
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. 06.02.02-13

Technical Report APR1400-E-N-NR-14001-P, Section 4.2.2.3, "Components of Interest," states that Table 4.2-1, "Components in the Flow Path during an LBLOCA," of Technical Report APR1400-E-N-NR-14001-P lists the ECCS/shutdown cooling system (SCS)/in-containment refueling water storage tank (IRWST) components in the downstream effects evaluation. The components in the ECCS flow path during small break LOCA (SBLOCA) and large break LOCA (LBLOCA) operations include pumps, heat exchangers, valves, orifices, containment spray nozzles, and piping. The NRC staff reviewed the components of interest and identified the following inconsistencies:

The applicant states that Table 4.2-1 lists ECCS/SCS/IRWST components in the downstream effects evaluation. However, Table 4.2-1 lists only components in the safety injection system (SIS) and CSS. The applicant is requested to clarify ECCS/SCS/IRWST components in the downstream effects evaluation in the technical report.

Table 4.2-1 lists valves in the CSS miniflow line but does not include the CSS miniflow heat exchangers or the 4-inch miniflow recirculation piping. The applicant is requested to clarify in the technical report whether these components are required to be included in the downstream effects evaluation. Also, the applicant is requested to review and confirm that all applicable SI and CS components required to be included in the downstream effects evaluation are included in Table 4.2-1 with any changes to the table as appropriate.

Response – (Rev.1)

Components in the flow path during an LBLOCA include the ECCS and CSS components. Section 4.2.2.3 of the Technical Report will be revised to be consistent with Table 4.2-1. The CS pump miniflow heat exchangers and the 4-inch miniflow recirculation piping are included in the

downstream effects evaluation. KHNP has reviewed the SI and CS components required to be included in the downstream effects evaluation and has either added, changed, or deleted them from Table 4.2-1.

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 4.2.2.3 and Table 4.2-1 will be revised as indicated in the attached markup.

2) SBLOCA scenario

The most limiting SBLOCA is assumed to occur in a DVI line break LOCA.

The worst case SBLOCA assumes some time delay before pumped flow reaches the core. For the larger range of small breaks, the rate of blowdown is such that the increase in fuel clad temperature is terminated mainly by the SITs, with pumped flow then providing continued cooling. As break size continues to decrease, the SITs and an SIP both play a part in terminating the rise in clad temperature.

Above process (blowdown, passive injection, and recovery) takes longer time period compared with LBLOCA and the duration depends on the break size and the performance of the ECCS.

For this evaluation, the SBLOCA is bounded by the LBLOCA and post-LOCA long-term cooling. The debris quantity and the ECCS flows during the SBLOCA are considered much smaller than during the LBLOCA.

Therefore, the SBLOCA scenario in the evaluation of the downstream effect is bounded by the conditions of the LBLOCA scenario.

4.2.2.2 Mission Time

Mission time represents the maximum period of time for which a System, Structure or Component remains to perform their safety function. It is the accident analysis credit time.

For this evaluation, the mission time of the downstream effect evaluation is defined as 30 days following the Chapter 15 of the DCD (Reference [3-1]).

4.2.2.3 Components of Interest

Table 4.2-1 lists the ~~ECCS/SCS/RWST~~ components in the downstream effects evaluation. These components are in the ECCS flow path during SBLOCA and LBLOCA operations.

ECCS and CSS

and CSS

4.2.2.4 Post-LOCA Fluid Constituents

Debris in the post-LOCA fluid consists of latent debris (particulate and fiber), coating particles (i.e., epoxy), insulation materials, and miscellaneous debris. Miscellaneous debris includes materials placed inside containment for an operational, maintenance, or engineering purpose. Materials include tape, tags, stickers, adhesive labels used for component identification, fire barrier materials, and other materials (e.g., rope, fire hoses, ventilation filters, plastic sheeting).

Debris sizes are classified as particulates, fines, and large pieces. The sizes in Table 4.2-2 are based on the following:

Table 4.2-1 Components in the Flow Path during an LBLOCA (1 of 2)

Component	Description
Pumps	
SI pump (SI-PP02A/02B/02C/02D)	Type: multi-stage centrifugal pump Arrangement: horizontal Flow rate: ~4,675 L/min (1,235 gpm) (maximum) ⁽¹⁾
CS Pump (CS-PP01A/01B)	Type: centrifugal Arrangement: vertical Flow rate: ~24,605 L/min (6,500 gpm) (maximum) ⁽¹⁾
Heat Exchangers	
CS Heat Exchanger (CS-PP01A/01B) 	Type: shell and tube, U-tube, horizontally mounted Number of shell in series:1 Number of tube passes: 2 Tube material; austenitic steel Flow rate: ~18,927 L/min (5,000 gpm) (during LBLOCA Containment Spray)
Valves	
CS-V1001/1002	Swing check, 18 inch 
CS-V1003/1004	Gate (manual), 18 inch 
CS-V1007/1008	Swing check, 14 inch
CS-V1015/1016/1017/1018	Globe (manual), 4 inch
CS-V001/002/003/004	Gate (MOV), 14 inch
SI-V304/305	Gate (MOV), 20 inch
SI-V470/402/130/131	Gate (manual), 10 inch
SI-V404/405/434/446	Swing check, 4 inch
SI-V435/447/476/478	Gate (manual), 4 inch
SI-V308/309	Gate (MOV), 20 inch
SI-V347/348	Gate (MOV), 18 inch
SI-V157/158	Swing check, 18 inch
SI-V340/342	Gate (MOV), 18 inch
SI-V424/426/448/451	Swing check, 4 inch
SI-V410/411/412/413	Globe (manual), 4 inch
SI-V302/303	Globe (MOV), 4 inch
SI-V100/101	Swing check, 10 inch
SI-V395	Gate (MOV), 10 inch
SI-V959	Gate (manual), 10 inch
SI-V106/107	Gate (manual), 18 inch
SI-V568/569	Swing check, 14 inch
SI-V578/579	Gate (manual), 14 inch
SI-V341/343	Gate (MOV), 14 inch
SI-V265/269	Globe (Manual), 4 inch
SI-V604/609	Gate (MOV), 4 inch
SI-V344/346	Gate (MOV), 18 inch

Note : SI-V302 | Gate(manual), 4 inch

(1) Including minimum bypass flow

CS Pump Miniflow Heat Exchanger (CS-HE02A/02B)	Type: shell and tube, U-tube, horizontally mounted Number of shell in series:1 Number of tube passes: 2 Tube material; austenitic steel Flow rate: ~ 1,817 L/min (480 gpm)
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Design Features to Address GSI-191

APR1400-E-N-NR-14001-NP, Rev.0

SI-V-123/143 | Swing check, 12 inch
 SI-V-541/543 | Swing check, 12 inch

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Table 4.2-1 Components in the Flow Path during an LBLOCA (2 of 2)

Component	Description
Valves (Cont.)	
SI-V159/160	Swing check, 18 inch
SI-V616/626/636/646	Globe (MOV), 4 inch
SI-V113/123/133/143	Swing check, 4 inch
SI-V540/541/542/543	Swing check, 4 inch
SI-V614/624/634/644	Gate (MOV), 12 inch
SI-V217/227/237/247	Swing check, 12 inch
SI-V217/227/237/247	Swing check, 12 inch
SI-V321/331	Globe (MOV, throttling), 4 inch
SI-V523/533	Swing check, 4 inch
SI-V957/V958	Gate (manual), 4 inch
SI-V522/532	Swing check, 4 inch
Orifice	
CS-OR01A/B	CS pump miniflow orifice, 4 inch
CS-FE338/348	CS pump outlet flow instrument orifice, 14 inch
CS-02A/B, 03A/B	CS main spring ring header orifice, 8 inch
CS-OR04A/B	CS main spring ring header orifice, 4 inch
CS-OR05A/B, 06A/B	CS auxiliary spring ring header orifice, 4 inch
SI-OR01A/B/C/D, 08A/B/C/D, 20A/B/C/D	SI pump miniflow orifice, 4 inch
SI-OR02A/B	SI pump miniflow orifice, 4 inch
SI-OR06A/B/C/D	SI pump outlet flow orifice, 12 inch
SI-OR07A/B	Hotleg injection flow orifice, 4 inch
SI-FE311D/321B/331C/341A	SI pump outlet flow instrument orifice, 4 inch
SI-FE390C/390D	Hotleg injection flow instrument orifice, 4 inch
Containment Spray Nozzle	
Main spray nozzle	Orifice size 13.1 mm (0.516 inch)
Auxiliary spray nozzle	Orifice size 5.6 mm (0.22 inch)
Piping	
16 inch CS pump suction line (SS Sch. 80)	
14 inch CS pump discharge line (SS Sch. 80)	
12 inch CS pump discharge line (SS Sch. 80S)	
14 inch CS spray header line (SS Sch. STD)	
12 inch CS spray header line (SS Sch. 40S)	
8 inch CS spray header line (SS Sch 40S)	
6 inch CS spray ring line (SS Sch 40S)	
4 inch CS spray ring line (SS Sch 40S)	
24 inch SI pump suction line (SS Sch. 80)	
20 inch SI pump suction line (SS Sch. 80)	
10 inch SI pump suction line (SS Sch. 80S)	
4 inch SI pump discharge line (SS Sch. 120)	
4 inch SI pump miniflow line (SS Sch. 120)	
4 inch SI pump hot leg Injection line (SS Sch. 120)	
4 inch SI pump discharge line (SS Sch. 160)	
12 inch SI pump discharge line (SS Sch. 160)	

391D

4 inch

18 inch CS pump suction line (SS Sch. 80)

4 inch CS pump miniflow line(SS Sch. 40)
 10 inch SI IRWST return line (SS Sch. 120)

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 SRP Section: 06.02.02 - Containment Heat Removal Systems
 Application Section: 6.2.2
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Question No. 06.02.02-16

Technical Report APR1400-E-N-NR-14001-P, Section 4.2.2.6, "Summary of Assumptions and Conservatisms," states that concentration of the post-LOCA fluid constituents listed in Table 4.2-5 is conservatively estimated based on the assumption that the IRWST contains 946.4 m³ (250,000 gallons) of water during post-LOCA operation, which is less than the minimum IRWST water volume of 993.2 m³ (262,388 gallons). The applicant also states that 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. In this section, the applicant described the IRWST water volume used in determining the concentration of the post-LOCA fluid constituents listed in Table 4.2-5. To support the conclusion that a conservative water volume was used, the NRC staff requests that applicant describe in the technical report (a) the total volume of water that is being recirculated by the SIS and CSS from all sources (e.g., reactor coolant system, safety injection tanks, etc.), (b) the volume from each source, and (c) the calculations used in determining the debris concentrations.

Response – (Rev.1)

Response to (a)

As described in Section 3.9.2 and Figure 3.9-3, the IRWST minimum water volume is 627,000 gallons to ensure an adequate supply of borated water to the SIS and CSS.

The minimum water volume was calculated as follows:

$$V_{\text{Minimum}} = V_{\text{ESF}} + V_{\text{Holdup}} + V_{\text{Inactive}} - V_{\text{SIT}} = 609,332 \text{ gallon}$$

Where,

$$- V_{\text{Minimum}} = \text{IRWST minimum water volume}$$

- V_{ESF} = Minimum water volume for ESF operation, 262,388 gallon
- V_{Holdup} = Holdup volume on the way to the IRWST, 162,829 gallon
- $V_{Inactive}$ = Inactive pool volume, 224,282 gallon
- V_{SIT} = Three SITs volume, 40,167 gallon

From the above calculation, the IRWST design minimum water volume is 627,000 gallons.

The total volume of water recirculated by the SIS and CSS is calculated as follows.

$$V_{\text{Recirculated water}} = V_{\text{Minimum}} + V_{\text{SIT}} - V_{\text{Inactive}} = V_{\text{ESF}} + V_{\text{Holdup}} = 425,217 \text{ gallon}$$

The minimum RCS water volume is not considered for conservatism.

A conservative value of 250,000 gallons is used for the recirculated water volume, instead of 425,217 gallons calculated above, when determining the debris concentrations.

Section 4.2.2.6 of the technical report will be revised to replace the phrase, “the minimum IRWST water volume of 993.2 m³ (262,388 gallon)” to “the minimum IRWST water volume for ESF operation of 993.2 m³ (262,388 gallon)” in order to avoid confusion.

Response to (b)

As described in the response to (a), because the recirculated water volume was determined to be less than the minimum IRWST water volume for ESF operation, the water source recirculated by the SIS and CSS is not provided.

Response to (c)

Based on the IRWST water volume of 250,000 gallon, debris concentrations are calculated as follows:

Debris Type	Debris Quantity	Density	Mass(lb)	Concentration (ppm)
Qualified epoxy coating	3.1 ft ³	94 lbm/ft ³	291.4	148
Latent particulates	185 lb	-	185	94
Latent fiber	15 lb	-	15	8
Total			491.4	250

IRWST water mass: 250,000 gal X 58.82lb/ft³ / 7.48 gal/ft³ = 1,966,000 lb

Based on the above calculation results, Table 4.2-5 of the technical report will be revised.

In addition, Section 4.2.2.5, 4.2.2.6, 4.2.3.3.2, and Table 4.2-7 of the technical report will be revised to simplify the flowrates of SIS and CSS assumed for component wear rate evaluation and to incorporate the debris concentration to the wear rate evaluation.

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 [4.2.2.5](#), [4.2.2.6](#), [4.2.3.3.2](#), Table 4.2-5, and Table 4.2-7 will be revised as shown in Attachment.

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Safety Injection Pump flow is assumed to be 303 L/min (80 gpm) for evaluating debris settlement in the SIS. Flow is assumed to be 6,057 L/min (1,600 gpm) for component wear rate evaluations. Engineering design range of flow is 397 L/min (105 gpm) at shutoff and 4,675 L/min (1,235 gpm) at runout.

27,255 L/min (7,200 gpm)

CS pump flow is assumed to be 1,552 L/min (410 gpm) for evaluating debris settlement in the CSS. Flow is assumed to be ~~26,963 L/min (7,123 gpm)~~ for component wear rate evaluations. Engineering design range of flow is 1,817 L/min (480 gpm) at shutoff and 24,605 L/min (6,500 gpm) at runout. The component wear rate evaluation is detailed in Subsection 4.2.3.1.

The terminal settling velocities of the debris source materials are listed in Table 4.2-4. The velocity of the debris in the post-LOCA fluid is equal to the velocity of the fluid. If the ECCS fluid velocity is greater than the terminal settling velocity of the debris, the debris will not settle.

The minimum flow rate of the SI and CS pumps at shutoff head conditions will be verified during component procurement.

4.2.2.6 Summary of Assumptions and Conservatism

Assumptions and conservatism used in this evaluation are summarized as follows:

- 1) Only 100% of all particulates (i.e., coating debris, latent particulates) and 100% of latent fiber are assumed to pass through the strainers and enter into the ECCS and CSS. RMI doesn't bypass through the sump strainer because the size of the RMI debris is greater than the perforated plate hole size sump strainer.
- 2) SIP flow is assumed to be 303 L/min (80 gpm) for the purpose of calculating settling velocities. Flow is assumed to be 6,057 L/min (1,600 gpm) for the purpose of component wear rate evaluations. Engineering design range of flow is 397 L/min (105 gpm) at shutoff and 4,675 L/min (1,235 gpm) at runout.
- 3) CSP flow is assumed to be 1,552 L/min (410 gpm) for the purposes of calculating settling velocities. Flow is assumed to be ~~26,963 L/min (7,123 gpm)~~ for the purpose of component wear rate evaluations. Engineering design range of flow is 1,817 L/min (480 gpm) at shutoff and 24,605 L/min (6,500 gpm) at runout.
- 4) Wear is calculated from "time zero", i.e. start of the event. Worst case fluid properties are assumed to be present. This assumption is conservative since it does not credit debris transport or the slow increase of fluid properties due to long term mixing.
- 5) Fluid velocity through a single CS heat exchanger tube is assumed to be 4.57 m/s (15 ft/s). 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 specifications.

27,255 L/min (7,200 gpm)

Table 4.2-5 lists the amount of debris in the post-LOCA fluid (downstream of the IRWST sump strainer) that will be used for confirmatory tests. The amount of debris in the ECCS during post-LOCA operation is based on above assumption 1). The amount of latent debris in Table 4.2-5 is conservatively based on the maximum amount of latent particulates and 100% of the maximum amount of fiber listed in Table 4.2-3.

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 m³ (250,000 gallons) of water during post-LOCA operation, which is less than the minimum IRWST water volume of 993.2 m³ (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.

for ESF operation

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.
- 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

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

4) Orifice

ECCS and CSS flow is controlled through 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.

27,255 L/min (7,200 gpm)

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.

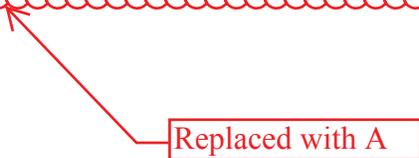
The wear rate of ECCS valves will be provided by the vendor. The vendor will qualify the ECCS valves to operate with the post-LOCA fluids for at least 30 days, using the qualification guidance of ASME QME-1-2007 endorsed by RG1.100 Revision 3. As part of the qualification process, the vendor will provide 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.

Table 4.2-5 Post-LOCA Fluid Constituents Downstream of IRWST Sump Strainer

Debris Type	Debris Quantity (kg / lbm)	Density (g/cm ³ / lb/ft ³)	Concentration (ppm)
Qualified epoxy coating	132.2 / 291.4	1.51 g/cm ³ / 94 lbm/ft ³	139.7
Latent particulates	83.9 / 185	2.70 g/cm ³ / 168.6 lbm/ft ³	88.7
Latent fiber	6.8 / 15	0.038 g/cm ³ / 2.4 lbm/ft ³	7.2
Total	222.9 / 491.4		235.6



Replaced with A

A

Table 4.2-5 Post-LOCA Fluid Constituents Downstream of IRWST Sump Strainer

Debris Type	Debris Quantity	Density	Debris Mass (kg / lb)	Concentration (ppm)
Qualified epoxy coating	0.0878 m ³ / 3.1 ft ³	1.51 g/cm ³ / 94 lb/ft ³	132.2 / 291.4	148
Latent particulates	83.9 kg / 185 lb		83.9 / 185	94
Latent fiber	6.8 kg / 15 lb		6.8 / 15	8
Total			222.9 / 491.4	250

Table 4.2-7 ECCS and CSS Components Wear vs. Time

Component	Diametric Wear (x10 ⁻⁴ , inch)	Flow Rate Increase (%)
Orifice		
CS-OR01A/B	0.73	0.004
CS-FE338/348	1.41	0.003
CS-OR02A/B	2.09	0.009
CS-OR03A/B	1.54	0.006
CS-OR04A/B	0.92	0.007
CS-OR05A/B	3.34	0.050
CS-OR06A/B	3.81	0.063
SI-OR01A/B/C/D	3.43	0.086
SI-OR02A/B	0.59	0.003
SI-OR06A/B	10.17	0.128
SI-OR06C/D	9.35	0.113
SI-OR07A/B	9.49	0.115
SI-OR08A/B/C/D	9.11	0.371
SI-OR20A/B/C/D	1.65	0.029
SI-FE311D/321B/331C/341A	5.72	0.054
SI-FE390C/390D	5.72	0.054
Containment Spray Nozzle		
Main spray nozzle	1.36	0.05
Auxiliary spray nozzle	1.97	0.18
Piping		
16" CS pump suction line (SS Sch. 80)	0.59	0.0008
14" CS pump discharge line (SS Sch. 80)	0.74	0.0012
12" CS pump discharge line (SS Sch. 80S)	0.83	0.0014
14" CS spray header line (SS Sch. STD)	0.66	0.0010
12" CS spray header line (SS Sch. 40S)	0.72	0.0012
8" CS spray header line (SS Sch 40S)	0.65	0.0016
6" CS spray ring line (SS Sch 40S)	0.59	0.0020
4" CS spray ring line (SS Sch 40S)	0.59	0.0029
24" SI pump suction line (SS Sch. 80)	0.59	0.0005
20" SI pump suction line (SS Sch. 80)	0.59	0.0007
10" SI pump suction line (SS Sch. 80S)	0.59	0.0012
4" SI pump discharge line (SS Sch. 120)	1.59	0.0079
4" SI pump miniflow line (SS Sch. 120)	0.59	0.0029
4" SI pump hot leg Injection line (SS Sch. 120)	1.59	0.0079
4" SI pump discharge line (SS Sch. 160)	2.19	0.0127
12" SI pump discharge line (SS Sch. 160)	0.59	0.0012



Replaced with B

B

Table 4.2-7 ECCS and CSS Components Wear during 30 days

Component	Design Flow Rate (gpm)	Assumed Flow Rate (gpm)	Assumed Velocity (ft/sec)	Diametric Wear (x10 ⁻⁴ , in)	Flow Rate Increase (%)
Orifice					
CS-OR01A/B	509	900	29.80		
CS-FE338/348	5,991	7,200	35.91		
CS-OR02A/B	2,149	3,600	74.47		
CS-OR03A/B	2,111	3,600	55.83		
CS-OR04A/B	339	450	26.01		
CS-OR05A/B	304	450	104.89		
CS-OR06A/B	295	450	123.76		
SI-OR01A/B/C/D	105	200	127.50		
Deleted					
SI-OR06A/B	1,130	1,600	256.92		
SI-OR06C/D	1,130	1,600	236.33		
SI-OR07A/B	1,130	1,600	239.78		
SI-OR08A/B/C/D	105	200	338.48		
SI-OR20A/B/C/D	105	200	61.38		
SI-FE311D/321B/331C/341A	1,130	1,600	144.43		
SI-FE390C/391D	1,130	1,600	144.43		
Containment Spray Nozzle					
Main spray nozzle	18	30	45.97		
Auxiliary spray nozzle	4	6	50.58		
Piping					
16" CS pump suction line (SS Sch. 80)	6,500	7,200	14.34		
14" CS pump discharge line (SS Sch. 80)	6,500	7,200	18.80		
12" CS pump discharge line (SS Sch. 80S)	6,500	7,200	21.28		
14" CS spray header line (SS Sch. STD)	5,991	7,200	16.73		
12" CS spray header line (SS Sch. 40S)	5,392	7,200	20.40		
8" CS spray header line (SS Sch 40S)	2,149	3,600	23.06		
6" CS spray ring line (SS Sch 40S)	1,319	1,800	19.97		
4" CS spray ring line (SS Sch 40S)	339	450	11.33		
4" CS pump miniflow line (SS Sch 40)	509	900	22.65		
10" SI IRWST return line (SS Sch 120)	6,500	7,200	35.77		
24" SI pump suction line (SS Sch. 80)	6,660	7,200	6.32		
20" SI pump suction line (SS Sch. 80)	6,660	7,200	9.13		
10" SI pump suction line (SS Sch. 80S)	1,235	1,600	6.87		
4" SI pump discharge line (SS Sch. 120)	1,235	1,600	49.71		
4" SI pump miniflow line (SS Sch. 120)	105	200	6.21		
4" SI pump hot leg Injection line (SS Sch. 120)	1,130	1,600	49.71		
4" SI pump discharge line (SS Sch. 160)	1,130	1,600	55.23		
12" SI pump discharge line (SS Sch. 160)	1,130	1,600	6.37		

18" CS pump suction line (SS Sch. 80) | 6,500 | 7,200 | 14.34

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.1)

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.

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.

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:

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.

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 RG1.100 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.

Based on the above discussion, Technical Report Sections 4.2.3.1 and 4.2.3.3.2 will be 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 m³ (250,000 gallons) of water during post-LOCA operation, which is less than the minimum IRWST water volume of 993.2 m³ (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.
- 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

tests or combination of tests and analyses

Design Features to Address GSI-191

APR1400-E-N-NR-14001-NP, Rev.0

RAI 63-7983 - Question 06.02.02-18_Rev.1

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.

tests or combination of tests and analyses

- 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).

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

A

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:

TS

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.

RAI 63-7983 - Question 06.02.02-18_Rev.1

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.

(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 m²-K/W (0.0005 hr-ft²-°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.

tests or combination of tests and analyses

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 through 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.

Replaced with B

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

B

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.

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. 06.02.02-22

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, "Blockage and Debris Settling Evaluation for Valves, Orifices and Pipes," evaluates debris settling for valves, orifices, pipes and spray nozzles. The velocity of the debris in the post-LOCA fluid is assumed equal to the velocity of the fluid. If the fluid velocity is greater than the terminal settling velocity of the debris, the debris will not settle. Technical Report APR1400-E-N-NR-14001-P, Table 4.2-6, "Affected Equipment/Flow Rates," lists the size, flow rate and maximum settling velocity for the orifices, spray nozzles and piping in the downstream ex-vessel effects evaluation. The applicant compared the actual flow velocities with the maximum settling velocity of 0.70 ft/sec for latent debris as calculated in Table 4.2-4 and determined that flow velocities are above the settling velocities in all components except the following:

- 61.0 cm (24 inch), 50.8 cm (20 inch), and 30.5 cm (10 inch) SI pump suction lines and
- 25.4 cm (12 inch) SI pump discharge line

In cases where the flow velocity is less than the terminal settling velocity, the applicant states that debris settling is a longer term phenomenon and has no short term impact on flow and, therefore, the potential of piping plugging or blockage and its impact on system operation is very low. The NRC staff requests that the applicant to provide technical justification in the technical report that debris settling will not occur or affect system operation in piping and any associated valves where the flow velocity for latent debris is less than the terminal settling velocity. As part of this evaluation, the applicant should identify any valves located in the piping where the flow velocity for latent debris is less than the terminal settling velocity, and provide justification that debris settling will not occur in these valves.

Response – (Rev.1)

To evaluate debris settling in piping, valves, orifices, and spray nozzles, the terminal settling velocity of debris materials and the assumed flow velocity in piping, valves, orifices, and spray nozzles are summarized in Table 4.2-4 and Table 4.2-6, respectively.

Some conservative assumptions are considered to facilitate the comparison and are discussed below.

First, the pump shutoff flow rates at which pump cavitation is likely to occur, rather than the design flow rates, are used to calculate the flow velocities. This lowers the flow velocities for additional conservatism for the debris settling evaluation. These calculated velocities are compared to the settling velocities of 0.046 m/s (0.15 ft/s) and 0.002 m/s (0.008 ft/s) for coating and latent fiber, respectively, as reported in Table 4-2 of NEI 04-07. Since the assumed flow velocities are considerably higher than the settling velocities, the debris is not likely to settle in the SI and CS systems. For latent particle debris, there is no information in NEI 04-07, so terminal settling velocity is conservatively calculated using Stokes' Law.

All particle sizes used for terminal settling velocity of the latent particle debris are assumed to be the strainer hole size of 0.094 inch, which is considerably large compared to Table V-2 of SE for NEI 04-07. This maximizes the terminal settling velocity. The maximum terminal settling velocity is considerably higher than the terminal settling velocities for other debris listed in Table 4-2 of NEI 04-07. Sufficient conservatism is thus provided for the debris settling evaluation.

Because debris settling is a longer term phenomenon, there is no short term impact on the flow velocities over the time period of interest. This fact, combined with the conservatism in the flow velocities and the latent particle debris terminal settling velocity make the probability of blockages in piping extremely low.

Based on the above considerations, debris settling will not occur or affect system operation in piping and any associated valves where the flow velocity for latent debris is less than the terminal settling velocity.

The piping and associated valves with lower assumed flow velocity than the debris settling velocity are listed in Table 1 below. In the listed piping and associated valves, the particle settling may rarely occur. However, since the flow cross sectional area decreases as particles settle down and reduction of flow cross sectional area increases the flow velocity, the particle settling may occur no longer after the flow velocity equals the terminal settling velocity. Therefore, the piping and associated valves are not blocked and the effect on system operation is negligible.

Table 1 Piping and Associated Valves with Lower Assumed Flow Velocity than Settling Velocity

Piping	Associated valves	Description
4" CS spray ring line	None	
24" SI pump suction line	None	
20" SI pump suction line	SI-V304/305/308/309	Gate (MOV), 20 inch
10" SI pump suction line	SI-V130/131/402/470	Gate (Manual), 10 inch
12" SI pump discharge line	SI-V123/143/217/227/237/247/ 541/543	Swing Check, 12 inch
18" CS pump suction line	SI-V347/348 SI-V157/158	Gate (MOV), 18 inch Swing Check, 18 inch

Section 4.2.3.3.1 and Table 4.2-9 of technical report APR1400-E-N-NR-14001-P/NP will be added to incorporate the information presented in this response.

In addition, Table 4.2-6 will be revised to simplify the assumed flow rate and assumed velocity. This change does not affect the settling evaluation.

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 [4.2.2.5](#), [4.2.2.6](#), 4.2.3.3.1, Table 4.2-6, and Table 4.2-9 will be revised or added, as indicated in the attachment associated with this response.

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Safety Injection Pump flow is assumed to be 303 L/min (80 gpm) for evaluating debris settlement in the SIS. Flow is assumed to be 6,057 L/min (1,600 gpm) for component wear rate evaluations. Engineering design range of flow is 397 L/min (105 gpm) at shutoff and 4,675 L/min (1,235 gpm) at runout.

1,514 L/min(400 gpm)

CS pump flow is assumed to be ~~1,552 L/min (410 gpm)~~ for evaluating debris settlement in the CSS. Flow is assumed to be 26,963 L/min (7,123 gpm) for component wear rate evaluations. Engineering design range of flow is 1,817 L/min (480 gpm) at shutoff and 24,605 L/min (6,500 gpm) at runout. The component wear rate evaluation is detailed in Subsection 4.2.3.1.

The terminal settling velocities of the debris source materials are listed in Table 4.2-4. The velocity of the debris in the post-LOCA fluid is equal to the velocity of the fluid. If the ECCS fluid velocity is greater than the terminal settling velocity of the debris, the debris will not settle.

The minimum flow rate of the SI and CS pumps at shutoff head conditions will be verified during component procurement.

4.2.2.6 Summary of Assumptions and Conservatism

Assumptions and conservatism used in this evaluation are summarized as follows:

- 1) Only 100% of all particulates (i.e., coating debris, latent particulates) and 100% of latent fiber are assumed to pass through the strainers and enter into the ECCS and CSS. RMI doesn't bypass through the sump strainer because the size of the RMI debris is greater than the perforated plate hole size sump strainer.
- 2) SIP flow is assumed to be 303 L/min (80 gpm) for the purpose of calculating settling velocities. Flow is assumed to be 6,057 L/min (1,600 gpm) for the purpose of component wear rate evaluations. Engineering design range of flow is 397 L/min (105 gpm) at shutoff and 4,675 L/min (1,235 gpm) at runout.
- 3) CSP flow is assumed to be ~~1,552 L/min (410 gpm)~~ for the purposes of calculating settling velocities. Flow is assumed to be 26,963 L/min (7,123 gpm) for the purpose of component wear rate evaluations. Engineering design range of flow is 1,817 L/min (480 gpm) at shutoff and 24,605 L/min (6,500 gpm) at runout.
- 4) Wear is calculated from "time zero", i.e. start of the event. Worst case fluid properties are assumed to be present. This assumption is conservative since it does not credit debris transport or the slow increase of fluid properties due to long term mixing.
- 5) Fluid velocity through a single CS heat exchanger tube is assumed to be 4.57 m/s (15 ft/s). 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 specifications.

Table 4.2-5 lists the amount of debris in the post-LOCA fluid (downstream of the IRWST sump strainer) that will be used for confirmatory tests. The amount of debris in the ECCS during post-LOCA operation is based on above assumption 1). The amount of latent debris in Table 4.2-5 is conservatively based on the maximum amount of latent particulates and 100% of the maximum amount of fiber listed in Table 4.2-3.

~~The SI pump suction line is a 24 inch Schedule 80 stainless steel pipe (ID = 547.7 mm (21.562 inch)). The velocity in this line at the minimum flow rate is 0.13 m/s (0.43 ft/s). This velocity is less than the terminal settling velocities of the post LOCA debris materials (Table 4.2-4). Therefore, settling will occur in the SI flow path to the RCS.~~

~~The CS pump suction line is a 16 inch Schedule 80 stainless steel pipe (ID = 363.5 mm (14.312 inch)). The velocity in this line at the minimum flow rate is 0.25 m/s (0.82 ft/s). This velocity is greater than the terminal settling velocities of the post LOCA debris materials (Table 4.2-4). Therefore, settling will not occur in the CS flow path to the containment.~~

~~Debris settling is a longer term phenomena and has no short term impact on flow. Therefore, the potential of piping plugging or blockage and its impact on system operation is very low. Reliability of the SIS is considered in the design, procurement, and installation/layout of components.~~

Replaced with A

Valves

The valve types that are used in the flow-path during an accident are gate, check, globe and butterfly valves, see Table 4.2-1.

1) Gate valves

except for gate valves on 20 inch and 10 inch SI pump suction lines and 18 inch CS pump suction lines

Gate valves are used full-open or full-close. The gate valve sizes are above 101.6 mm (4 inch) (see Table 4.2-1). Flow velocities in all cases are above the settling velocities of the post-LOCA fluid (refer to Table 4.2-6). NUREG/CR-6902 (Reference [4-4]) states that valve openings significantly larger than the debris size will not clog. The strainer hole size is 2.38 mm (0.094 inch). The 101.6 mm (4 inch) valve opening is considerably larger than any expected particle passing through the sump strainer. Therefore, the valves do not clog due to post-LOCA insulation debris.

2) Check valves

except for check valves on 12 inch SI pump suction lines and 18 inch CS pump suction lines

Check valves are used with sufficient flow rate, and check valve sizes are above 101.6 mm (4 inch) (see Table 4.2-6). Flow velocities in all cases are above the settling velocities of the post-LOCA fluid (refer to Table 4.2-6). Reference [4-4] states that valve openings significantly larger than the debris size will not be clogged. The strainer hole size is 2.38 mm (0.094 inch). The 101.6 mm (4 inch) valve opening is considerably larger than any expected particle passing through the sump strainer. Therefore, the valves do not clog due to post-LOCA insulation debris.

3) Globe valves

ECCS and CSS flow is controlled through a combination of orifices and throttled valves. Globe valves normally are full open but may be used for throttling system flow. ECCS and CSS pressure and flow are monitored in the MCR. In general, if a globe valve is in a throttled position and it begins to clog, system flow will decrease. Operator action may be taken to open the valve, thus clearing the potential clog. In the APR1400, globe valve sizes are above 101.6 mm (4 inch) (see Table 4.2-1). Reference [4-4] states that valve openings significantly larger than the debris size will not be clogged. The strainer hole size is 2.38 mm (0.094 inch). Throttle valves are expected to be throttled to a minimum of 50.8 mm (2 inch) open between the valve disc and seat. The 50.8 mm (2 inch) valve opening is considerably larger than any expected particle passing

A

Some conservative assumptions are considered to facilitate the comparison and are discussed below.

First, the pump shutoff flow rates at which pump cavitation is likely to occur, rather than the design flow rates, are used to calculate the flow velocities. This lowers the flow velocities for additional conservatism for the debris settling evaluation. These calculated velocities are compared to the settling velocities of 0.046 m/s (0.15 ft/s) and 0.002 m/s (0.008 ft/s) for coating and latent fiber, respectively, as reported in Table 4-2 of NEI 04-07. Since the assumed flow velocities are considerably higher than the settling velocities, the debris is not likely to settle in the SI and CS systems. For latent particle debris, there is no information in NEI 04-07, so terminal settling velocity is conservatively calculated using Stokes' Law.

All particle sizes used for terminal settling velocity of the latent particle debris are assumed to be the strainer hole size of 0.094 inch, which is considerably large compared to Table V-2 of SE for NEI 04-07. This maximizes the terminal settling velocity. The maximum terminal settling velocity is considerably higher than the terminal settling velocities for other debris listed in Table 4-2 of NEI 04-07. Sufficient conservatism is thus provided for the debris settling evaluation.

Because debris settling is a longer term phenomenon, there is no short term impact on the flow velocities over the time period of interest. This fact, combined with the conservatism in the flow velocities and the latent particle debris terminal settling velocity make the probability of blockages in piping extremely low.

Based on the above considerations, debris settling will not occur or affect system operation in piping and any associated valves where the flow velocity for latent debris is less than the terminal settling velocity.

The piping and associated valves with lower assumed flow velocity than the debris settling velocity are listed in Table 4-9. In the listed piping and associated valves, the particle settling may rarely occur. However, since the flow cross sectional area decreases as particles settle down and reduction of flow cross sectional area increases the flow velocity, the particle settling may occur no longer after the flow velocity equals the terminal settling velocity. Therefore, the piping and associated valves are not blocked and the effect on system operation is negligible.

Design Features to Address GSI-191

Replaced with B

Table 4.2-6 Affected Equipment/Flow Rates (1 of 2)

Component	Inner Diameter (inch)	Designed Flow Rate (gpm)	Assumed Flow Rate (gpm)	Assumed Velocity (ft/s)	Maximum Settling Velocity (ft/s)
Orifice					
CS-OR01A/B	3.51	480	410	13.58	0.70
CS-FE338/348	9.045	480	410	2.04	0.70
CS-OR02A/B	4.441	172	147	3.04	0.70
CS-OR03A/B	5.129	169	145	2.25	0.70
CS-OR04A/B	2.657	27	23	1.33	0.70
CS-OR05A/B	1.323	24	21	4.9	0.70
CS-OR06A/B	1.218	23	20	5.50	0.70
SI-OR01A/B/C/D	0.8	105	80	51.0	0.70
SI-OR02A/B	3.51	105	80	2.65	0.70
SI-OR06A/B	1.594	105	80	12.85	0.70
SI-OR06C/D	1.662	105	80	11.82	0.70
SI-OR07A/B	1.65	105	80	11.99	0.70
SI-OR08A/B/C/D	0.491	105	80	135.39	0.70
SI-20A/B/C/D	1.153	105	80	24.55	0.70
SI-FE311D/321B/331C/341A	2.126	105	80	7.22	0.70
SI-FE390C/390D	2.126	105	80	7.22	0.70
Containment Spray Nozzle					
Main spray nozzle	0.516	15.2	1.3	1.99	0.70
Auxiliary spray nozzle	0.22	3	0.3	2.53	0.70

Design Features to Address GSI-191

B

Table 4.2-6 Affected Equipment/Flow Rates (1 of 2)

Component	Inner Diameter (inch)	Designed Flow Rate (gpm)	Assumed Flow Rate (gpm)	Assumed Velocity (ft/s)	Maximum Settling Velocity (ft/s)
Orifice					
CS-OR01A/B	3.51	480	400	13.25	0.70
CS-FE338/348	9.045	480	400	1.99	0.70
CS-OR02A/B	4.441	172	150	3.10	0.70
CS-OR03A/B	5.129	169	150	2.33	0.70
CS-OR04A/B	2.657	27	20	1.16	0.70
CS-OR05A/B	1.323	24	20	4.66	0.70
CS-OR06A/B	1.218	24	20	5.50	0.70
SI-OR01A/B/C/D	0.8	105	80	51.00	0.70
Deleted					
SI-OR06A/B	1.594	105	80	12.85	0.70
SI-OR06C/D	1.662	105	80	11.82	0.70
SI-OR07A/B	1.65	105	80	11.99	0.70
SI-OR08A/B/C/D	0.491	105	80	135.39	0.70
SI-OR20A/B/C/D	1.153	105	80	24.55	0.70
SI-FE311D/321B/331C/341A	2.126	105	80	7.22	0.70
SI-FE390C/391D	2.126	105	80	7.22	0.70
Containment Spray Nozzle					
Main spray nozzle	0.516	15.2	1.5	2.30	0.70
Auxiliary spray nozzle	0.22	3	0.3	2.53	0.70

Design Features to Address GSI-191

Replaced with C

Table 4.2-6 Affected Equipment/Flow Rates (2 of 2)

Component	Inner Diameter (inch)	Designed Flow Rate (gpm)	Assumed Flow Rate (gpm)	Assumed Velocity (ft/sec)	Maximum Settling Velocity (ft/sec)
Piping					
16" CS pump suction line (SS Sch. 80)	14.312	480	410	0.82	0.70
14" CS pump discharge line (SS Sch. 80)	12.5	480	410	1.07	0.70
12" CS pump discharge line (SS Sch. 80S)	11.75	480	410	1.21	0.70
14" CS spray header line (SS Sch. STD)	13.25	480	410	0.95	0.70
12" CS spray header line (SS Sch. 40S)	12	432	369	1.05	0.70
8" CS spray header line (SS Sch 40S)	7.981	172	147	0.94	0.70
6" CS spray ring line (SS Sch 40S)	6.065	169	145	1.61	0.70
4" CS spray ring line (SS Sch 40S)	4.026	27	23	0.58	0.70
24" SI pump suction line (SS Sch. 80)	21.562	105	490	0.43	0.70
20" SI pump suction line (SS Sch. 80)	17.938	105	490	0.62	0.70
10" SI pump suction line (SS Sch. 80S)	9.75	105	80	0.34	0.70
4" SI pump discharge line (SS Sch. 120)	3.624	105	80	2.49	0.70
4" SI pump miniflow line (SS Sch. 120)	3.624	105	80	2.49	0.70
4" SI pump hot leg Injection line (SS Sch. 120)	3.624	105	80	2.49	0.70
4" SI pump discharge line (SS Sch. 160)	3.438	105	80	2.76	0.70
12" SI pump discharge line (SS Sch. 160)	10.126	105	80	0.32	0.70

Design Features to Address GSI-191

C

Table 4.2-6 Affected Equipment/Flow Rates (2 of 2)

Component	Inner Diameter (inch)	Designed Flow Rate (gpm)	Assumed Flow Rate (gpm)	Assumed Velocity (ft/sec)	Maximum Settling Velocity (ft/sec)
Piping					
6" CS pump suction line (SS Sch. 80)	14.312	480	400	0.80	0.70
14" CS pump discharge line (SS Sch. 80)	12.5	480	400	1.04	0.70
12" CS pump discharge line (SS Sch. 80S)	11.75	480	400	1.18	0.70
14" CS spray header line (SS Sch. STD)	13.25	480	400	0.93	0.70
12" CS spray header line (SS Sch. 40S)	12	432	400	1.13	0.70
8" CS spray header line (SS Sch 40S)	7.981	172	150	0.96	0.70
6" CS spray ring line (SS Sch 40S)	6.065	106	80	0.89	0.70
4" CS spray ring line (SS Sch 40S)	4.026	27	20	0.50	0.70
4" CS pump miniflow line (SS Sch 40)	4.026	480	400	10.07	0.70
10" SI IRWST return line (SS Sch 120)	9.062	480	400	1.99	0.70
24" SI pump suction line (SS Sch. 80)	21.562	585	480	0.42	0.70
20" SI pump suction line (SS Sch. 80)	17.938	585	480	0.61	0.70
10" SI pump suction line (SS Sch. 80S)	9.75	105	80	0.34	0.70
4" SI pump discharge line (SS Sch. 120)	3.624	105	80	2.49	0.70
4" SI pump miniflow line (SS Sch. 120)	3.624	105	80	2.49	0.70
4" SI pump hot leg Injection line (SS Sch. 120)	3.624	105	80	2.49	0.70
4" SI pump discharge line (SS Sch. 160)	3.438	105	80	2.76	0.70
12" SI pump discharge line (SS Sch. 160)	10.126	105	80	0.32	0.70

18" CS pump suction line (SS Sch. 80) | 16.124 | 480 | 400 | 0.63 | 0.70

Table 4.2-9 Piping and Associated Valves with Lower Assumed Flow Velocity than Settling
Velocity

Piping	Associated valves	Description
4" CS spray ring line	None	
24" SI pump suction line	None	
20" SI pump suction line	SI-V-304/305/308/309	Gate (MOV), 20 inch
10" SI pump suction line	SI-V-130/131/402/470	Gate (Manual), 10 inch
12" SI pump discharge line	SI-V-123/143/217/227/237/ 247/541/543	Swing Check, 12 inch
18" CS pump suction line	SI-V-347/348 SI-V-157/158	Gate(MOV), 18 inch Swing Check, 18 inch

Added