# RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

**APR1400 Design Certification**

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

**Docket No. 52-046**

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| **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** |

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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

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:

$V_{Minimum} = V_{ESF} + V_{Holdup} + V_{Inactive} – V_{SIT} = 609,332$ gallon

Where,

- $V_{Minimum}$ = 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.

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

The minimum RCS water volume is not considered for conservatism.

A conservative 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 will be revised to replace the phrase, “the minimum IRWST water volume of 993.2 $m^3$ (262,388 gallon)” to “the minimum IRWST water volume for ESF operation of 993.2 $m^3$ (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 58.82$lb/ft^3$ / 7.48 $gal/ft^3$ = 1,966,000 lb

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

In addition, Section 4.2.2.5, 4.2.2.6, 4.2.3.3.2, and Table 4.2-7 will 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-NP, Section 4.2.2.6, Table 4.2-5, and Table 4.2-7 will be revised as shown in Attachment.

# LIST OF TABLES

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 Conservatisms

Assumptions and conservatisms 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.

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

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 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 for ESF operation 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.

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 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)~~ 27,255 L/min (7,200 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.

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 | | |

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# RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

**APR1400 Design Certification**

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

**Docket No. 52-046**

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|---|---|
| **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** |

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## 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 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

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 |

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.

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**Impact on DCD**

There is no impact on the DCD.

**Impact on PRA**

There is no impact on the PRA.

**Impact on Technical Specifications**

There is no impact on the Technical Specifications.

**Impact on Technical/Topical/Environmental Reports**

Technical report APR1400-E-N-NR-14001-NP, Section 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.

# LIST OF TABLES

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 Conservatisms

Assumptions and conservatisms 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.

1,514 L/min(400 gpm)

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

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

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 though 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.

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 |

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 |

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 |

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 | 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 |

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 |

Added