From:	WILLIFORD Dennis (AREVA) [Dennis.Williford@areva.com]
Sent:	Thursday, February 14, 2013 4:54 PM
To:	Snyder, Amy
Cc:	Gleaves, Bill; DELANO Karen (AREVA); LEIGHLITER John (AREVA); ROMINE Judy (AREVA); RYAN Tom (AREVA); WILLS Tiffany (AREVA); KOWALSKI David (AREVA)
Subject:	Response to U.S. EPR Design Certification Application RAI No. 553 (6573, 6463), FSAR Ch. 6, Supplement 2
Attachments:	RAI 553 Supplement 2 Response US EPR DC.pdf

Amy,

AREVA NP Inc. provided a schedule for technically correct and complete responses to the two questions in RAI No. 553 on August 24, 2012. Supplement 1 response to RAI No. 553 was sent on February 1, 2013 to provide a response to Question 06.03-18. Based on NRC staff feedback received during the public telecon on February 11th, we have provided a revised final response to Question 06.03-18.

Appended to this file are affected pages of the U.S. EPR Final Safety Analysis Report in redline-strikeout format which support the revised response to RAI 553 Question 06.03-18.

The following table indicates the respective pages in the response document, “RAI 553 Supplement 2 Response US EPR DC.pdf,” that contain AREVA NP’s response to the subject question.

Question #	Start Page	End Page
RAI 553 — 06.03-18	2	7

The schedule for a technically correct and complete response to the remaining question has not changed and is provided below.

Question #	Response Date
RAI 553 — 06.02.05-31	June 28, 2013

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
Email: Dennis.Williford@areva.com

From: WILLIFORD Dennis (RS/NB)
Sent: Friday, February 01, 2013 5:20 PM
To: Amy.Snyder@nrc.gov
Cc: bill.gleaves@nrc.gov; DELANO Karen (RS/NB); LEIGHLITER John (RS/NB); ROMINE Judy (RS/NB); RYAN Tom

(RS/NB); WILLS Tiffany (CORP/QP); KOWALSKI David (RS/NB); GUCWA Len (External RS/NB)
Subject: Response to U.S. EPR Design Certification Application RAI No. 553 (6573, 6463), FSAR Ch. 6, Supplement 1

Amy,

AREVA NP Inc. provided a schedule for a technically correct and complete response to the two questions in RAI No. 553 on August 24, 2012.

The attached file, “RAI 553 Supplement 1 Response US EPR DC.pdf,” provides a technically correct and complete final response to one of the two remaining questions. Appended to this file are affected pages of the U.S. EPR Final Safety Analysis Report in redline-strikeout format which support the response to RAI 553 Question 06.03-18.

The following table indicates the respective pages in the response document, “RAI 553 Supplement 1 Response US EPR DC.pdf,” that contain AREVA NP’s response to the subject question.

Question #	Start Page	End Page
RAI 553 — 06.03-18	2	7

The schedule for a technically correct and complete response to the remaining question has not changed and is provided below.

Question #	Response Date
RAI 553 — 06.02.05-31	June 28, 2013

Sincerely,

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

From: WILLIFORD Dennis (RS/NB)
Sent: Friday, August 24, 2012 3:18 PM
To: Tesfaye, Getachew
Cc: BENNETT Kathy (RS/NB); DELANO Karen (RS/NB); LEIGHLITER John (RS/NB); ROMINE Judy (RS/NB); RYAN Tom (RS/NB); KOWALSKI David (RS/NB); GUCWA Len (External RS/NB)
Subject: Response to U.S. EPR Design Certification Application RAI No. 553 (6573, 6463), FSAR Ch. 6

Getachew,

Attached please find AREVA NP Inc.’s response to the subject request for additional information (RAI). The attached file, “RAI 553 Response US EPR DC.pdf,” provides a schedule since a technically correct and complete response to the two questions cannot be provided at this time.

The following table indicates the respective pages in the response document, "RAI 553 Response US EPR DC.pdf," that contain AREVA NP's response to the subject questions.

Question #	Start Page	End Page
RAI 553 — 06.02.05-31	2	3
RAI 553 — 06.03-18	4	5

The schedule for technically correct and complete responses to these questions is provided below.

Question #	Response Date
RAI 553 — 06.02.05-31	**June 28, 2013**
RAI 553 — 06.03-18	**November 27, 2012**

Sincerely,

Dennis Williford, P.E.
U.S. EPR Design Certification Licensing Manager
AREVA NP Inc.
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From: Tesfaye, Getachew [mailto:Getachew.Tesfaye@nrc.gov]
Sent: Wednesday, July 25, 2012 4:27 PM
To: ZZ-DL-A-USEPR-DL
Cc: Grady, Anne-Marie; Ashley, Clinton; McKirgan, John; Budzynski, John; Donoghue, Joseph; Gleaves, Bill; Segala, John; ArevaEPRDCPEm Resource
Subject: U.S. EPR Design Certification Application RAI No. 553 (6573, 6463), FSAR Ch. 6

Attached please find the subject requests for additional information (RAI). A draft of the RAI was provided to you on June 26, 2012, and discussed with your staff on June 27, July 3 and July 10, 2012. Draft RAI Question 06.02.05-31(e) was modified as a result of those discussions. 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/LB1
(301) 415-3361

Hearing Identifier: AREVA_EPR_DC_RAIs
Email Number: 4221

Mail Envelope Properties (554210743EFE354B8D5741BEB695E6560C804F)

Subject: Response to U.S. EPR Design Certification Application RAI No. 553 (6573, 6463), FSAR Ch. 6, Supplement 2
Sent Date: 2/14/2013 4:54:06 PM
Received Date: 2/14/2013 4:54:59 PM
From: WILLIFORD Dennis (AREVA)

Created By: Dennis.Williford@areva.com

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"Gleaves, Bill" <Bill.Gleaves@nrc.gov>
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Tracking Status: None

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Files	**Size**	**Date & Time**
MESSAGE	5645	2/14/2013 4:54:59 PM
RAI 553 Supplement 2 Response US EPR DC.pdf	849688	

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

Response to

Request for Additional Information No. 553, Supplement 2

7/25/2012

U. S. EPR Standard Design Certification
AREVA NP Inc.
Docket No. 52-020
SRP Section: 06.02.05 - Combustible Gas Control in Containment
SRP Section: 06.03 - Emergency Core Cooling System

Application Section: FSAR Chapter 6

QUESTIONS for Containment & Ventilation Branch (SCVB)

QUESTIONS for Reactor System, Nuclear Performance and Code Review (SRSB)

Question 06.03-18:

Open Item

Follow-up to RAI 416, Question 6.3-15

In response to RAI 416, Question 06.03-15 (June 2011), the applicant references SECY 11-0014, “Use of Containment Accident Pressure in Analyzing Emergency Core Cooling System and Containment Heat Removal System Pump Performance in Postulated Accidents” (January, 2011).

In this Commission paper (SECY 11-0014, ML102590196), the staff presented options to the Commission to resolve outstanding issues related to the use of containment accident pressure (CAP) in determining the net positive suction head (NPSH) margin of safety related pumps.

The Commission provided direction to the staff in Staff Requirements Memorandum (SRM) SECY 11-0014 (ML110740254), on March 15, 2011. Included in the Commission’s response was direction to implement the staff’s guidance.

In FSAR 6.3.3 markup in response to RAI 498 Supplement 4 Question 06.02.02-119 AREVA clarifies that the US EPR does use containment accident pressure in assessing the adequacy of NPSH for ECCS pumps.

However, in response to RAI 416, Question 06.03-15, the applicant did not include a description of how or if the US EPR met the staff guidance contained in SECY 11-0014. Therefore, the staff request AREVA provide information that addresses the guidance, as appropriate.

As an example, the SECY paper guidance (section 6.3) discusses evaluating effective required NPSH (NPSHreff) and Cavitation Erosion. For NPSHreff, the staff guidance proposes that the NPSH margin be calculated from NPSHa − NPSHreff, where NPSHreff is the NPSHr3% value with uncertainties in NPSHr included. This calculated NPSH margin should be equal to or greater than zero. For Cavitation Erosion (or maximum erosion zone) staff guidance states that pump tests indicate that the zone of maximum erosion rate lies between NPSH ratios of 1.2 to 1.6 for pumps operating outside of the zone of suction recirculation. The staff selected a time limit of 100 hours for the time permitted in the maximum erosion zone. NPSH ratio = NPSHa/NPSHreff.

To complete the staff evaluation of the 6.3 SER Phase 2 Open Item 06.03-15 in support of ECCS pump performance, the staff request that AREVA address guidance contained in SECY 11-0014 and provide key NPSH information in FSAR section 6.3 that identifies the limiting or worst case NPSH evaluation for the ECCS pumps with justification for the selected data. At a minimum, the staff expects the FSAR to contain the limiting ECCS pump NPSH evaluation, to include the following parameters and plots, and to specify the basis for the ECCS pump flowrate selected and NPSHr uncertainty. Note, all heads and pressures should be expressed in feet of liquid at the pumping temperature selected for the evaluation.

NPSHa

- Minimum elevation (static) head (feet)
- Strainer loss (feet)

- Line/friction loss (feet)
- Atmosphere Pressure (feet)
- Vapor Pressure of liquid at pump suction (feet)
- NPSHreff where NPSHreff = (1 + uncertainty) x NPSHr3%
- Plot of NPSHa and NPSHreff vs. Time

In addition, as a follow-up to RAI 498, Question 6.2.2-119, the applicant is requested to describe why Tables 6.3-2 and 6.3-3 of the FSAR does not identify pump characteristics for flow rates up to 3220 gpm and 1110 gpm for the LHSI and MHSI pumps since these upper flow rates are identified in Section G.2.5 of Technical Report ANP-10293.

Response to Question 06.03-18:

This response is organized in six parts: (1) The introduction explains the sequence of events used to evaluate the limiting case of net positive suction head (NPSH) for the low-head safety injection (LHSI) and medium-head safety injection (MHSI) pumps, (2) Explains the NPSH evaluation prior to operator manual action, (3) Explains the NPSH evaluation after operator action as the containment continues to heat up, (4) Discusses pump erosion due to cavitation, (5) Explains pump flows used in Technical Report ANP-10293, “U.S. EPR Design Features to Address GSI-191,” and (6) Provides the conclusion.

1. Introduction:

To facilitate understanding of the post-LOCA (loss of coolant accident) sequence of events, the heatup and subsequent cooldown of the in-containment refueling water storage tank (IRWST) is shown in Figure 06.03-18-1–IRWST Liquid Temperature for the large break loss of coolant accident (LBLOCA).

Available NPSH ($NPSH_a$) for the LHSI and MHSI pumps is maintained greater than the required NPSH ($NPSH_r$) to provide adequate flow post-LOCA. This meets the guidance of NRC SECY-11-0014. U.S. EPR FSAR Tier 2, Sections 6.3.3.3 and 6.3.6 will be revised to incorporate this new reference.

2. NPSH Evaluation Before Operator Action:

During a LBLOCA the core blows down rapidly and both sets of LHSI and MHSI pumps provide flow taking suction on a common suction header, one for each of the four trains of the safety injection system (SIS) from the IRWST. U.S. EPR FSAR Tier 2, Section 6.3.3.3, “NPSH Evaluation,” will be revised to provide additional description of the $NPSH_a$ factors.

Minimum static head, h_{static}, for the U.S. EPR design results from the difference in elevation between the liquid surface of the IRWST and the centerline of the pump suction. The IRWST level elevation was conservatively taken as -10.2 ft for all LOCA scenarios, which accounts for liquid holdup in upper containment and does not credit emptying the accumulators or water flowing out of the break. Suction elevation for the LHSI and MHSI pumps is approximately -26.2 ft. The resulting static head is 16.0 ft.

When considering the head loss resulting from fluid friction and fittings in the flow path to the pump, suction flange strainer loss and line/friction loss (feet) are major factors. During a

LBLOCA, debris could accumulate on the IRWST SIS inlet strainer. The head loss values used in the design of the strainers for pressure loss due to debris clogging of the filter bed are based on correlations from experiments performed by AREVA for German utilities and are similar to NUREG/CR-6224, “Parametric Study of the Potential for BWR ECCS Strainer Blockage Due to LOCA Generated Debris,” methods. Pressure loss coefficients (K) were developed and interpolated for temperature. These values were applied to the LBLOCA NPSH calculation. The value for debris head loss is 4.92 ft at 104°F and 3756 gpm. The corresponding value for clean strainer head loss is 1.32 ft. Total strainer head loss is 6.24 ft.

U.S. EPR GSI-191 testing found actual debris-loaded strainer head loss values to be 0.427 ft at a total flow of 3447 gpm. The values used in the design of the strainers for pressure loss due to debris clogging of the filter bed are reasonably conservative.

New U.S. EPR FSAR Tier 2, Figure 6.3-8—LHSI in LB LOCA and Figure 6.3-9—MHSI in LB LOCA, will be provided to show NPSH over time for the LHSI and MHSI pumps, respectively.

3. <u>NPSH Evaluation After Operator Action:</u>

After the initial blowdown and refill, decay heat increases IRWST temperature until the heat removal rate of the LHSI heat exchangers matches the rate of decay heat as shown in Figure 06.03-18-1. The head equivalent to the vapor pressure of the water varies with temperature. U.S. EPR FSAR Tier 2, Section 6.3.3.3, NPSH Evaluation, will be revised to provide additional description of the evaluation of the $NPSH_a$ during this period.

When considering uncertainty with respect to NPSH, $NPSH_a$ and $NPSH_r$ terms are evaluated separately. U.S. EPR FSAR Tier 2, Section 6.3.3.3, NPSH Evaluation, will be revised to provide additional description of the evaluation of the $NPSH_a$ and $NPSH_r$ uncertainty. Table 06.03-18-1 shows the uncertainties considered in the $NPSH_a$ calculations.

U.S. EPR FSAR Tier 2, Tables 6.3-2 and 6.3-3, will be revised to include effective required NPSH ($NPSH_{reff}$) values. $NPSH_a$ values have been deleted from these tables since $NPSH_a$ is a function of time dependent temperature and system configuration. “Maximum strainer head loss during LBLOCA” was also deleted from the tables since the information has been added in U.S. EPR FSAR Tier 2, Section 6.3.3.3, “NPSH Evaluation.”

4. <u>Susceptibility to Erosion During Cavitation:</u>

Generic pump tests indicate that the zone of maximum cavitation erosion rate lies between NPSH margin ratios of 1.2 to 1.6 according to NRC SECY-11-0014. The NPSH margin over time where NPSH ratio is between 1.2 and 1.6 are shown in new U.S. EPR FSAR Tier 2 Figure 6.3-8 and Figure 6.3-9.

The first part of the NPSH evaluation considers the period without operator action as the IRWST heats up and then the interval in the low NPSH margin range that is approximately two hours for LHSI. Therefore, the time of greatest susceptibility to cavitation erosion is very limited. Figure 06.03-18-1 shows that IRWST temperatures were above 200°F for approximately six hours.

This predicted period of operation during cavitation erosion concern of six hours is only 6 percent of the 100 hour limit established in SECY-11-0014 and does not significantly affect pump long term capability.

5. Explanation of Flows used in Technical Report ANP-10293:

Many scenarios were investigated to evaluate NPSH. The flow rates of 2925 gpm (LHSI flow) and 1107 gpm (MHSI flow) represent maximized flow rates in a scenario to conservatively assess limiting NPSH. A combined flow rate of 3447 gpm (before the RCS fully depressurizes) is considered appropriate for U.S. EPR GSI-191 analyses and testing. The effect of a higher flow during the GSI-191 testing is not significant as the debris loading was insufficient to fully cover the strainer.

In addition, U.S. EPR GSI-191 testing found actual debris-loaded strainer head loss values to be 0.427 ft at a total flow of 3447 gpm. The values used in the NPSH analysis of the strainers for pressure loss due to debris clogging of the filter bed are reasonably conservative.

U.S. EPR FSAR Tier 2, Table 6.3-2 and Table 6.3-3, will be revised to include LHSI flow of 3220 gpm and MHSI flow of 1110 gpm.

6. Conclusion:

Large NPSH margin exists during the blowdown and refill phases, as shown in U.S. EPR FSAR Tier 2, Figure 6.3-8—LHSI in LB LOCA and Figure 6.3-9—MHSI in LB LOCA. At approximately one hour into the event operator action to align LHSI flow, required for simultaneous cold-leg and hot-leg injection and stop MHSI flow, is taken to limit pump runout. This corresponds to the slightly positive LHSI pump NPSH margin.

Note: The NPSH Margin and NPSHA curves in U.S. EPR FSAR Tier 2, Figure 6.3-8 exhibits what appears to be a slight discontinuity around 2000 seconds. This apparent discontinuity has been evaluated and verified to result from the Excel curve plotting application attempting to plot a smooth curve on a log-log scale plot. There is no data error associated with this plot.

Table 06.03-18-1 NPSH$_a$ Uncertainty

Uncertainty Factor	Pressure/Head	Flow
Friction Loss Factors for Piping & Fittings	+/- 20%	N/A
Friction Loss Factors for flow coefficient (Cv) Values of Valves	+/- 5%	N/A
Pump Wear (4)	(1)	-10% (3)
Pump Manufacturing Tolerances (4)	+ 3% (2)	+ 3% (3)
Plant Instrument Uncertainty (4)	+/- 2% (2)	+/- 2% (3)
Grid Frequency Variation (4)	+/- 1.7% (2)	+/- 0.83% (3)

Notes:

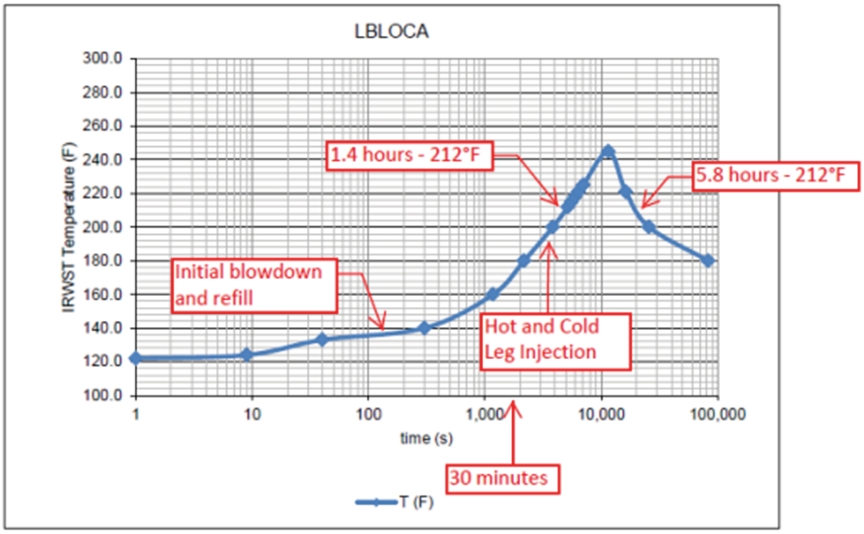
(1) Apply to flow, as flow degradation (seals) is more likely than mechanical wear based on infrequent service of pumps.

(2) Apply to the pump total dynamic head.

(3) Apply to pump design flow

(4) These values are considered independent of each other and may be combined using the “sum of the squares” method.

Figure 06.03-18-1–IRWST Liquid Temperature



FSAR Impact:

U.S. EPR FSAR Tier 2, Sections 6.3.3.3 and 6.3.6 and Tables 6.3-2 and 6.3-3 will be revised as described in the response and indicated on the enclosed markup.

U.S. EPR FSAR Tier 2, Figures 6.3-8 and 6.3-9 will be added as described in the response and indicated on the enclosed markup.

Technical Report Impact:

Technical Report ANP-10293P, “U.S. EPR Design Features to Address GSI-191,” will not be changed as a result of this question.

U.S. EPR Final Safety Analysis Report Markups

occurs. Automatic partial cooldown (via the secondary side) is unnecessary due to the rapid depressurization caused by the break.

SIS actuates on receipt of a low pressurizer pressure signal. The most limiting single failure for this event is the loss of one SIS train (i.e., loss of one MHSI pump and one LHSI pump). Because one other train is conservatively assumed to be unavailable due to maintenance or other activity, only two pump trains are available for the event. Four accumulators are assumed to be available, as accumulator maintenance is prohibited during power operation and the downstream accumulator isolation valves are secured open (breakers racked out) to protect against active single failure.

When the RCS pressure falls below the accumulator pressure, fluid from the accumulators is injected into the cold legs. SIS flow injects into the RCS when system startup-time delays have elapsed and primary system pressure falls below the respective shutoff heads of the MHSI and LHSI systems. While some of the ECCS flow bypasses the core and goes directly out of the break, the downcomer and lower plenum gradually refill. During this refill phase, heat is primarily transferred from the hotter fuel rods to cooler fuel rods and structures by radiative heat transfer.

When the lower plenum is refilled to the bottom of the fuel rod heated length, the refill phase ends and the reflood phase begins. The ECCS fluid flowing into the downcomer provides the driving head to move coolant through the core. As the mixture level moves up the core, steam is generated and liquid is entrained. As this entrained liquid is carried into the SGs, it vaporizes because of the higher temperature in the SGs. This causes steam binding, which reduces the core reflooding rate. The fuel rods are cooled and quenched by radiation and convective heat transfer as the quench front moves up the core. Long term recirculation cooling is maintained by the LHSI function of the SIS.

6.3.3.3 NPSH Evaluation

An evaluation of the MHSI and LHSI pumps demonstrates sufficient NPSH is available during postulated DBAs.

The basic relationship that describes available NPSH is:

$$NPSH_a = h_{atm} + h_{static} - h_{loss} - h_{vp}$$

Where:

h_{atm} = the head on the liquid surface resulting from the pressure in the atmosphere above the IRWST

h_{static} = the head resulting from the difference in elevation between the liquid surface and the centerline of the pump suction

h_{loss} = the head loss resulting from fluid friction and fittings in the flowpath to the pump suction flange

h_{vp} = the head equivalent to the vapor pressure of the water at the water temperature

The head equivalent to the vapor pressure of the water at the water temperature varies with temperature. For IRWST water properties during the time period prior to the IRWST reaching 212°F, the analysis assumes subcooled liquid at 1 atm which was the containment pressure before the accident. When IRWST temperature is greater than 212°F, the atmospheric pressure term is set equal to the IRWST liquid vapor pressure.

This evaluation includes the effects of IRWST temperature, sump screen resistance with debris, pump performance with uncertainties, and uncertainties in hydraulic resistances. The uncertainties associated with pump performance and hydraulic resistances include:

- Friction loss factors for piping and fittings;
- Friction loss factors for flow coefficient (C_V) values of valves;
- Pump wear;
- Pump manufacturing tolerances;
- Plant instrument uncertainties;
- Grid frequency variation.

IRWST temperatures are calculated using RELAP5/B&W (Reference 16) to determine the mass and energy release, and GOTHIC (Reference 17) to determine the containment and IRWST responses. The IRWST temperatures are calculated conservatively by mixing the condensed liquid in the containment with the IRWST water. The limiting case is the double-ended guillotine (DEG) hot-leg break, Figure 6.3-7—IRWST LOCA Temperature Response. The peak IRWST temperature is calculated to be 246.2°F. The limiting evaluation of NPSH credits containment accident pressure since it conservatively assumes the IRWST liquid is at the saturation pressure corresponding to the peak calculated IRWST temperature.

The SIS pump NPSH evaluation for LBLOCA events is performed using the maximum pump flow head-capacity curves (with uncertainties biased towards enhanced pump performance), minimum system resistances, debris laden sump screen resistance, and a reduced IRWST level to account for liquid hold up in the containment.

Required NPSH is specified by the pump vendor as a result of factory testing as the value of NPSH which results in a 3-percent drop in pump discharge head ($NPSH_{r3\%}$).

$NPSH_r$ is a property of the pump itself. Following the guidance of SECY-11-0014 (Reference 20), uncertainties associated with $NPSH_r$ are used to determine the effective $NPSH_r$ ($NPSH_{reff}$), where:

$$NPSH_{reff} = (1 + \text{uncertainty})\, NPSH_{r3\%}$$

The following uncertainty factors that affect $NPSH_r$ developed during pump testing were considered:

1. The $NPSH_r$ varies with changes in pump speed caused by motor slip.
2. The $NPSH_r$ decreases with increasing water temperature.
3. Incorrectly designed field suction piping adversely affects the $NPSH_r$.
4. The air content of the water used in the vendor's test may be lower than that of the pumped water in the field.
5. Wear ring leakage impacts $NPSH_r$.

The $NPSH_r$ curves have not been adjusted to consider the positive impact of increasing water temperature (Item 2). This results in a conservative value for $NPSH_r$. A 21 percent margin has been applied to account for the effects of the other four uncertainty factors. This margin is consistent with that used in operating plants. Therefore:

$$NPSH_{reff} = (1 + 0.21)NPSH_{r3\%}$$

$$NPSH_{margin} = NPSH_a - NPSH_{reff}$$

For the LBLOCA event, MHSI and LHSI flow is credited to reflect core quench. In Section 15.6.5, the LBLOCA event was analyzed over a period of approximately 800 seconds. During this time frame, the MHSI and LHSI pumps maintain adequate NPSH margin (see Figure 6.3-8—LHSI in LB LOCA and Figure 6.3-9—MHSI in LB LOCA). The MHSI and LHSI NPSH margin is calculated under the following conditions:

~~For the LBLOCA, MHSI flow is most important during the peak cladding temperature (PCT) analysis period. The MHSI pump is calculated to have an NPSH margin of 309 percent under the following conditions:~~

- IRWST temperature of 135°F.~~;~~
- IRWST level elevation at -10.2 ft.~~;~~
- Minimum static head of 16.0 ft.

- Strainer head loss of 1.11 ft.
- Strainer head loss, including debris, of 4.21 ft.
- RCS break pressure of 45 psia (RCS pressure remains at or above this pressure until after PCT has been reached).~~;~~
- Containment pressure reduced to 1 atm (containment pressure prior to the accident).~~;~~
- Enhanced pump performance and degraded system resistances.

~~The NPSH evaluation for MHSI is more limiting than the evaluation for LHSI. For analyses with IRWST at temperatures that exceed 212°F, containment vapor pressure is used.~~

~~For the LBLOCA, simultaneous operation of both the MHSI and LHSI pumps is considered. The increase in IRWST temperature is taken into account for the LBLOCA analysis in Section 15.6.5. The LBLOCA analysis inherently bounds the SBLOCA analysis.~~

For the LBLOCA, after approximately 1.4 hours IRWST temperature exceeds 212°F. However, before reaching this temperature, operator action for termination of MHSI flow when the core outlet remains saturated can proceed when total LHSI flow exceeds the minimum flow rate specified by accident analysis as described in Reference 4 of Section 13.8. If the core outlet remains saturated, initiation of LHSI hot leg injection at approximately 60 minutes is performed to prevent boron precipitation and mitigate steaming from the break as described in Section 6.3.2.8, Manual Actions, and Section 15.6.5.4.1.3, Boron Precipitation Assessment.

During the period that IRWST temperature exceeds 212°F, the atmospheric pressure term is set equal to the IRWST liquid vapor pressure and is used in calculating $NPSH_a$. During this period, the following equation applies:

$$NPSH_a = h_{static} - h_{loss}$$

The liquid temperature continues to increase until about 3 hours into the event when the heat removal capacity of the LHSI heat exchangers exceeds the heat addition to the IRWST by the liquid break flow.

The most limiting case for NPSH for the LHSI pump is 2925 gpm during simultaneous injection, saturated liquid in the IRWST, and saturation pressure both in containment and at the break at 212°F as shown in Figure 6.3-8—LHSI in LB LOCA. For this case, the MHSI pump is switched off so the LHSI pump discharge flow rate equals the total suction flow rate. The results are:

$h_{atm} = h_{vp}$

$h_{static} = 16.0$ ft

$h_{loss} = 0.80$ ft (strainer)

$h_{loss} = 1.34$ ft (debris)

$h_{loss} = 7.63$ ft (total = debris + strainer + piping)

LHSI $NPSH_a = 8.37$ ft

LHSI $NPSH_{reff} = 8.35$ ft

LHSI NPSH Margin = 0.02 ft or 0.2 percent

The most limiting case for NPSH for the MHSI pump is 1107 gpm before reaching saturated conditions above 200°F, as shown in Figure 6.3-9 - MHSI in LB LOCA. For this case, the total suction flow rate is 3750 gpm because the MHSI and LHSI systems operate together at the beginning of a LOCA. The analyzed LHSI flow rate is 2643 gpm. The results are:

$h_{atm} = 1$ atm = 35.4 ft

$h_{vp} = 11.5$ psia = 27.6 ft

$h_{static} = 16.0$ ft

$h_{loss} = 1.32$ ft (strainer)

$h_{loss} = 2.36$ ft (debris)

$h_{loss} = 7.47$ ft (total = debris + strainer + piping)

MHSI $NPSH_a = 16.33$ ft

MHSI $NPSH_{reff} = 10.41$ ft

MHSI NPSH Margin = 5.9 ft or 57 percent

The SIS lineup for evaluating the most limiting case for NPSH is when only one SIS train is injecting to the RCS considering one train is unavailable due to a single failure; another train is out for maintenance, and another train feeds the broken loop. Initially both the LHSI and MHSI pumps of the remaining trains inject into the RCS cold leg. This is followed by the lineup where the MHSI pump is stopped and the LHSI pump simultaneously injects to the hot and cold legs of the RCS.

Most significant cavitation erosion effects occur between NPSH ratios of 1.2 to 1.6. A short period of approximately six hours, during which the NPSH ratios are in this range, does not significantly affect MHSI or LHSI pump long term capability, as shown in Figure 6.3-8—LHSI in LB LOCA and Figure 6.3-9—MHSI in LB LOCA

6.3.4 Tests and Inspections

Refer to Section 14.2 (Test abstract #014, #015, #016, #022, #175, and #177) for initial plant testing. Applicable guidance from RG 1.79 is incorporated in the initial plant testing described in Section 14.2.

Surveillance Requirements 3.5.1, 3.5.2, 3.5.3, and 3.5.4 in Chapter 16 describe the SIS surveillance requirements.

The installation and design of the SIS and IRWSTS provides accessibility for periodic testing and in-service inspection. Sections 3.9.6, 5.2.4, and 6.6 address the pre-service and in-service testing and inspection programs for the SIS.

6.3.5 Instrumentation Requirements

The SIS trains and IRWSTS are monitored and controlled from the main control room through the instrumentation and control systems. The instrumentation and control systems process and display information in the main control room, and actuate the safety injection function as required by plant process safety parameters.

Operator intervention to protect the SIS equipment is required in the event of alarms that indicate unacceptable parameters, such as high bearing oil, motor winding, or motor air temperatures, or loss of suction head. Such conditions alarm or indicate in the control room.

The SIS pumps start automatically on receipt of a safety injection signal, with independent power supply for each train provided by the emergency power supply system. When the permissive P12 is not validated (RCS pressure is at or near that for power operation), the SIS pumps start on the receipt of a low pressurizer pressure signal. When the permissive P12 is validated (RCS pressure indicates reactor shutdown and cooldown in progress), the SIS pumps start on the receipt of a low RCS delta-Psat signal (difference between the RCS hot-leg actual pressure and the RCS hot-leg saturation pressure). In the event a LOCA occurs when permissive P15 is validated (LHSI is in RHR mode with no RCPs in operation), the MHSI pumps start automatically on loss of RCS level. Permissive signals are described in Section 7.2.1.3.

On receipt of a safety injection signal, the motor operated valves in the injection paths receive a signal to open and the hot-leg suction or alternate injection line isolation valves receive a signal to close.

14. BL 01-01, “Circumferential Cracking of Reactor Pressure Vessel Head Penetration Nozzles,” U.S. Nuclear Regulatory Commission, August 2001.
15. BL 02-01, “Reactor Pressure Vessel Head Degradation and Reactor Coolant Pressure Boundary Integrity,” U.S. Nuclear Regulatory Commission, March 2002.
16. BAW-10164P-A, Revision 6, “RELAP5/ MOD2-BAW – An Advanced Computer Program for Light Water Reactor LOCA and Non-LOCA Transient Analyses,” AREVA NP Inc., June 2007.
17. BAW-10252(NP)-A, Revision 0, “Analysis of Containment Response to Postulated Pipe Ruptures Using GOTHIC,” Framatome ANP, September 2005.
18. GL 2004-02, “Potential Impact of Debris Blockage on Emergency Recirculation during Design Basis Accidents at Pressurized-Water Reactors,” U.S. Nuclear Regulatory Commission, September 2004.
19. ANP-10293P, Revision 4, “U.S. EPR Design Features to Address GSI-191,” AREVA NP Inc., November 2011.
20. NRC SECY Paper, “Use of Containment Accident Pressure in Analyzing Emergency Core Cooling System and Containment Heat Removal System Pump Performance in Postulated Accidents,” SECY-11-0014, January 31, 2011.

All changes are in response to RAI 553, Question 06.03-18

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

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
Nominal motor power (approximate)	340 kW

LHSI Pump Characteristics

Pump Flow (gpm)	TDH (ft)	NPSH~~R~~$_{r3\%}$ (ft)	NPSH~~A~~$_{reff}$ (ft)
0.0	782	2.5	3.0~~15.9~~
440	760	2.8	3.4~~15.2~~
880	718	3.2	3.9~~14.2~~
1320	656	3.8	4.6~~12.9~~
1760	575	4.4	5.3~~11.1~~
2200	480~~475~~	5.3	6.4~~9.1~~
2640	356	6.2	7.5~~6.7~~
3220	108	8.2	9.9

All changes are in response to RAI 553, Question 06.03-18

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

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
Nominal motor power (approximate)	455 kW

MHSI Pump Characteristics

Pump Flow (gpm)	TDH (ft)	NPSH~~R~~$_{r3\%}$ (ft)	NPSH~~A~~$_{reff}$ (ft)
0.0	3281	N/A	N/A~~15.9~~
220	3146	7.4	9.0~~15.7~~
440	2751	4.7~~5.1~~	5.7~~15.4~~
660	2096	5.1	6.2~~15.0~~
880	1182	6.7	8.1~~14.5~~
1110~~1053~~	328~~281~~	8.6~~7.9~~	10.4~~14.0~~

Figure 6.3-8—LHSI in LB LOCA

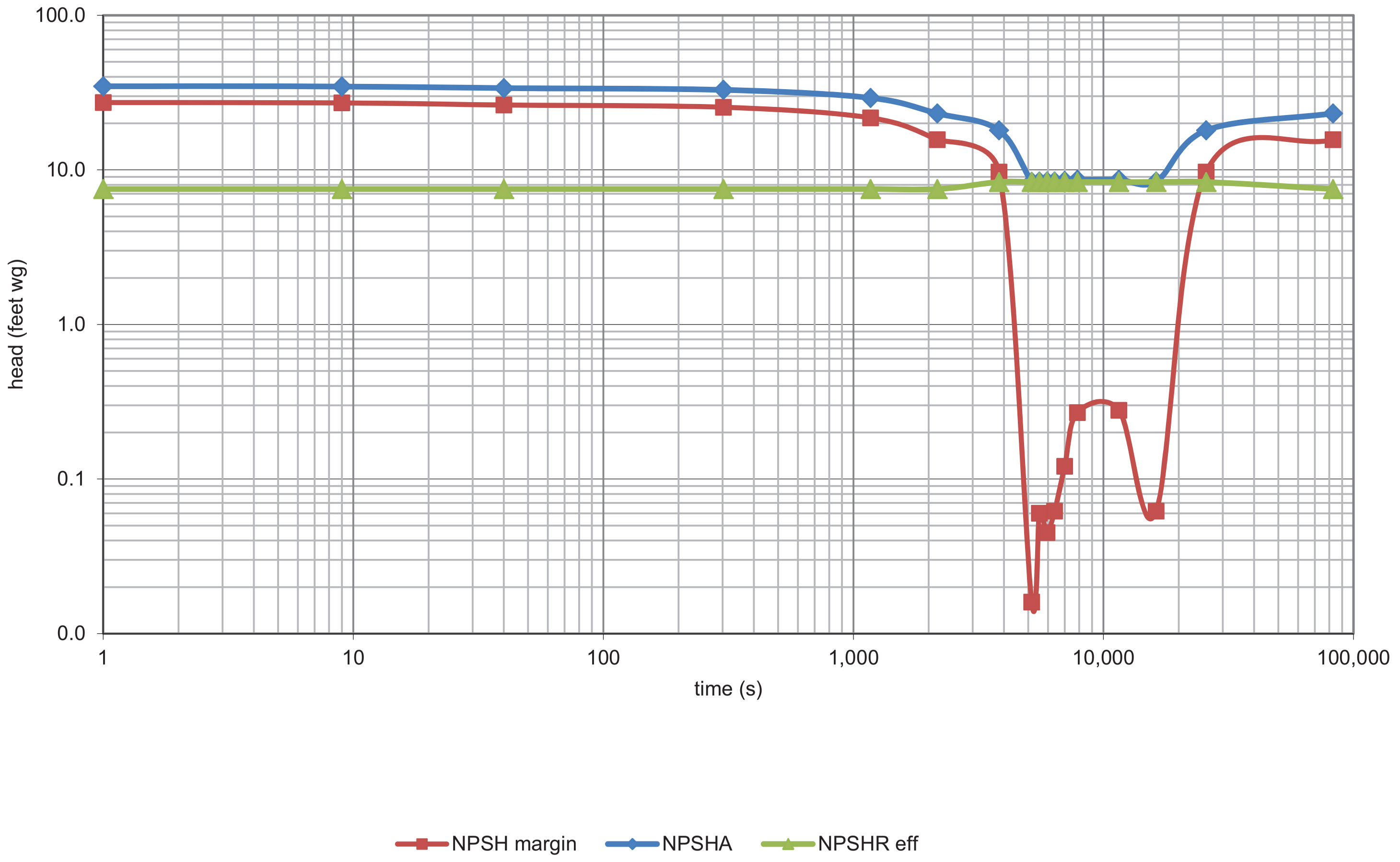


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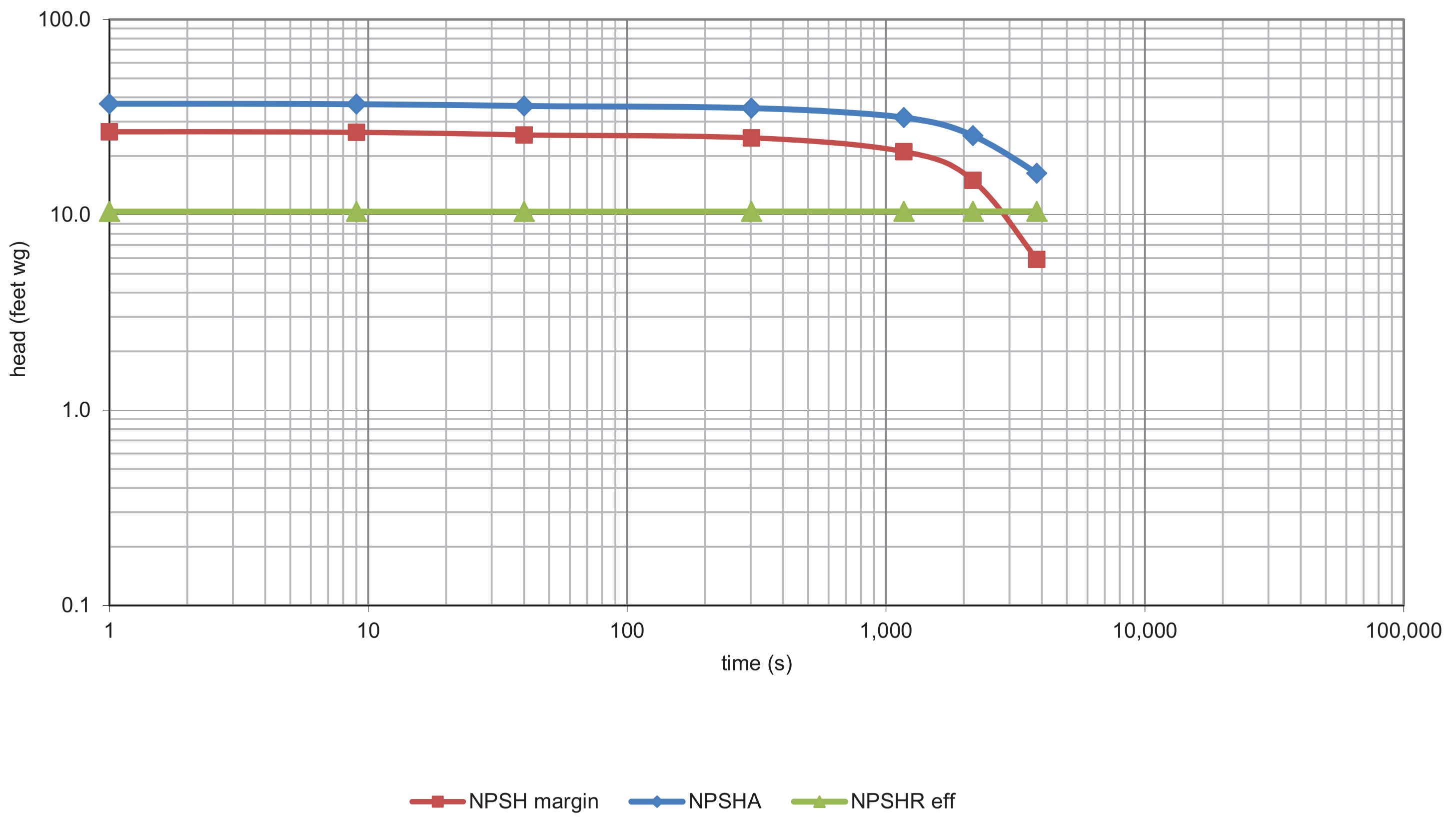
Figure 6.3-9—MHSI in LB LOCA



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