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. 06.02.02-18

Technical Report APR1400-E-N-NR-14001-P, Section 4.2.3.1, states that as part of the qualification process, the pump vendor, at a minimum, will fulfill specific pump qualification criteria. The pump criteria specify that qualification will be performed using tests and/or analyses. However, to be consistent with ASME QME-1-2007 as accepted by RG 1.100, Revision 3, the criteria should specify qualification of pumps by test or a combination of test and analysis. Therefore, the NRC staff requests that the applicant revise the technical report to specify that the qualification of pumps will be accomplished by test or a combination of test and analysis. The same revision should be made wherever qualification using this standard is referenced in the report, including the wear rate evaluation description in Section 4.2.3.3.2.

Response – (Rev.2)

The SI and CS pumps and associated mechanical seals will be qualified to operate with the post-LOCA fluids for at least 30 days in accordance with ASME QME-1-2007 as endorsed by RG1.100 Revision 3. As a part of qualification, three aspects of pump operability, i.e. hydraulic performance, mechanical shaft seal assembly performance, and pump mechanical performance (vibration), are considered in evaluating the SI and CS pumps for operation with debris-laden water in accordance with the guidance of RG 1.82 Revision 4.

Technical Report Sections 4.2.3.1 and 4.2.3.3.2 will revised to provide the pumps and valves evaluation for operation with the post-LOCA fluids, as a part of the qualification in accordance with ASME QME-1-2007.

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 4.2.3.1 and 4.2.3.3.2 will be revised as indicated in the attached markup.

The size range of the debris materials is based on (i) the assumption that 100% of particulates will bypass the ECCS strainers, and (ii) guidance from NEI 04-07 Volume 2 Appendix V. The concentration of the post-LOCA fluid constituents is conservatively estimated based on the assumption that the IRWST contains 946.4 m^3 (250,000 gallons) of water during post-LOCA operation, which is less than the minimum IRWST water volume of 993.2 m^3 (262,388 gallons). Estimating the debris concentration at less than the expected IRWST volume yields a more concentrated debris-laden fluid for confirmatory tests, and produces conservative test results.

4.2.3 ECCS Component Evaluations

This section evaluates the ECCS pumps, heat exchangers, valves, instrument tubes, and piping regarding wear, blockage, and fouling (heat exchanger).

4.2.3.1 SI and CS Pump Evaluation

The SI pumps are motor-driven horizontal, multistage, centrifugal pumps with mechanical seals. The pumps are sized to deliver 3,085 L/min (815 gpm) at a discharge head of 869 m (2,850 ft). The CS pumps are motor-driven centrifugal pumps with mechanical seals. The pumps are sized to deliver 20,536 L/min (5,425 gpm) (including bypass flow 1,609 L/min (425 gpm)) at a discharge head of 125 m (410 ft). The 100% capacity design flow rate is based upon a 57.5 L/min (15.2 gpm) flow per nozzle.

The SI and CS pumps and associated mechanical seals will be qualified 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 pump vendor, at a minimum, will fulfill the following pump criteria:

1) Provide ~~tests and/or analyses~~ to confirm that the opening sizes and internal running clearances of the SI and CS pumps yield acceptable operation in post-LOCA fluids for at least 30 days. Also, provide a list of the opening sizes and internal running clearances in the qualification documentation.

2) Provide hydraulic performance ~~test results and/or analyses~~ to confirm that the SI and CS pumps can provide the required safety injection flow for at least 30 days of ECCS post-LOCA operation.

3) Provide ~~tests and/or analyses~~ to confirm that the wear rates of the SI and CS pump wetted surface materials (e.g., wear rings, pump internals, bearing, and casing) provide acceptable operation in the post-LOCA fluids for at least 30 days. Also, provide a list of the wetted pump surfaces materials, hardness of each material, and verification of acceptable wear rates in the qualification documentation.

tests or combination of tests and analyses

4) Provide mechanical performance (i.e., pump vibration, rotor dynamics, and bearing load) ~~test results and/or analyses~~ to confirm that there will be no adverse changes in system vibration response or rotor dynamics performance during ECCS operation for at least 30 days. Also, provide relevant ~~test results and/or analyses~~ to confirm that any increases in internal bypass flow caused by impeller or casing wear will not decrease the performance of the pumps or cause accelerated internal wear for at least 30 days of post-LOCA operation.

5) Provide mechanical seal assembly performance ~~test results and/or analyses~~ to confirm that ECCS

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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~~ tests or combination of tests and analyses 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).

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

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The SI and CS pumps and associated mechanical seals will be qualified to operate with the post-LOCA fluids for at least 30 days in accordance with ASME QME-1-2007 as endorsed by RG 1.100 Revision 3. As a part of qualification, three aspects of pump operability, i.e. hydraulic performance, mechanical shaft seal assembly performance, and pump mechanical performance (vibration), are considered in evaluating the SI and CS pumps for operation with debris-laden water in accordance with the guidance of RG 1.82 Revision 4.

Hydraulic Performance

According to the guidance of WCAP-16406-P-A, as endorsed by RG 1.82 Revision 4, loss of hydraulic efficiency for a pump due to the possible wear ring gap increases caused by abrasive wear is small for the assumed 30-day mission times for the SI and CS pumps. For this reason, TS

According to the guidance of WCAP-16406-P-A, as endorsed by RG 1.82 Revision 4, the following requirements for hydraulic evaluation for pumps will be specified in the design specification for SI pumps and procurement specification for CS pumps to meet the requirements of RG 1.82. If the requirements are satisfied, no further hydraulic evaluation is necessary. But if any of the requirements are not satisfied, additional evaluation will be performed in accordance with the guidance of WCAP-16406-P-A. The requirements are listed as follows:

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Mechanical Shaft Seal Assembly Performance

According to the guidance of WCAP-16406-P-A, as endorsed by RG 1.82 Revision 4, the pump design specification for SI pumps and procurement specification for CS pumps will specify the following requirements for mechanical shaft seal assembly performance:

a. A cyclone separator or any filtering device designed to protect the mechanical seal shall not be used in the seal injection system.

b. Seal design shall be such that leakage shall not exceed 50 gpm in the event of seal failure during long term operation after a LOCA.

Pump Mechanical Performance (Vibration)

According to the guidance of WCAP-16406-P-A, as endorsed by RG 1.82 Revision 4, the pump design specification for SI pumps will contain specification(s) to provide the lateral dynamic analysis in order to confirm the effect of pump close running clearance wear on the dynamic characteristics of the rotor-bearing system. The lateral dynamic analysis shall be performed in accordance with API 610 Annex I.

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(Reference [4-3]).

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.~~

tests or combination of tests and analyses

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.

Revised in response to RAI 63-7983 Question 06.02.02-24

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 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

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.

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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.

tests or combination of tests and analyses

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.

Revised in response to RAI 63-7983 Question 06.02.02-24

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The ECCS and CSS valves will be qualified to operate with the post-LOCA fluids for at least 30 days in accordance with ASME QME-1-2007 as endorsed by RG 1.100 Revision 3. As a part of the qualification, the wear evaluation for the ECCS and CSS valves in the flow path during an accident, such as gate, check, globe and butterfly valves, is performed. The valves are not required to be throttled in the system operation because the systems are flow balanced by the flow orifices. An increase in flow area due to erosive wear applies to manually throttled valves only, in accordance with the guidance provided in NRC Information Notice 97-76. In addition, because the valve wall is always generally thicker than the pipe wall thickness, and if the thickness of associated pipes are acceptable, the valves are also acceptable. Therefore, there is no expected impact due to erosive wear on the ECCS and CSS valves. These valves therefore comply with the guidance of ~~WCAP-16406-P-A as endorsed by~~ RG 1.82 Revision 4.

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