ArevaEPRDCPEm Resource

From: WILLIFORD Dennis (AREVA) [Dennis.Williford@areva.com]
Sent: Wednesday, November 02, 2011 10:26 AM
To: Tesfaye, Getachew
Cc: BENNETT Kathy (AREVA); CRIBB Arnie (EXTERNAL AREVA); DELANO Karen (AREVA); HATHCOCK Phillip (AREVA); ROMINE Judy (AREVA); RYAN Tom (AREVA); GUCWA Len (EXTERNAL AREVA); PATTON Jeff (AREVA); BALLARD Bob (AREVA)
Subject: DRAFT Response to U.S. EPR Design Certification Application RAI No. 498 (5842), FSAR Ch. 6, Questions 6.2.2-110 to 6.2.2-118
Attachments: RAI 498 Draft Response - Questions 6.2.2-110 to 6.2.2-118 US EPR DC.pdf

Getachew,

Attached is a draft response for RAI 498, Questions 6.2.2-110 through 6.2.2-118 in advance of the final response date of November 18, 2011 shown below.

Please let me know if the staff has questions or if these responses can be sent as final.

NOTE: Will the NRC staff be ready to discuss during tomorrow's GSI-191 telecon?

Thanks,

Dennis Williford, P.E.
U.S. EPR Design Certification Licensing Manager
AREVA NP Inc.
7207 IBM Drive, Mail Code CLT 2B
Charlotte, NC 28262
Phone: 704-805-2223
Email: Dennis.Williford@areva.com

From: WILLIFORD Dennis (RS/NB)
Sent: Friday, September 09, 2011 2:51 PM
To: Getachew.Tesfaye@nrc.gov
Cc: BENNETT Kathy (RS/NB); DELANO Karen (RS/NB); ROMINE Judy (RS/NB); RYAN Tom (RS/NB); GUCWA Len (External RS/NB)
Subject: Response to U.S. EPR Design Certification Application RAI No. 498 (5842), FSAR Ch. 6, Supplement 1

Getachew,

AREVA NP Inc. (AREVA NP) provided a schedule for a technically correct and complete response to the 10 questions in RAI 498 on August 10, 2011. The schedule for responding to these questions has been revised as described in the GSI-191 Closure Plan (AREVA NP Inc. letter NRC:11:092 dated August 25, 2011) and as provided below.

Question #	Response Date
RAI 498 — 06.02.02-110	**November 18, 2011**
RAI 498 — 06.02.02-111	**November 18, 2011**
RAI 498 — 06.02.02-112	**November 18, 2011**
RAI 498 — 06.02.02-113	**November 18, 2011**
RAI 498 — 06.02.02-114	**November 18, 2011**

RAI 498 — 06.02.02-115	**November 18, 2011**
RAI 498 — 06.02.02-116	**November 18, 2011**
RAI 498 — 06.02.02-117	**November 18, 2011**
RAI 498 — 06.02.02-118	**November 18, 2011**
RAI 498 — 06.02.02-119	**November 18, 2011**

Sincerely,

Dennis Williford, P.E.
U.S. EPR Design Certification Licensing Manager
AREVA NP Inc.
7207 IBM Drive, Mail Code CLT 2B
Charlotte, NC 28262
Phone: 704-805-2223
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From: WILLIFORD Dennis (RS/NB)
Sent: Wednesday, August 10, 2011 2:03 PM
To: Getachew.Tesfaye@nrc.gov
Cc: BENNETT Kathy (RS/NB); DELANO Karen (RS/NB); ROMINE Judy (RS/NB); RYAN Tom (RS/NB); GUCWA Len (External RS/NB)
Subject: Response to U.S. EPR Design Certification Application RAI No. 498 (5842), FSAR Ch. 6

Getachew,

Attached please find AREVA NP Inc.'s response to the subject request for additional information (RAI). The attached file, "RAI 498 Response US EPR DC.pdf," provides a schedule since a technically correct and complete response to the 10 questions is not provided.

The following table indicates the respective pages in the response document, "RAI 498 Response US EPR DC.pdf," that contain AREVA NP's response to the subject questions.

Question #	Start Page	End Page
RAI 498 — 06.02.02-110	2	2
RAI 498 — 06.02.02-111	3	3
RAI 498 — 06.02.02-112	4	4
RAI 498 — 06.02.02-113	5	5
RAI 498 — 06.02.02-114	6	6
RAI 498 — 06.02.02-115	7	7
RAI 498 — 06.02.02-116	8	8
RAI 498 — 06.02.02-117	9	9
RAI 498 — 06.02.02-118	10	10
RAI 498 — 06.02.02-119	11	11

A complete answer is not provided for 10 of the 10 questions. The schedule for a technically correct and complete response to these questions is provided below.

Question #	Response Date
RAI 498 — 06.02.02-110	September 29, 2011
RAI 498 — 06.02.02-111	September 29, 2011
RAI 498 — 06.02.02-112	September 29, 2011
RAI 498 — 06.02.02-113	September 29, 2011
RAI 498 — 06.02.02-114	September 29, 2011
RAI 498 — 06.02.02-115	September 29, 2011
RAI 498 — 06.02.02-116	September 29, 2011
RAI 498 — 06.02.02-117	September 29, 2011
RAI 498 — 06.02.02-118	September 29, 2011
RAI 498 — 06.02.02-119	September 29, 2011

Sincerely,

Dennis Williford, P.E.
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From: Tesfaye, Getachew [mailto:Getachew.Tesfaye@nrc.gov]
Sent: Tuesday, July 12, 2011 4:23 PM
To: ZZ-DL-A-USEPR-DL
Cc: Strnisha, James; Terao, David; Carneal, Jason; Colaccino, Joseph; ArevaEPRDCPEm Resource
Subject: U.S. EPR Design Certification Application RAI No. 498 (5842), FSAR Ch. 6

Attached please find the subject request for additional information (RAI). A draft of the RAI was provided to you on July 1, 2011, and on July 8, 2011, you informed us that the RAI is clear and no further clarification is needed. As a result, no change is made to the draft RAI. The schedule we have established for review of your application assumes technically correct and complete responses within 30 days of receipt of RAIs. For any RAIs that cannot be answered within 30 days, it is expected that a date for receipt of this information will be provided to the staff within the 30 day period so that the staff can assess how this information will impact the published schedule.

Thanks,
Getachew Tesfaye
Sr. Project Manager
NRO/DNRL/NARP
(301) 415-3361

Hearing Identifier: AREVA_EPR_DC_RAIs
Email Number: 3512

Mail Envelope Properties (2FBE1051AEB2E748A0F98DF9EEE5A5D4979367)

Subject: DRAFT Response to U.S. EPR Design Certification Application RAI No. 498 (5842), FSAR Ch. 6, Questions 6.2.2-110 to 6.2.2-118
Sent Date: 11/2/2011 10:26:14 AM
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From: WILLIFORD Dennis (AREVA)

Created By: Dennis.Williford@areva.com

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Files	**Size**	**Date & Time**
MESSAGE	5527	11/2/2011 10:26:29 AM
RAI 498 Draft Response - Questions 6.2.2-110 to 6.2.2-118 US EPR DC.pdf	521467	

Options
Priority: Standard
Return Notification: No
Reply Requested: No
Sensitivity: Normal
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Recipients Received:

Response to

Request for Additional Information No. 498

7/12/2011

U. S. EPR Standard Design Certification
AREVA NP Inc.
Docket No. 52-020
SRP Section: 06.02.02 - Containment Heat Removal Systems
Application Section: 6.2.2

QUESTIONS for Component Integrity, Performance, and Testing Branch 1 (AP1000/EPR Projects) (CIB1)

Question 06.02.02-110:

ANP-10293P, Revision 3, Sections G.2.4 and G.2.6, describe the total debris generated during a large break LOCA and the downstream post-LOCA fluid constituents which are assumed to pass through the strainers and ingested into the ECCS. Since components in the ECCS will be design and qualified to operate in the post-LOCA fluid environment, NRC requests the following additional information to further describe the downstream post-LOCA fluid constituents:

a. Table G.2.2, “Total Debris Generated during the LB LOCA,” lists the debris sizes as particulate, small fines, and large pieces. To better define the debris sizes, describe the range of sizes for particulate, small fines, and large pieces.

b. Table G.2.2 states that 1476 ft^3 of RMI small fines are generated during a LB LOCA. Since no RMI is included in the post-LOCA fluid constituents in Table G.2.3, provide justification for the assumption that no RMI will enter the ECCS. [Note: ANP-10293P, Section E.4.1 states, “RMI debris pieces of 2 mil thickness and various sizes from RMI 0.25”x0.25” up to 4”x4” were shown to sink and settle on the bottom of the retaining basket.” It also states that “Removing RMI from subsequent tests also prevents the possibility of RMI debris trapping fibrous debris in the retaining basket, thus resulting in less conservative test conditions.” NRC agrees that this test is conservative for bypass of fibers but it is not conservative for downstream component evaluation.]

c. Table G.2.2 states that 100 ft^3 of miscellaneous large pieces of debris are generated during a LB LOCA. Since no miscellaneous debris is included in the post-LOCA fluid constituents in Table G.2.3, describe the miscellaneous debris and provide justification that no miscellaneous debris or pieces of miscellaneous debris will enter the ECCS.

d. The post-LOCA fluid constituents listed in Table G.2.3 will be used by the vendor for design and qualification of downstream ECCS components to ensure operation during the mission time. The table lists debris amount and concentration but does not list material properties such as density, abrasiveness, size, etc. that may be needed by the vendor for component design and qualification. Describe the post-LOCA fluid constituent properties that may be needed by the vendor for component design and qualification.

Response to Question 06.02.02-110:

Technical Report ANP-10293, Appendix G, Section G.2.4 will be revised to include:

a) Size range for particulates, small fines, and large pieces.

b) Justification that no RMI will enter the ECCS.

c) Description of miscellaneous debris materials and justification that no miscellaneous debris will enter the ECCS.

d) Debris material properties such as density and size.

Technical Report ANP-10293, Appendix G, Table G.2.5 will be revised to include the post-LOCA fluid constituent properties that will be used by vendors for the design and qualification of

ECCS components to provide 30 days of post-LOCA operation. These properties include density, size, concentration, and amount.

FSAR Impact:

The U.S. EPR FSAR will not be changed as a result of this question.

Technical Report Impact:

Technical Report ANP-10293 will be revised as described in the response and indicated on the enclosed markup.

Question 06.02.02-111:

ANP-10293P, Revision 3, Section G.2.5 for ECCS Flow Rate and Flow Velocity states, "the SIS design allows fluid velocity in excess of debris material terminal settling velocities to exist, and debris settling will not occur." Provide justification that debris settling will not occur by providing additional information such as flow velocities through ECCS, the settling velocity, system realignments that may reduce flow rates, etc.

Response to Question 06.02.02-111:

Technical Report ANP-10293, Appendix G, Section G.2.5 will be revised to include information on ECCS flow velocities and settling velocities to justify analysis that debris settling will not occur.

FSAR Impact:

The U.S. EPR FSAR will not be changed as a result of this question.

Technical Report Impact:

Technical Report ANP-10293 will be revised as described in the response and indicated on the enclosed markup.

Question 06.02.02-112:

ANP-10293P, Revision 3, Section G.3.1 for Wear Rate Evaluation states, “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. The component vendor(s) will provide data to support acceptable wear rates based on the provided equipment specifications.” Appendix G does not provide details that may be needed by the vendor such as debris material properties, debris abrasiveness, flow velocities for each component, valve position, etc. Provide details of the information needed by the vendor to perform component wear evaluations.

Response to Question 06.02.02-112:

Technical Report ANP-10293, Appendix G, Table G.2-5 and Table G.3-1 will be revised to include debris properties and velocities needed for component wear evaluation.

FSAR Impact:

The U.S. EPR FSAR will not be changed as a result of this question.

Technical Report Impact:

Technical Report ANP-10293 will be revised as described in the response and indicated on the enclosed markup.

Question 06.02.02-113:

ANP-10293P, Revision 3, Section G.3.2 for LHSI and MHSI Pump Evaluation describes the methodology for the design and qualification of LHSI and MHSI pumps. To more fully describe the design and qualification process for the pumps in a post-LOCA fluid environment, NRC requests that AREVA address the following item:

> The NRC approved qualification standard for pumps is QME-1-2007. This standard is applicable for service conditions when debris is present in the operating fluid. Therefore, NRC staff requests that, "the LHSI and MHSI pumps be qualified per QME-1-2007 as endorsed by RG 1.100 revision 3 to operate with the post LOCA fluids for at least 30 days. As part of the qualification process, the pump vendor, at a minimum, will evaluate the pump criteria listed in Appendix G, Section G.3.2. Any additional potential pump malfunctions shall be identified by the vendor per QME-1-2007, Section QP-7200."

Response to Question 06.02.02-113:

Technical Report ANP-10293, Appendix G, Section G.3.1 will be revised to include the provision that the vendor will qualify the LHSI and MHSI pumps to operate with the post-LOCA fluids for at least 30 days, using the qualification guidance of QME-1-2007. The vendor will also identify any additional potential pump malfunctions, per QME-1-2007 Section QP-7200.

FSAR Impact:

The U.S. EPR FSAR will not be changed as a result of this question.

Technical Report Impact:

Technical Report ANP-10293 will be revised as described in the response and indicated on the enclosed markup.

Question 06.02.02-114:

ANP-10293P, Revision 3, Section G.3.2 for LHSI and MHSI Pump Evaluation describes five actions for the pump vendor during the design and qualification process. However, the design, qualification, and acceptance criteria are not fully described. To more fully describe the design, qualification, and acceptance criteria for the pumps in the post-LOCA fluid environment, NRC requests that AREVA address the following items.

a. State that the vendor is to provide a list of the opening sizes and internal running clearances for the LHSI and MHSI pumps. This statement does not describe the acceptance criteria. To better describe the evaluation methodology and acceptance criteria, the vendor should provide tests and/or analyses to confirm that pump opening sizes and internal running clearances provide acceptable operation in post-LOCA fluids during the 30-day mission time. Opening sizes and internal running clearances are to be recorded in the qualification documentation.

b. State that hydraulic performance test results confirming that the LHSI and MHSI pumps can provide the required safety injection flow rates for at least 30 days of ECCS post-LOCA operation. Discuss if pump design parameters such as NPSHA (available) accounts for suction head losses due to strainer clogging.

c. State that the vendor is to provide, “a list of materials of the wetted pump surfaces (such as wear rings, pump internals, bearing, and casing) and the hardness of each material (for example, Brinell hardness number).” To better describe the evaluation methodology and acceptance criteria, the vendor should provide tests and/or analyses to confirm that the pump wetted surface material (such as wear rings, pump internals, bearing, and casing) wear rates provide acceptable operation in post-LOCA fluids during the 30 day mission time. A list of materials of the wetted pump surfaces, the hardness of each material, and verification of acceptable wear rates are to be recorded in the qualification documentation.

d. Describe design and testing for the pump mechanical seals. The NRC approved qualification standard for pump mechanical seals is QME-1-2007. This standard is applicable for service conditions when debris is present in the operating fluid. Therefore, NRC staff requests that, “the LHSI and MHSI pump mechanical seals be qualified per QME-1-2007 as endorsed by RG 1.100 revision 3 to operate with the post LOCA fluids for at least 30 days.

e. State that, “The pump vendor should also provide an analysis to confirm that the cyclone separator, if applicable, is not susceptible to clogging or impairment by fiber or other particulates and that there is no adverse impact on pump performance or reliability. If the cyclone separators will be impaired in 30 days of operation with post- LOCA fluids, test results and/or analysis should be provided to show that the absence of cyclone separators yields acceptable seal performance.” NRC staff suggests revising “cyclone separator” to state “cyclone separator or any filtering device”.

Response to Question 06.02.02-114:

Technical Report ANP-10293, Appendix G will be revised to include the additional information stated below.

Response to Part a:

ANP-10293, Section G.3.1 will be revised to include provisions to address Part a of this question.

Response to Part b:

As stated in U.S. EPR FSAR, Tier 2, Section 6.3.3.3, the NPSH evaluation accounts for suction head losses due to debris on the sump strainers. ITAAC 3.1 will be revised in U.S. EPR FSAR Tier 1, Section 2.2.3 and Table 2.2.3-3 to provide type tests or analyses to confirm LHSI and MHSI pump operation for a minimum of 30 days of continuous post-LOCA.

Response to Part c:

ANP-10293 Section G.3.1 will be revised to address Part C of this question.

Response to Part d:

ANP-10293 Section G.3.1 will be revised to reflect that the mechanical seals of the LHSI and MHSI pumps will be qualified to operate with the post-LOCA fluids for at least 30 days, using the qualification guidance of QME-1-2007 endorsed by RG1.100, Revision 3.

Response to Part e:

ANP-10293 Section G.3.1 will be revised to state “cyclone separator or any filtering device.”

FSAR Impact:

U.S. EPR FSAR, Tier 1, Section 2.2.3 and Table 2.2.3-3 will be revised as described in the response and indicated on the enclosed markup.

Technical Report Impact:

Technical Report ANP-10293 will be revised as described in the response and indicated on the enclosed markup.

Question 06.02.02-115:

ANP-10293P, Revision 3, Section G.3.3 for LHSI Heat Exchanger Evaluation states, "The LHSI heat exchangers are evaluated for susceptibility to tube plugging. The vendor will verify that plugging by post-LOCA debris constituents will not occur or adversely affect the performance of the heat exchanger." However, this section does not address the heat exchanger heat transfer performance for post-LOCA fluid conditions. The applicant is requested to discuss how it intends to verify acceptable performance of the LHSI heat exchangers in post-LOCA fluids during the 30-day mission time.

Response to Question 06.02.02-115:

Technical Report ANP-10293, Appendix G, Section G.3.2.2 will be revised to address LHSI heat exchanger performance during the 30-day mission time. ITAAC 7.12 in U.S. EPR FSAR Tier 1 Table 2.2.3-3 will be revised to provide for type test, analysis, or a combination of type test and analyses to confirm acceptable LHSI heat exchanger performance during the 30-day mission time.

FSAR Impact:

U.S. EPR FSAR, Tier 1, Table 2.2.3-3 will be revised as described in the response and indicated on the enclosed markup.

Technical Report Impact:

Technical Report ANP-10293 will be revised as described in the response and indicated on the enclosed markup.

Question 06.02.02-116:

ANP-10293P, Revision 3, Section G.3.4 for Evaluation of Valves states, “The ECCS valves, pipes, and orifices are evaluated for susceptibility to blockage. An analysis will be performed to verify adequate performance during operation with post-LOCA fluid.” NRC staff requests the applicant to address the following comments:

a. The title should be expanded to include Orifices, Pipes, and Instrument Tubing.

b. The NRC approved qualification standard for valves is QME-1-2007. This standard is applicable for service conditions when debris is present in the operating fluid. Therefore, NRC staff requests that, the valves be qualified per QME-1-2007 as endorsed by RG 1.100 revision 3 to operate with the post-LOCA fluids for at least 30 days.

Response to Question 06.02.02-116:

Technical Report ANP-10293, Appendix G will be revised to include the additional information stated below.

The title of ANP-10293, Section G.3.3 will be revised to be “Evaluation of Valves, Orifices, Pipes and Instrument Tubing.” Section G.3.3.2 will be revised to state that the ECCS valves will be qualified per QME-1-2007 to operate with post-LOCA fluids for at least 30 days.

FSAR Impact:

The U.S. EPR FSAR will not be changed as a result of this question.

Technical Report Impact:

Technical Report ANP-10293 will be revised as described in the response and indicated on the enclosed markup.

Question 06.02.02-117:

ANP-10293P, Revision 3, Section G.3.5 for Confirmatory Items states, “The design, procurement, installation, and layout of components consider the reliability of the SIS, RHRS, and ECCS. Based on the ex-vessel downstream effects evaluation, the following ECCS components need verification to confirm post-LOCA operation (with debris constituents listed in Table G.2-3) for a minimum of 30 days.” NRC staff has the following comments regarding confirmatory items:

a. For Item 1, LHSI and MHSI pumps, these items should be revised as needed to be consistent with any revisions due to RAIs. Also, pump design and qualification in a post-LOCA environment should be addressed by a specific component ITAAC.

b. For Item 2, LHSI heat exchanger should state that the vendor will verify that post-LOCA debris constituent will not affect heat exchanger performance. Also, LHSI heat exchanger test/analysis should be addressed by a specific component ITAAC.

c. For Item 3, Valves and Orifices should be revised as needed to be consistent with any revisions due to RAIs. Also, valve design and qualification in a post-LOCA environment should be addressed by a specific component ITAAC.

Response to Question 06.02.02-117:

Technical Report ANP-10293, Appendix G will be revised to include the additional information stated below:

Response to Part a:

ANP-10293 Section G.3.5, item 1 will be revised to reflect the changes due to RAI 498 Question 06.02.02-113 and Question 06.02.02-114.

LHSI and MHSI pump design and qualification in post-LOCA environment is addressed in U.S. EPR FSAR Tier 1, Section 2.2.3 and Table 2.2.3-3 as ITAAC 3.1.

Response to Part b:

ANP-10293 Section G.3.5, item 2 will be revised to contain a provision that the vendor will confirm that debris constituent will not affect heat exchanger performance by:

- Providing test and/or analyses to confirm that the debris plugging and settlement will not occur in the heat exchanger tubes and/or affect the performance of the heat exchanger (due to fouling by post-LOCA debris) for the 30-day mission time.
- Providing test and/or analyses to confirm that the heat exchanger tube material will not degrade significantly in the post-LOCA fluid over the 30-day mission time.

The aforementioned LHSI heat exchanger test/analysis will be included in U.S. EPR FSAR Tier 1, Section 2.2.3 and Table 2.2.3-3 as ITAAC 7.12.

Response to Part c:

ANP-10293, Section G.3.5 will be revised to contain provisions that:

- ECCS valves will be qualified to operate with the post-LOCA fluids for at least 30 days, using the qualification guidance of QME-1-2007.
- As part of qualification process, vendor will provide data and/or analyses to support acceptable wear rates during post-LOCA operation.

The design and qualification of the ECCS valves for operation in post-LOCA will be included in U.S. EPR FSAR Tier 1, Section 2.2.3 and Table 2.2.3-3 as ITAAC 3.1.

FSAR Impact:

U.S. EPR FSAR, Tier 1, Section 2.2.3 and Table 2.2.3-3 will be revised as described in the response and indicated on the enclosed markup.

Technical Report Impact:

Technical Report ANP-10293 will be revised as described in the response and indicated on the enclosed markup.

Question 06.02.02-118:

FSAR Tier 2, Section 6.3, “Emergency Core Cooling System,” Tables 6.3-2 and 6.3-3 for the LHSI and MHSI pump design and operating parameters do not list the Service Fluid. To clarify the operating fluids for these pumps, these tables should be revised to list the normal operating fluids and the “Post-LOCA Downstream Fluid (for 30-day mission time).” Also, FSAR Tier 2, Table 6.3-5 for the LHSI heat exchanger design and operating parameters lists the tube side fluid as primary coolant. To clarify the tube side fluid for the LHSI heat exchanger, the table should be revised to include Post-LOCA Downstream Fluids (for 30-day mission time). In order to provide a link between the ECCS design criteria in FSAR Tier 2, Section 6.3 and the design criteria in ANP-10293P, Appendix G, the applicable portions of FSAR Tier 2, Section 6.3 should reference ANP-10293P, Appendix G for additional component design and evaluation parameters for downstream ex-vessel components exposed to post-LOCA fluids.

Response to Question 06.02.02-118:

U.S. EPR FSAR, Tier 2, Section 6.3.2.5, Tables 6.3-2, 6.3-3, and 6.3-4 will be revised to list “primary coolant” and “post-LOCA downstream fluid” as service fluids for the pumps and heat exchangers.

U.S. EPR FSAR, Tier 2, Section 6.3.2.5 will be revised to reference Appendix G of ANP-10293P for additional component design and evaluation parameters for the ex-vessel downstream components exposed to post-LOCA fluids.

FSAR Impact:

U.S. EPR FSAR, Tier 2, Section 6.3.2.5, Tables 6.3-2, 6.3-3, and 6.3-4 will be revised as described in the response and indicated on the enclosed markup.

Technical Report Impact:

Technical Report ANP-10293 will not be changed as a result of this question.

U.S. EPR Final Safety Analysis Report Markups

2.2.3 Safety Injection System and Residual Heat Removal System

1.0 Description

The safety injection system and residual heat removal system (SIS/RHRS) is a safety-related system. The SIS/RHRS has four divisions. The SIS/RHRS provides the following safety-related functions:

- Emergency core cooling.
- Residual heat removal.
- Reactor coolant pressure boundary integrity.
- Containment isolation.

2.0 Arrangement

2.1 The functional arrangement of the SIS/RHRS is as shown on Figure 2.2.3-1—Safety Injection System and Residual Heat Removal System Functional Arrangement.

2.2 The location of the SIS/RHRS equipment is as listed in Table 2.2.3-1—SIS/RHRS Equipment Mechanical Design.

2.3 Physical separation exists between ~~the~~ divisions of the SIS/RHRS located in the Safeguard Buildings as shown in Figure 2.2.3-1.

06.02.02-114, 117

3.0 Mechanical Design Features

3.1 Pumps and valves listed in Table 2.2.3-1 will be functionally designed and qualified such that each pump and valve is capable of performing its intended function for a full range of system differential pressure and flow, ambient temperatures, and available voltage (as applicable) and with debris-laden coolant fluids under conditions ranging from normal operating to design-basis accident conditions.

3.2 Check valves listed in Table 2.2.3-1 will function to change position as listed in Table 2.2.3-1 under system operating conditions.

3.3 Deleted.

3.4 Components identified as Seismic Category I in Table 2.2.3-1 can withstand seismic design basis loads without a loss of the function listed in Table 2.2.3-1.

3.5 Deleted.

3.6 Deleted.

3.7 Deleted.

3.8 Deleted.

3.9 Deleted.

3.10 SIS/RHRS piping shown as ASME Code Section III on Figure 2.2.3-1 is designed in accordance with ASME Code Section III requirements.

3.11 SIS/RHRS piping shown as ASME Code Section III on Figure 2.2.3-1 is ~~installed~~ reconciled in accordance with ~~an~~ ASME Code Section III ~~Design Report~~design requirements.

3.12 Pressure boundary welds in SIS/RHRS piping shown as ASME Code Section III on Figure 2.2.3-1 are ~~in accordance with~~meet ASME Code Section III non-destructive examination requirements.

3.13 SIS/RHRS piping shown as ASME Code Section III on Figure 2.2.3-1 retains pressure boundary integrity at design pressure.

3.14 SIS/RHRS piping shown as ASME Code Section III on Figure 2.2.3-1 is fabricated, installed, and inspected in accordance with ASME Code Section III requirements.

3.15 Components listed in Table 2.2.3-1 as ASME Code Section III are designed in accordance with ASME Code Section III requirements.

3.16 Components listed in Table 2.2.3-1 as ASME Code Section III are ~~fabricated~~ reconciled in accordance with ASME Code Section III design requirements.

3.17 Pressure boundary welds on components listed in Table 2.2.3-1 as ASME Code Section III ~~are in accordance with~~meet ASME Code Section III non-destructive examination requirements.

3.18 Components listed in Table 2.2.3-1 as ASME Code Section III retain pressure boundary integrity at design pressure.

3.19 Components listed in Table 2.2.3-1 as ASME Code Section III are fabricated, installed, and inspected in accordance with ASME Code Section III requirements.

3.20 Containment isolation valves are located close to containment penetrations.

4.0 Instrumentation and Controls (I&C) Design Features, Displays, and Controls

4.1 Displays listed in Table 2.2.3-2—SIS/RHRS Equipment I&C and Electrical Design are ~~retrievable~~ indicated in the main control room (MCR) and the remote shutdown station (RSS)~~ as listed in Table 2.2.3-2~~.

4.2 Controls on the PICS in the MCR and the RSS perform the function ~~The SIS/RHRS equipment controls are provided in the MCR and the RSS as~~ listed in Table 2.2.3-2.

4.3 Deleted.~~Equipment listed as being controlled by a priority and actuator control system (PACS) module in Table 2.2.3-2 responds to the state requested by a test signal.~~

4.4 ~~The~~ Interlocks for the SIS/RHRS ~~has~~ initiate the following~~ system interlocks~~:

- Opening of the accumulator injection path.
- Opening authorization of the residual heat removal system suction path from the reactor coolant system.
- Opening authorization of the hot-leg safety injection path.

5.0 Electrical Power Design Features

5.1 The components designated as Class 1E in Table 2.2.3-2 are powered from the Class 1E division as listed in Table 2.2.3-2 in a normal or alternate feed condition.

5.2 Deleted.

6.0 Environmental Qualifications

6.1 Components designated as harsh environment in Table 2.2.3-2, that are designated as harsh environment, will perform the function listed in Table 2.2.3-1 under normal environmental conditions, containment test conditions, anticipated operational occurrences, and accident and post-accident environmental conditions.in the environments that exist during and following design basis events.

7.0 Equipment and System Performance

7.1 The SIS/RHRS heat exchangers listed in Table 2.2.3-1 have the capacity to transfer the design heat load to the component cooling water system.

7.2 The accumulators listed in Table 2.2.3-1 provide a required storage volume.

7.3 Each accumulator line has a minimum head loss coefficient (fL/D + K).

7.4 The pumps listed in Table 2.2.3-1 have net positive suction head available (NPSHA) that is greater than net positive suction head required (NPSHR) at system run-out flow.

7.5 The SIS/RHRS delivers water to the reactor coolant system for core cooling.

7.6 Deleted.The SIS/RHRS delivers water to the reactor coolant system within the system run-out flow rate and pump shutoff head for core cooling due to design basis events.

7.7 Class 1E valves listed in Table 2.2.3-2 can perform the will function to change position as listed in Table 2.2.3-1 under system operating conditions.

7.8 The SIS/RHRS provides for flow testing of the SIS/RHRS pumps during plant operation.

7.9 Safety injection pumped flow will be delivered to the RCS before the maximum elapsed time.

7.10 Each LHSI pump delivers water at the required flow rate to its respective hot leg of the reactor coolant system.

7.11 Deleted.LHSI pump and MHSI pump provide safety injection flow to the RCS during post-LOCA operation.

7.12 LHSI heat exchanger cools the post-LOCA fluid for a minimum of 30 days.

7.13 LHSI and MHSI systems provide safety injection flow to the RCS during post-LOCA operation.

8.0 Inspections, Tests, Analyses, and Acceptance Criteria

Table 2.2.3-3 lists the SIS/RHRS ITAAC.

Table 2.2.3-3—Safety Injection System and Residual Heat Removal System ITAAC (10 Sheets)

	Commitment Wording	Inspections, Tests, Analyses	Acceptance Criteria
2.1	The functional arrangement of the SIS/RHRS is as shown on Figure 2.2.3-1.	Inspections An inspection of the as-built system as shown on Figure 2.2.3-1 will be performedconducted.	The as-built SIS/RHRS conforms with to the functional arrangement as shown on Figure 2.2.3-1.
2.2	The location of the SIS/RHRS equipment is as listed in Table 2.2.3-1.	An inspection will be performed. of the location of the equipment listed in Table 2.2.3-1.	The SIS/RHRS equipment listed in Table 2.2.3-1 is located as listed in Table 2.2.3-1.
2.3	Physical separation exists between the divisions of the SIS/RHRS located in the Safeguard Buildings as shown on Figure 2.2.3-1.	An inspection will be performed. to verify that the divisions of the SIS/RHRS are located in separate Safeguard Buildings.	The divisions of the SIS/RHRS are located in separate Safeguard Buildings as shown on Figure 2.2.3-1.
3.1	Pumps and valves listed in Table 2.2.3-1 will be functionally designed and qualified such that each pump and valve is capable of performing its intended function for a full range of system differential pressure and flow, ambient temperatures, and available voltage (as applicable) and with debris-laden coolant fluids under conditions ranging from normal operating to design-basis accident conditions.	Tests or type tests Type test, analyses, or a combination of type test and analyses of the pumps and valves listed in Table 2.2.3-1 will be performedconducted to demonstrate that the pumps and valves function under conditions ranging from normal operating to design-basis accident conditions.	A test report exists and concludes that the pumps and valves listed in Table 2.2.3-1 function under conditions ranging from normal operating to design-basis accident conditions. Test result/report confirms that the ECCS valves, LHSI, pumps and MHSI pumps all perform their intended functions during post-LOCA operation for a minimum of 30 days.
3.2	Check valves listed in Table 2.2.3-1 will function to change position as listed in Table 2.2.3-1 under system operating conditions.	Tests will be performed for the operation of the check valves listed in Table 2.2.3-1.	The check valves change position as listed in Table 2.2.3-1 under system operating conditions.perform the functions listed in Table 2.2.3-1.
3.3	Deleted.	Deleted.	Deleted.

06.02.02-114, 117

Table 2.2.3-3—Safety Injection System and Residual Heat Removal System ITAAC (10 Sheets)

	Commitment Wording	Inspections, Tests, Analyses	Acceptance Criteria
7.1	The SIS/RHRS heat exchangers listed in Table 2.2.3-1 have the capacity to transfer the design heat load to the component cooling water system.	Tests and analyses will be performed to demonstrate the capability of one of the SIS/RHRS heat exchangers as listed in Table 2.2.3-1 to transfer the heat load to the component cooling water system.	The Each SIS/RHRS heat exchanger has the capacity to remove the designtransfer a heat load of at least 2.35E+08 BTU/hr to the component cooling water system via the heat exchangers listed in Table 2.2.3-1.: Heat load per heat exchanger ≥ 2.35E+08 BTU/hr.
7.2	The accumulators listed in Table 2.2.3-1 provide a required storage volume.	Inspections and analyses will be performed to verify the storage volume for accumulators listed in Table 2.2.3-1.	The accumulators listed in Table 2.2.3-1 provide a minimum total volume of 1942.3 ft^3 per accumulator.
7.3	Each accumulator line has a minimum head loss coefficient (fL/D + K).	Tests and analyses will be performed to verify each accumulator line minimum head loss coefficient (fL/D + K).	Each accumulator line provides the following head loss coefficient: has a mMinimum head loss coefficient (fL/M01 + K) per accumulator line =of 3.71 for a flow area of 0.3941ft^2 and f = 0.014.
7.4	The pumps listed in Table 2.2.3-1 have NPSHA that is greater than NPSHR at system run-out flow.	Testing Tests and analyses will be performed. to verify NPSHA for pumps listed in Table 2.2.3-1.	The pumps listed in Table 2.2.3-1 have NPSHA that is greater than NPSHR at system run-out flow.

Table 2.2.3-3—Safety Injection System and Residual Heat Removal System ITAAC (10 Sheets)

	Commitment Wording	Inspections, Tests, Analyses	Acceptance Criteria
7.5	The SIS/RHRS delivers water to the reactor coolant system for core cooling.	Tests will be performed. to determine the SIS/RHRS delivery rate under design conditions.	The SIS/RHRS delivers the following flowrate to the reactor coolant system: a. MHSI pump capacity: ≥ 600 gpm @ 580 psia (cold leg pressure). b. LHSI pump capacity: ≥ 2200 gpm @ 25 psia (cold leg pressure). c. MHSI pump capacity: ≥ 165 gpm @ pressure greater than 1300.0 psia (shutoff condition) d. LHSI pump capacity: ≥ 525 gpm @ pressure greater than 300.0 psia (shutoff head condition) e. MHSI pump capacity: ≤ 1110 gpm @ 14.5 psia (run-out condition) f. LHSI pump capacity: ≤ 3220 gpm @ 14.5 psia (run-out condition)
7.6	Deleted. The SIS/RHRS delivers water to the reactor coolant system within the system run-out flow rate and pump shutoff head for core cooling.	Deleted. a. Tests will be performed to verify satisfactory operations of the SIS/RHRS pumps at run-out flow rate. Deleted .b. Tests will be performed to verify satisfactory operations of the SIS/RHRS pumps at shutoff head.	Deleted. a. The SIS/RHRS pumps perform satisfactorily at system run-out flow rate. Deleted. b. The SIS/RHRS pumps perform satisfactorily at shutoff head (minimum recirculation flow).

06.02.02-114

Table 2.2.3-3—Safety Injection System and Residual Heat Removal System ITAAC (10 Sheets)

Commitment Wording		Inspections, Tests, Analyses	Acceptance Criteria
7.7	Class 1E valves listed in Table 2.2.3-2 ~~can perform the~~ will function to change position as listed in Table 2.2.3-1 under system operating conditions.	~~Tests and analyses or a combination of tests and analyses will be performed to demonstrate the ability of the valves listed in Table 2.2.3-2 to change position as listed in Table 2.2.3-1 under system operating conditions.~~ Tests will be performed for the operation of the valves listed in Table 2.2.3-2.	The valves changes position as listed Table 2.2.3-1 under system operating conditions.
7.8	The SIS/RHRS has provisions to allow flow testing of the SIS/RHRS pumps during plant operation.	~~Testing for flow of the SIS/RHRS pumps through the flow test line~~ Tests will be performed.	The flow test line allows the SIS/RHRS pumps to deliver the following flow rates: a. MHSI pump: Flow rate per pump is greater than or equal to 480 gpm. b. LHSI pump: Flow rate per pump is greater than or equal to 1760 gpm.
7.9	Safety injection pumped flow will be delivered to the RCS before the maximum elapsed time.	Tests will be performed to determine the safety injection pumped flow delivery time using test signals.	Time for safety injection flow to reach full flow does not exceed 15 seconds with offsite power available or 40 seconds with loss of offsite power after receipt of a test signal.
7.10	Each LHSI pump delivers water at the required flow rate to its respective hot leg of the reactor coolant system.	Testing will be performed to demonstrate that each LHSI pump delivers the required flow to its respective hot leg of the RCS.	Each LHSI pump delivers a flow rate greater than or equal to 1720 gpm to its respective hot leg of the RCS at an equivalent RCS pressure of 69.27 psia.

Table 2.2.3-3—Safety Injection System and Residual Heat Removal System ITAAC (10 Sheets)

	Commitment Wording	Inspections, Tests, Analyses	Acceptance Criteria
7.11	Deleted. ~~LHSI pump and MHSI pump provide safety injection flow to the RCS during post-LOCA operation.~~	Deleted. ~~Type tests, analyses, or a combination of type tests and analyses for LHSI and MHSI pumps will be performed.~~	Deleted. ~~Test results confirm that the LHSI and MHSI pumps are capable of providing their required safety injection flow for a minimum of 30 days of continuous post-LOCA operation.~~
7.12	LHSI heat exchanger cools the post-LOCA fluid for a minimum of 30 days.	Type tests, analyses, or a combination of type tests and analyses for heat exchanger performance will be ~~provided by the vendor~~performed.	Type tests, analyses, or a combination of type tests and analyses confirm that debris plugging and settlement in the tubes will not occur, and/or affect the performance of the heat exchanger for the 30-day mission time. Type tests, analyses, or a combination of type tests and analyses also confirms that failure due to abrasive wear will not degrade the performance of the heat exchanger below the 30-day acceptance criteria. ~~Analysis confirms that tube plugging and failure due to abrasive wear will not degrade the performance of the heat exchanger below the 30-day acceptance criteria.~~

06.02.02-117b, and 06.02.02-115

vented to maintain it full of coolant whenever the system is required to be operable to prevent loss of pump suction pressure that could result from accumulation of gases in the piping. Components of the SIS, including those for its support and auxiliary equipment, are designed, procured, installed, and maintained to the appropriate quality and reliability standards. These quality standards, coupled with the system redundancy and physical and electrical separation, allow the SIS to fulfill the design objectives presented in Section 6.3.1.

The RB floor drains direct leakage within the containment, up to an accumulation of two inches depth, to the RB sump where it is monitored, quantified, and processed as liquid waste. The RB floor drains are part of the NIDVS described in Section 5.2.5. Accumulation of leakage in containment greater than two inches depth, which is indicative of a LOCA, flows into the IRWST where it is available for accident response. The relatively low volume of the RB drains, in comparison to that of the IRWST, allows mixing of coolant during injection and recirculation so that no areas accumulate very high to low pH solutions.

The IRWSTS design responds to the post-LOCA ECCS sump performance issues of GSI-191 in accordance with the guidance of RG 1.82. The IRWSTS deters post-accident debris accumulation and SIS sump strainer blockage, in accordance with the expectations of RG 1.82, by:

- Minimizing the post-accident debris source term. The RCS piping and components, and other potentially insulated systems or components within a zone of influence, are insulated with RMI, and or no fibrous or microporous insulation. Due to its high density, RMI is not susceptible to transport and therefore does not contribute to strainer head loss.

- Providing a three-tiered debris retention design. The combination of weirs/trash racks and retaining baskets are effective in retaining most post-accident debris. Furthermore, the sump strainers (the third stage of the three-tiered debris retention design) have a large screen surface area to accommodate the small amount of debris that reaches it. The full coverage screens and retention baskets, which are rigidly mounted to the IRWST floor, limit bypass of debris into the suction lines.

The design features addressing GSI-191 and the performance evaluations are further described in Section 6.3.2.2.2 and Reference 19. Reference 19 also describes the component test program and compares the design to the regulatory positions of RG 1.82 and the information requested in GL 2004-02. Additional component design and evaluation parameters for downstream ex-vessel components exposed to post-LOCA fluids are given in Appendix G of Reference 19.

06.02.02-118

Table 6.3-2—Low Head Safety Injection Pumps Design and Operating Parameters

06.02.02-118

Parameter	Value
Number	4
Type/arrangement	Centrifugal/horizontal
Type of fluid	primary coolant; post-LOCA downstream fluid
Maximum strainer head loss during LBLOCA (at 212°F)	2.1 ft
Design pressure/temperature	1160 psig/360°F
Normal flowrate (approximate)	2200 gpm
Normal flow head (approximate)	480 ft
Minimum flowrate (approximate)	530 gpm
Flow head at minimum flowrate (approximate)	750 ft
NPSH required at maximum flowrate (approximate)	8.2 ft
Nominal motor power (approximate)	340 kW

LHSI Pump Characteristics

Pump flow (gpm)	TDH (ft)	NPSHR (ft)
0.0	787.4	N/A
440	771.0	N/A
880	721.8	3.3
1320	656.2	3.9
1760	574.1	4.6
2200	475.7	5.2
2640	360.9	6.2

Table 6.3-3—Medium Head Safety Injection Pumps Design and Operating Parameters

06.02.02-118

Parameter	Value
Number	4
Type/arrangement	Centrifugal/horizontal
Type of fluid	primary coolant; post-LOCA downstream fluid
Maximum strainer head loss during LBLOCA (at 212°F)	2.1 ft
Design pressure/temperature	1525 psig/250°F
Normal flowrate (approximate)	600 gpm
Normal flow head (approximate)	2260 ft
Minimum flowrate (approximate)	165 gpm
Flow head at minimum flowrate (approximate)	3200 ft
NPSH required at maximum flowrate (approximate)	10 ft
Nominal motor power (approximate)	455 kW

MHSI Pump Characteristics

Pump flow (gpm)	TDH (ft)	NPSHR (ft)
0.0	3280.8	N/A
220	3116.8	8.9
440	2706.7	6.2
660	2050.5	6.6
880	1148.3	7.9

Table 6.3-4—LHSI Heat Exchanger Design and Operating Parameters

06.02.02-118

Parameter	Value
Type	U-Tube, horizontally mounted
Number of units	4
Type of fluid (tube side)	Primary coolant; post-LOCA downstream fluid
Type of fluid (shell side)	Cooling water from CCWS
Material (tube side)	Austenitic stainless steel
Material (shell side)	Ferritic steel
Design pressure (tube side)	1160 psig
Design pressure (shell side)	175 psig
Design temperature (tube side)	360°F
Design temperature (shell side)	225°F
CCWS maximum inlet temperature (normal cooldown)	100.4°F
CCWS maximum inlet temperature (design basis accident)	113°F
LHSI flowrate – injection mode LBLOCA (including minimum flow)	392.4 lb_m/s
LHSI flowrate – RHR operation (minimum flow line closed)	330.7 lb_m/s
CCWS flowrate Trains 1 and 4 (shell side)	828.9 lb_m/s
CCWS flowrate Trains 2 and 3 (shell side)	608.5 lb_m/s
Heat transfer coefficient (UA value)	3.5361 x 10^6 BTU/(hr °F)

Note:

1. Physical dimensions are approximate values.

ANP-10293 Markups

Appendix G
Ex-Vessel Downstream Effects Evaluation

G.1 Introduction

This appendix documents the ex-vessel downstream effects evaluation for the U.S. EPR ECCS/SIS to verify that this system and its components function as designed under post-LOCA conditions. This evaluation verifies that inadequate core or containment cooling will not occur because of debris blockage at flow restrictions, plugging or excessive wear of close-tolerance subcomponents in pumps, valves, and other components in the ECCS flow path. This evaluation uses the guidance of NRC Generic Letter GL 2004-02 for ex-vessel downstream evaluation.

G.1.1 Safety Injection Function

Each SIS train delivers borated water to the RCS by one of three systems that share common piping and valves:

- MHSI.
- LHSI.
- Accumulator injection systems.

The MHSI and LHSI systems share an isolable suction line from the IRWST, and a three-way valve connects the IRWST to either the MHSI or LHSI pump suctions. The injection pumps draw water from the IRWST for their emergency function. The discharge lines for the MHSI, LHSI, and accumulator injection systems branch together to a single injection nozzle on the associated RCS cold leg. The MHSI and the accumulators inject directly into the cold legs. The LHSI pumps inject through the LHSI heat exchangers to the cold legs. In the long-term cooling following a LOCA, the LHSI discharge can be switched to the RCS hot legs to prevent boron precipitation and mitigate steaming from the break.

G.2 Assumptions and Design Information

G.2.1 Accident Scenarios

SIS actuation provides protection for different postulated transients, accidents, and operating events. This evaluation addresses accident scenarios with the potential for debris transportation to the IRWST that could get to the SIS sump strainers and potentially affect ECCS operation. These accidents are the following:

- Small break LOCA (SBLOCA)
- Large break LOCA (LBLOCA)

This evaluation addresses ECCS operation during long-term decay heat removal from the RCS and mitigation of boric acid precipitation.

G.2.1.1 *SBLOCA*

The most limiting SBLOCA is a break with a cross-sectional area of up to approximately 0.5 ft^2 in the cold leg between the SIS injection location and the RPV, with coincident loss of offsite power (LOOP). This event may not immediately challenge the SIS if the CVCS compensates for the reactor coolant loss. The loss of primary coolant eventually results in a decrease in primary system pressure and pressurizer level. The SIS actuates on low pressurizer pressure and automatically starts the MHSI and LHSI pumps. During partial cooldown, the RCS pressure decreases sufficiently to allow MHSI injection into the cold legs. The LHSI pumps actuate and re-circulate, through their specific tangential minimum flow line, into the IRWST, where they take suction.

In contrast to a LBLOCA, the stages of the SBLOCA (such as partial cooldown, controlled state and safe shutdown state) prior to long-term decay heat removal occur over a longer period. The duration of each stage depends on the break size and the performance of the ECCS.

For this evaluation, the SBLOCA is bounded by the LBLOCA, recirculation, and post-LOCA, long-term cooling. The ECCS flows and debris generated during a SBLOCA will be smaller than during a LBLOCA. The SBLOCA is bounded by the conditions of the LBLOCA regarding the evaluation of downstream components.

G.2.1.2 *LBLOCA*

For the LBLOCA, the break is assumed to open instantaneously and results in a large loss of reactor coolant inventory, and high temperature and pressure inside the containment. This LBLOCA, also called the double-ended break, evolves in three phases:

- The blowdown until accumulator injection.
- Refill of the RPV lower plenum by the SIS.
- Re-flooding of the core by the accumulators first, and then by the MHSI and LHSI pumps until a complete quenching of the core is obtained.

To reach the safe shutdown state, the LHSI cold leg injection is switched to LHSI hot leg injection (required for cold leg breaks) to prevent boron precipitation inside the core and excessive boron dilution inside the IRWST. The break flow is compensated by the ECCS/SIS. The SIS aids in containment heat removal.

The MHSI pumps maintain cold leg injection.

G.2.2 Mission Time

“Mission time” is defined as the amount of time that a given component is required to fulfill its safety function in a post-LOCA accident condition. Defining a mission time for this evaluation establishes a duration for which wear or debris-induced failure of a component will not have an adverse impact on ECCS operation. For this evaluation, the mission time for ECCS components following a LBLOCA is 30 days of continuous operation.

G.2.3 Components of Interest

Table G.2-1 lists the SIS/RHRS/IRWST components in the downstream effects evaluation. These components are in the ECCS flow path during SBLOCA and LBLOCA operations.

Table G.2-1 Components in the ECCS Flow Path during a LBLOCA

Components	Description
PUMPS	
LHSI Pump (30JND10/20/30/40 AP001)	**Type**: Centrifugal **Arrangement**: Horizontal **Flow Rate**: ~441.6 lbm/s (maximum)
MHSI Pump (30JNG10/20/30/40 AP001)	**Type**: Centrifugal **Arrangement**: Horizontal **Flow Rate**: ~152.6 lbm/s (maximum)
HEAT EXCHANGERS	
LHSI Heat Exchanger (30JNG10/20/30/40 AC001)	**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**: ~392.4 lbm/s (during LBLOCA LHSI Injection)
VALVES AND ORIFICES	
Motor Operated Valves:	
30JNG10/20/30/40 AA102	**Function**: LHSI Heat Exchanger Control Valve **Size**: 8 inches **Type**: Globe Valve
30JNG10/20/30/40 AA104	**Function**: LHSI Throttle Control Valve **Size**: 8 inches **Type**: Globe Valve
30JNG10/20/30/40 AA060	**Function**: LHSI Discharge Valve **Size**: 8 inches **Type**: Globe Valve
30JNG10/20/30/40 AA061	**Function**: LHSI Discharge Valve **Size**: 4 inches **Type**: Globe Valve

Components	Description
30JNA10/20/30/40 AA002	**Function**: Hot Leg (RCPB) Isolation Valve **Size**: 10 inches **Type**: Globe Valve
30JNG10/20/30/40 AA001	**Function**: LHSI Pump Suction from IRWST Isolation Valve **Size**: 14 inches **Type**: Gate Valve
30JNG12/22/32/42 AA001	**Function**: LHSI Hot Leg Injection Isolation Valve **Size**: 8 inches **Type**: Globe Valve
30JNK10/20/30/40 AA001	**Function**: IRWST 3-Way Isolation Valve **Size**: Inlet – 16 inches; MHSI Outlet – 10 inches; LHSI Outlet – 14 inches **Type**: 3-Way Globe Valve
30JND10/20/30/40 AA002	**Function**: MHSI Pump Discharge Valve **Size**: 6 inches **Type**: Globe Valve
30JND10/20/30/40 AA004	**Function**: MHSI Small Miniflow Line Isolation Valve **Size**: 2 inches **Type**: Globe Valve
30JNG10/20/30/40 AA004	**Function**: LHSI Tangential Miniflow Line Check Valve **Size**: 4 inches **Type**: Lift Check with Electric Motor
30JNA10/20/30/40 AA001	**Function**: Hot Leg (RCPB) Isolation Valve **Size**: 10 inches **Type**: Gate Valve
Manual Valves:	
30JND10/20/30/40 AA001	**Function**: MHSI Suction Isolation Valve **Size**: 10 inches **Type**: Globe Valve
30JND10/20/30/40 AA003	**Function**: MHSI 2nd RCPB Isolation Valve **Size**: 6 inches **Type**: Globe/Check Valve
30JNG10/20/30/40 AA006	**Function**: LHSI 2nd RCPB Isolation Valve **Size**: Inlet – 8 inches ; Outlet – 10 inches **Type**: Globe/Check Valve

Components	Description
Check valves:	
30JND10/20/30/40 AA007	**Function**: MHSI Check Valve **Size**: 6 inches **Type**: Swing Check Valve
30JNG12/22/32/42 AA002	**Function**: LHSI Hot Leg Injection Check Valve **Size**: 8 inches **Type**: Swing Check Valve
30JNG10/20/30/40 AA009	**Function**: LHSI Check Valve **Size**: 8 inches **Type**: Swing Check Valve
30JNG10/20/30/40 AA011	**Function**: LHSI Check Valve **Size**: 8 inches **Type**: Swing Check Valve
30JNG13/23/33/43 AA005	**Function**: Cold Leg Check Valve **Size**: 12 inches **Type**: Swing Check Valve
30JNK10/20/30/40 AA010	**Function**: MHSI Check Valve **Size**: 4 inches **Type**: Swing Check Valve
Orifices:	
30JND10/20/30/40 BP003	**Function**: MHSI Discharge Orifice **Size**: 6 inches
30JND10/20/30/40 BP002	**Function**: MHSI Miniflow Orifice **Size**: 2 inches
30JNG12/22/32/42 BP001	**Function**: LHSI Hot Leg Injection/Suction Orifice **Size**: 8 inches
30JNG10/20/30/40 BP001	**Function**: LHSI Tangential Miniflow Orifice **Size**: 4 inches
30JNG10/20/30/40 BP061	**Function**: LHSI Outside Containment Bypass Line Orifice **Size**: 4 inches

G.2.4 Post-LOCA Fluid Constituents

Debris in the post-LOCA fluid consist of latent debris (particulate and fiber), coating particles (i.e., epoxy, inorganic zinc, and unqualified), 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, small fines, and large pieces. The size range for each size category is given in Table G.2-2.

Table G.2-2 Size Range of Debris Materials

Debris Size Category	Size Range
Particulates	0 – 0.08 inches
Small Fines	< 4 inches
Large Pieces	> 4 inches

The total amount of debris generated during a LBLOCA is given in Table G.2-3.

Table G.2-3 Total Quantity of Debris Generated during a LBLOCA

Debris Source	Particulate	Small Fines	Large Pieces	Totals
Reflective Metal Insulation (RMI) (ft^2)	0	1589.27	529.76	2119.03
Microtherm (ft^3)	1.00	0	0	1.00
Qualified Epoxy Coatings (lbm)	126.30	0	0	126.30
Qualified IOZ Coatings (lbm)	958.70	0	0	958.70
Unqualified Coatings (lbm)	250.00	0	0	250.00
Latent Debris (lbm) Particulates – Dirt and Dust Small fines - Fibers	139.80* 127.50**	10.20* 22.50**	0	150.00
Miscellaneous (ft^2)	0	0	100.00	100.00

* Latent debris quantities used for downstream effects testing (based on recommendations from NUREG/CR 6877). Debris quantity is conservative with respect to amount of dust and dirt particulates.

** Latent debris quantities used for strainer testing (based on NRC recommended values of 85% particulate and 15% fiber). Debris quantity is conservative with respect to the amount of fiber.

The amount of debris that passes through the sump screen depends on the size of the sump screen hole, ratio of open to close area of the screen, the fluid approach velocity to the screen, and the screen geometry. This evaluation assumes that LBLOCA debris materials that are less than or equal to the mesh size of the sump screen (0.08 in × 0.08 in) will bypass the sump strainer. As a result, the ECCS will ingest 100 percent of the microtherm and coating particulates.

Miscellaneous debris materials are large pieces with a debris size range that is significantly greater than the mesh size of the sump screen. As a result, the ECCS will not ingest miscellaneous debris materials.

Bypass testing of the latent debris yielded a fiber bypass percentage of less than 70 percent (see Appendix E, Section E.7.3). This evaluation uses bounding bypass percentages of 100 percent for latent particulates (i.e., dust and dirt) and 70 percent for latent fiber.

Transport testing shows that the RMI debris generated during a LBLOCA will be stopped by the retention basket (see Appendix E, Section E.7.1). In addition, the size of the RMI debris pieces range from 0.25 × 0.25 inches to 4 × 4 inches, which is greater than the mesh size of the sump screen. As a result, this evaluation assumes no RMI bypass through the sump screen.

G.2.5 ECCS Flow Rate and Flow Velocity

To evaluate debris settlement and component wear during LBLOCA, this evaluation conservatively assumes ECCS flow rates ranging from shutoff head conditions to run-out conditions.

The LHSI and MHSI pumps provide minimum flow rates of 72.8 lbm/s (≈525 gpm) and 22.9 lbm/s (≈165 gpm), respectively, to provide pump operation at shutoff head conditions. These minimum flow rates are assumed for evaluating debris settlement in the ECCS.

The debris settlement evaluation (Section G.3.3.1) compares the ECCS fluid velocities with the terminal settling velocities of the debris source materials listed in Table G.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 LHSI and MHSI pumps at shutoff head conditions shall be verified during component procurement.

The SIS/ECCS is designed to limit maximum flow rates to 441.6 lbm/s (3220 gpm) and 152.6 lbm/s (1110 gpm) for the LHSI and MHSI pumps, respectively. Flow rates of

3520 gpm for the LHSI pumps and 1320 gpm for the MHSI pumps are conservatively assumed for component wear evaluation. The component wear rate evaluation is detailed in Section G.3.1.

Table G.2-4 Terminal Settling Velocity of Debris Source Materials

Debris Source Material	Terminal Settling Velocity (ft/sec)	Reference/Comments
Microtherm	N/A	Microtherm, a microporous insulation material similar to calcium silicate, is expected to dissolve in the post-LOCA fluid (NUREG/CR-6772).
Qualified Epoxy Coatings	0.15	NEI 04-07 (page 4-34, epoxy).
Qualified IOZ Coatings	0.000674	NEI 04-07 (page 4-34, inorganic zinc).
Unqualified Coatings	0.15	Estimated to the settling velocity of epoxy coatings.
Latent Debris	0.008	The dust and dirt in the latent debris are expected to dissolve in post-LOCA fluid (based on transport test data on calcium silicate). Therefore, the settling velocity is estimated to the settling velocity of individual fiber from NUKON fiberglass (NEI 04-07, page 4-29).

G.2.6 Summary of Assumptions and Conservatisms

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

1. 100 percent of all particulates (i.e., microtherm, coating debris, latent particulates) and 70 percent of latent fiber are assumed to pass through the strainers and enter into the ECCS. RMI debris generated during a LBLOCA will be stopped by the retention basket.
2. The minimum LHSI and MHSI pump flow rates of 72.8 lbm/s (~525 gpm) and 22.9 lbm/s (~165 gpm), respectively, are assumed for the evaluation of debris settlement in the ECCS.

3. LHSI and MHSI pump flow rates of 3520 gpm and 1320 gpm, respectively, are assumed for component wear evaluation.

Table G.2-5 lists the amount of debris in the post-LOCA fluid (downstream of the sump screen) that will be used for confirmatory tests. The amount of debris in the ECCS during post-LOCA operation is based on Assumption #1. The amount of latent debris in Table G.2-5 is conservatively based on the maximum amount of latent particulates and fiber listed in Table G.2-3.

The size range of the debris materials is based on (i) the assumption that 100 percent 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 400,000 gallons of water during post-LOCA operation which is less than the minimum IRWST water volume of 500,342 gallons. Estimating the debris concentration at less than the expected IRWST volume yields a more concentrated debris-laden fluid for confirmatory tests, and provides for conservative test results.

Table G.2-5 Post-LOCA Fluid Constituents downstream of ECCS Screen

Debris	Amount	Concentration (ppm)	Density (lb/ft^3)	Size Range (inches)	% by Mass
Microtherm	1.00 ft^3	3.6	12	0 – 0.08	100
Qualified Epoxy Coatings	126.30 lbm	38.4	94	0 – 0.08	100
Qualified IOZ Coatings	958.70 lbm	291	457	0 – 0.08	100
Unqualified Coatings	250.00 lbm	76	94	0 – 0.08	100
Latent Particulates	139.80 lbm	42.5	169		
Fine Sand				< 0.003	37.4
Medium Sand				0.003 – 0.02	35.3
Coarse Sand				0.02 – 0.08	27.3
Latent Fiber	22.5 lbm	6.8	2.4[a]	< 4	100

a. As-fabricated density

G.3 ECCS Component Evaluations

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

G.3.1 LHSI and MHSI Pump Evaluation

The LHSI and MHSI pumps are horizontally mounted, centrifugal pumps with single mechanical seals. The pumps are sized in safety injection mode to provide nominal flow rates.

Generally, particulates tend to accumulate and potentially affect flow through close clearances. The LHSI and MHSI pumps will be designed with increased clearances to support successful post-LOCA operations.

The LHSI and MHSI 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 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 LHSI and MHSI 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 LHSI and MHSI 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 LHSI and MHSI pump wetted surface materials (e.g., wear rings, pump internals, bearing, 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, 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 operation with post-LOCA fluids will not impair seal performance, or cause seal failure, or significantly degrade seal leakage during the 30 day post-LOCA mission time.
6. Provide test and/or analysis to confirm:
   - that the cyclone separator or any filtering device designed to protect the mechanical seal, if applicable, is not susceptible to clogging or impairment by fiber or other particulates;
   - and that there is no adverse impact on pump performance or reliability,

   for at least 30 days of operation with post-LOCA fluids. If the cyclone separator or any filtering device will be impaired within 30 days of post-LOCA operation, the test results and/or analysis should show that the absence of a cyclone separator or any filtering device yields acceptable seal performance.
7. The vendor shall also identify any additional potential pump malfunctions, per QME-1-2007 Section QP-7200.
8. The vendor will verify that the LHSI and MHSI pumps provide minimum flow rates of 72.8 lbm/s and 22.9 lbm/s, respectively, at shutoff head conditions.

9. The vendor will verify that LHSI and MHSI pumps provide flow rates at run-out conditions of less than 3520 gpm and 1320 gpm, respectively.

G.3.2 LHSI Heat Exchanger Evaluation

The LHSI heat exchangers are evaluated for potential susceptibility to tube plugging, fouling, and abrasive wear.

G.3.2.1 Heat Exchanger Tube Plugging

Post-LOCA debris will not plug the heat exchanger tubes if the tube's inside diameter is greater than the expected particle size (based on the opening size of the sump screen). In addition, debris will not settle in the heat exchanger tubes if the fluid velocity in the tubes is greater than the terminal settling velocity of the debris (Table G.2-4).

The vendor will provide data to confirm that post-LOCA debris will not plug the heat exchanger tubes during the 30 day mission time. In addition, the vendor will perform one of the following:

- Provide test and/or analyses to confirm that the debris settlement will not occur in the heat exchanger tubes and/or affect the performance of the heat exchanger (due to fouling by post-LOCA debris) for the 30 day mission time.
- Evaluate heat exchanger debris settlement, if the fluid velocity is less than the settling velocity, and provide results to confirm that the heat transfer performance of the heat exchanger will not be adversely affected over the 30 day mission time.

G.3.2.2 Heat Exchanger Performance and Wear

The LHSI heat exchangers are specified and designed with conservative fouling factors 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 LHSI heat exchangers decreases over the 30 day mission time.

Based on the conservative fouling factors, decrease in heat load over the 30 day mission time, and vendor confirmation that no plugging or settling of debris will occur in the tubes, the heat removal performance of the heat exchanger will not be degraded over the 30 day mission time.

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.

G.3.3 Evaluation of Valves, Orifices, Pipes and Instrument Tubing

G.3.3.1 *Blockage and Debris Settling Evaluation for Valves, Orifices, Pipes and Instrument Tubing*

Fluid velocity decreases with increase in pipe diameter. Therefore, the lowest velocity in the ECCS will occur in the region with the largest pipe diameter/flow area.

The suction lines of the LHSI and MHSI pumps are the largest lines in the ECCS/SIS.

The LHSI pump suction line is a 14-inch Schedule 30 stainless steel pipe (inside diameter = 13.25 inches). The velocity in this line at the minimum flow rate is 1.23 ft/s. This velocity is greater than the terminal settling velocities of the post-LOCA debris materials (Table G.2-4). Therefore, settling will not occur in the LHSI flow path to the RCS.

The MHSI pump suction line is a 10-inch Schedule 40S stainless steel pipe (inside diameter = 10.02 inches). The velocity in this line at the minimum flow rate is 0.68 ft/s. This velocity is greater than the terminal settling velocities of the post-LOCA debris materials (Table G.2-3). Therefore, settling will not occur in the MHSI flow path to the RCS.

An analysis will be performed to confirm that post-LOCA debris will not clog the ECCS instrument lines during post-LOCA operation for at least 30 days.

G.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 3520 (490 lbm/s) and 1320 gpm (184 lbm/s) for LHSI and MHSI, respectively, are conservatively assumed for the wear rate evaluation of the components listed in Table G.2-1.

The vendor will qualify the ECCS valves to operate with the post-LOCA fluids for at least 30 days, using the qualification guidance of 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 G.2-5) at the associated flow velocities listed in Table G.3-1.

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.

The ECCS design flow rates listed in Table G.3-1 include the maximum flow rate of the LHSI pump, MHSI pump, and the sum of the LHSI and MHSI flows based on system configuration. For conservatism, vendors will perform component wear evaluations at the assumed flow rates/velocities.

Table G.3-1 Flow Velocities for Component Wear Evaluation

Components	Inside Diameter (inches)	Designed ECCS Flow (lbm/s)	Assumed Flow Rate (lbm/s)	Assumed Velocity (ft/s)
Piping				
14” LHSI Pump Suction Line (SS Schedule 30)	13.25	441.6	490	8.27
8” LHSI Pump and Heat Exchanger Discharge (SS Schedule 80S)	7.625	441.6	490	24.73
10” MHSI Pump Suction Line (SS Schedule 40S)	10.02	152.6	184	5.37
6” MHSI Discharge Line (SS Schedule 40S)	6.065	152.6	184	14.66
10” RCS Cold Leg Discharge (SS Schedule 160)	8.5	< 594.2	674	27.37
8” Hot Leg Injection/Suction Line (SS Schedule 80S)	7.625	< 441.6	490	24.73
Orifice				
4” Orifice on LHSI valve/line bypass	-	< 441.6	490	-
8” Orifice on line between cold leg injection and hot leg injection/suction	-	< 441.6	490	-
6” Orifice on MHSI pump discharge line	-	152.6	184	-
2” Orifice on MHSI Miniflow Orifice	-	-	50	-

G.4 Conclusions

Vendor testing and/or analyses of the components identified in Section G.3 should show that the system as procured will meet the design requirements assumed in the design bases analyses. Meeting these requirements provides assurance that system components are not blocked by debris, or degraded to an extent that they cannot perform their safety function.