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. 06.02.02-20

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 4.2.3.2.2, “Heat Exchanger Performance and Wear,” states that the CSS heat exchanger is sized and designed with a fouling factor of 0.000088 m2-K/W (0.0005 hr-ft2-°F/Btu) to maximize heat transfer efficiency and performance. The applicant also states that potential heat exchanger plugging, fouling, and wear are considered as part of the equipment specification. The NRC staff requests that the applicant specify in the technical report that heat exchanger plugging, fouling, wear and heat transfer performance in the presence of post-LOCA debris will be evaluated by the vendor during the procurement process with a certificate of compliance to provide verification that the heat exchanger meets procurement specifications.

Response

The following statement will be incorporated in the technical report to reflect the NRC staff's request.

The heat exchanger plugging, fouling, wear, and heat transfer performance in the presence of post-LOCA debris will be evaluated by the vendor during the procurement process with a certificate of compliance to provide verification that the heat exchanger meets procurement specifications.

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, Section 4.2.3.2 will be revised as shown in the attachment associated with this response.

operation with post-LOCA fluids will not impair seal performance, or cause seal failure, or significantly degrade seal leakage during the 30 day post-LOCA mission time.

6) Provide test and/or analysis to confirm:

- that the cyclone separator or any filtering device designed to protect the mechanical seal, if applicable, is not susceptible to clogging or impairment by fiber or other particulates;
- that there is no adverse impact on pump performance or reliability, for at least 30 days of operation with post-LOCA fluids.

7) The vendor will also identify any additional potential pump malfunctions, per ASME QME-1-2007.

8) The vendor will verify that the SI and CS pumps provide minimum flow rates of 397 L/min (105 gpm) and 1,817 L/min (480 gpm), respectively, at shutoff head conditions.

9) The vendor will verify that SI and CS pumps provide flow rates at run-out conditions of less than 4,675 L/min (1,235 gpm) and 24,605 L/min (6,500 gpm), respectively.

4.2.3.2 Heat Exchanger Evaluation

The CSHXs are used to remove heat from the containment atmosphere during and after an accident. The units are designed to reduce the containment atmosphere pressure in 24 hours after an accident to half of the calculated peak pressure.

The CS/RHR heat exchangers are specified as shell and U-tube units. The heat exchangers are composed of 31.75 mm (1.25 inch) OD, Birmingham Wire Gauge (BWG) 18 (1.24 mm (0.049 inch)), 304 SS tubes. A single unit is provided in each of the two CSS divisions.

~~The heat exchanger plugging, fouling and wear evaluation are done in the context of the equipment specification.~~ For velocity, a maximum tube velocity of 4.57 m/s (15 ft/s) is assumed. A nominal design and operating heat exchanger velocity range is 0.91 to 3.05 m/s (3 to 10 ft/s). Therefore the use of 4.57 m/s (15 ft/s) is conservative from a heat exchanger design perspective and bounds the heat exchanger design and procurement specification(s).

The heat exchanger plugging, fouling, wear, and heat transfer performance in the presence of post-LOCA debris will be evaluated by the vendor during the procurement process with a certificate of compliance to provide verification that the heat exchanger meets procurement specifications.

4.2.3.2.1 Heat Exchanger Plugging

The heat exchanger tubes are 31.75 mm (1.25 inch) OD, 29.26 mm (1.152 inch) ID, BWG 18 (1.24 mm (0.049 inch)). The perforated plate hole size of the IRWST sump strainers is 2.38 mm (0.094 inch). The heat exchanger tubes are significantly larger than the largest expected particle size. Therefore, a heat exchanger tube will not be plugged or blocked by post-LOCA debris. The flow velocity within a heat exchanger tube is significantly greater than the terminal settling velocity of the debris (Table 4.2-4). Therefore, the debris will not settle in the heat exchanger tubes.

These conclusions are consistent with the referenced NRC Safety Evaluation on WCAP-16406-P

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

The description of flow balances and system performance, with respect to the accident analysis, is already described in the third paragraph of Section 4.2.3.3.2 of the technical report, and the qualification of the ECCS and CSS piping, nozzles, and orifices will be performed in accordance with QME-1-2007. Therefore, Section 4.2.3.3.2 will be revised to incorporate the above response.

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, Section 4.2.3.3.2 will be revised, as shown in the attachment associated with this response.

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.

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.

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.

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. 06.02.02-28

The NRC staff requests that the applicant identify in the technical report any instruments strapped or externally mounted to the outside of the SIS or CSS piping. Strapped or externally mounted instruments that make use of the velocity of sound through the fluid medium could be affected by the type and quantity of suspended debris, chemical composition, and presence of gases. If strapped or externally mounted instruments are used, provide justification for their accuracy with suspended debris, chemical composition, and presence of gases.

Response

All instruments applied in the SIS and CSS are externally mounted. Typically, sensing lines originate from a process line and terminate at an instrument forming a "dead end line". Fluid in such sensing lines is stagnant and transfers pressure to instruments. Because the sensing lines are stagnant, changes in composition of the fluids in the process lines do not affect instrumentation.

In addition, process tap orientation is designed according to process characteristic. For example, upper taps are used when sensing lines are to contain gas or air, and side taps for sensing lines which are to contain liquids. Therefore, suspended debris, chemical compositions, and the presence of gases in process lines have no influence on the accuracy of instruments.

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

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

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. 06.02.02-29

Technical Report APR1400-E-N-NR-14001-P, Section 4.2.3.5, Chemical Effects Evaluation," states that the qualification of the ECCS (SIS) pumps, performed with conservative amounts of post-LOCA debris 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. However, this section only addresses the SIS pumps and not the CSS pumps. Also, this section does not address the chemical effects for the CSS spray nozzles. The NRC staff requests that the applicant address chemical effects evaluation for the CSS pumps and CSS spray nozzles in the technical report.

Response

The CSS pumps and the CSS spray nozzles should be included in the chemical effects evaluation of the technical report.

Technical report Section 4.2.3.5 will be revised to incorporate the chemical effects evaluation for the CSS pumps and CSS spray nozzles.

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, Section 4.2.3.5 will be revised, as shown in the attachment associated with this response.

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.

and CSS and CSS and CSS spray nozzles,

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.

and CSS

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.

CSS and CSS

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

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