chemical precipitate is significantly less than the pump head that is available in the ECCS piping system. Secondly, similar to the particulate and fiber debris materials, only chemical precipitates smaller than (or equal to) the perforated plate hole size of IRWST sump strainer will be ingested by the ECCS. The diameter of the ECCS piping, orifices, valves and heat exchanger tubes are 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, components downstream of the sump strainers are not expected to become clogged with chemical precipitates such that blockage of flow occurs.

In addition, the qualification of the ECCS pumps, performed with conservative amounts of post-LOCA debris (Table 4.2-5), in accordance with ASME QME-1-2007, will include confirmation that the internal running clearance of the ECCS pumps is sufficiently large enough to avoid clogging, and supports acceptable pump and seal operation during the 30-day post-LOCA mission time.

The chemical precipitates are also unlikely to reduce the efficiency of the heat exchanger because most precipitates will form later in the post-LOCA event when temperatures have decreased ((NUREG/CR-6913 (Reference [4-5]) and NUREG/CR-6914 (Reference [4-6])) and when the required heat transfer capacity of the ECCS heat exchangers has ample margin. Precipitates that form soon after the pipe break are only expected to form, at most, thin deposit films on the heat exchanger tubes. Deposit thicknesses are limited by scrubbing from particulate in the coolant as well as the relatively high flow rate and pressure differential associated with the ECCS. In addition, the CS heat exchangers are designed and specified with conservative fouling factors to maximize heat transfer efficiency and performance. Operating experience has also demonstrated that fouling is a long-term phenomenon and heat exchangers can still perform adequately with significant fouling. Therefore, the chemical precipitates are not expected to significantly impair the heat transfer capability of the CS heat exchangers.

4.2.4 Evaluation Summary

Replaced with A

The intent of this section is to assess the downstream effects of ECCS and CSS of the APR1400 under

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Added

A

4.2.4 Overall System Evaluation

The flow increase less than 3% for an individual component due to erosive wear is considered as insignificant because the 3% value is well within nominal components manufacturing tolerances and well within the standard fluid flow calculation tolerances. Furthermore, if the flow increase for individual component is less than 3 %, the total system flow increase will become less than 3% and will be also considered as insignificant to the system flow calculations and design basis analysis.

The tube wear for the CS heat exchangers and CS pump miniflow heat exchangers is commonly calculated to 0.064 mm (0.00252 inch). The increase of tube flow area due to tube wear will result in the flow increase of 0.9% for the CS heat exchangers and 1.3% for the CS pump miniflow heat exchangers.

The flow increase in the piping, orifices, and spray nozzles are listed in the Table 4.2-7. The maximum flow increase of the components in the flow path of ECCS and CSS does not exceed 3% except for SI-OR08A/B/C/D orifices. These orifices are installed with the other orifices (SI-OR01A/B/C/D) in series on the SI pump miniflow path for the flow balance. A sufficient pressure drop will be still developed in the miniflow path through the other orifice with much less erosive wear; i.e., the flow balance to the miniflow path is still assured. In reality, the actual flow increase due to erosive wear through the orifices will be much less since the design flow to the miniflow path is 50% less than the assumed flow rate. Therefore, flow increase in the piping, orifices, and spray nozzles does not affect the overall injection flow path to the RCS and the overall spray flow path to the containment. In addition, the system flow rate and discharge pressure for the ECCS and CSS are continuously monitored in the MCR. Although valves in the flow path do not need to be adjusted during an accident, if necessary, safety injection and hot leg injection isolation valves may be throttled to satisfy the desired flow rate.

Based upon the results of wear evaluation for each component of ECCS and CSS, the flow increase due to wear does not exceed 3% in all flow paths of ECCS and CSS. Therefore, flow balances and system performance are not affected in an appreciable manner. The anticipated downstream effects on resulting flows and pressures are consistent or conservative with respect to the inputs used accident analysis. The minor resistance changes do not affect the system flow calculations and design basis analysis.

4.2.5 Evaluation Summary