Areva EPRDCPEm Resource

From: WELLS Russell (AREVA) [Russell.Wells@areva.com]
Sent: Thursday, September 30, 2010 5:18 PM
To: Tesfaye, Getachew
Cc: BRYAN Martin (EXTERNAL AREVA); BENNETT Kathy (AREVA); DELANO Karen (AREVA); ROMINE Judy (AREVA); ROMINE Judy (AREVA); LENTZ Tony (EXTERNAL AREVA); RYAN Tom (AREVA)
Subject: Response to U.S. EPR Design Certification Application RAI No. 265, FSAR Ch 3, Supplement 5
Attachments: RAI 265 Supplement 5 Response US EPR DC.pdf

Getachew,

On October 16, 2009. AREVA NP Inc. (AREVA NP) submitted the response to RAI 265 which provided a technically correct and complete response to 1 of the 7 questions. On December 18, 2010, AREVA NP submitted Supplement 1 to RAI 265 which provided a technically correct and complete response to the remaining 6 questions On June 3, 2010, AREVA NP Inc. submitted Supplement 2 to RAI No. 265 which responded to NRC comments on the AREVA NP response to Questions 03.06.03-20 and 03.06.03-21 that were provided in RAI No. 265 Supplement 1. The NRC comments were provided in a telecon with AREVA NP on April 7, 2010. A revised schedule for the response to the remaining NRC comment on Question 03.06.03-26, regarding the revised allowable load limit (ALL) diagrams for the pressurizer surge line (SL), was provided in Supplement 3 to RAI No. 265 on July 14 2010 and Supplement 4 to RAI No. 265 on August 30, 2010.

As committed, the attached file, “RAI 265 Supplement 5 Response US EPR DC.pdf” provides the revised ALL diagrams as requested by NRC. Please note that this file also contains a revised response to Question 03.06.03-26 that was originally provided in RAI 265 Supplement 2. The attached file provides: 1) the original NRC questions 03.06.03-20 and 03.06.03-26; 2) the original AREVA NP responses provided in RAI 265 Supplement 1; 3) the NRC comments on the AREVA NP responses to Questions 03.06.03-20 and 03.06.03-26; and 4) the AREVA NP responses to the NRC comments.

Appended to this file are affected pages of the U.S. EPR Final Safety Analysis Report in redline-strikeout format which supports the response to RAI 265 Question 03.06.03-26.

The following table indicates the respective pages in the response document, “RAI 265 Supplement 5 Response US EPR DC.pdf” that contains the AREVA NP’s response to the subject questions.

Question #	Start Page	End Page
RAI 265 — 03.06.03-20	2	6
RAI 265 — 03.06.03-26	7	9

This concludes the formal AREVA NP response to RAI 265, and there are no questions from this RAI for which AREVA NP has not provided responses.

Sincerely,

(Russ Wells on behalf of)
U.S. EPR Design Certification Licensing Manager
AREVA NP Inc.
Tel: (434) 832-3016
702 561-3528 cell
Martin.Bryan.ext@areva.com

From: BRYAN Martin (External RS/NB)
Sent: Monday, August 30, 2010 12:10 PM
To: 'Tesfaye, Getachew'
Cc: DELANO Karen (RS/NB); ROMINE Judy (RS/NB); BENNETT Kathy (RS/NB); WELLS Russell (RS/NB)
Subject: Response to U.S. EPR Design Certification Application RAI No. 265, FSAR Ch 3, Supplement 4

Getachew,

On June 3, 2010, AREVA NP Inc. submitted Supplement 2 to RAI No. 265 which responded to NRC comments on the AREVA NP response to Questions 03.06.03-20 and 03.06.03-21 that were provided in RAI No. 265 Supplement 1. The NRC comments were provided in a telecon with AREVA NP on April 7, 2010. On July 14 2010, AREVA NP submitted Supplement 3 to RAI No. 265 which provided a revised schedule for the response to the remaining NRC comment on Question 03.06.03-26, regarding the revised allowable load limit (ALL) diagrams for the pressurizer surge line (SL).

Additional time is needed to prepare the revised ALL diagrams. Accordingly , a revised schedule for the technically correct and complete response to the remaining NRC comment is provided below.

Question #	Response Date
RAI 265 — 03.06.03-26	September 30 2010

Sincerely,

Martin (Marty) C. Bryan
U.S. EPR Design Certification Licensing Manager
AREVA NP Inc.
Tel: (434) 832-3016
702 561-3528 cell
Martin.Bryan.ext@areva.com

From: BRYAN Martin (EXT)
Sent: Wednesday, July 14, 2010 3:05 PM
To: Tesfaye, Getachew
Cc: DELANO Karen V (AREVA NP INC); ROMINE Judy (AREVA NP INC); BENNETT Kathy A (OFR) (AREVA NP INC); WELLS Russell D (AREVA NP INC)
Subject: Response to U.S. EPR Design Certification Application RAI No. 265, FSAR Ch 3, Supplement 3

Getachew,

On June 3, 2010, AREVA NP Inc. submitted Supplement 2 to RAI No. 265 which responded to NRC comments on the AREVA NP response to Questions 03.06.03-20 and 03.06.03-21 that were provided in RAI No. 265 Supplement 1. The NRC comments were provided in a telecon with AREVA NP on April 7, 2010. The cover letter accompanying this RAI response (i.e., AREVA NP letter NRC 10:051), indicated that the response to the NRC comment on Question 03.06.03-26, regarding the revised allowable load limit (ALL) diagrams for the pressurizer surge line (SL) would be submitted to NRC by July 31, 2010. Additional time is needed to prepare the revised ALL diagrams.

The revised schedule for the technically correct and complete response to the remaining NRC comment is provided below.

Question #	Response Date
RAI 265 — 03.06.03-26	August 31, 2010

Sincerely,

Martin (Marty) C. Bryan
U.S. EPR Design Certification Licensing Manager
AREVA NP Inc.
Tel: (434) 832-3016
702 561-3528 cell
Martin.Bryan.ext@areva.com

From: BRYAN Martin (EXT)
Sent: Thursday, June 03, 2010 6:20 PM
To: 'Tesfaye, Getachew'
Cc: WELLS Russell D (AREVA NP INC); DELANO Karen V (AREVA NP INC); ROMINE Judy (AREVA NP INC); BENNETT Kathy A (OFR) (AREVA NP INC)
Subject: PROPRIETARY Response to U.S. EPR Design Certification Application RAI No. 265, FSAR Ch 3, Supplement 2

Getachew,

Attached are AREVA NP's letter (NRC 10:051), affidavit and PROPRIETARY and Non-Proprietary version of the response to RAI No. 265, Supplement 2.

Sincerely,

Martin (Marty) C. Bryan
U.S. EPR Design Certification Licensing Manager
AREVA NP Inc.
Tel: (434) 832-3016
702 561-3528 cell
Martin.Bryan.ext@areva.com

From: BRYAN Martin (EXT)
Sent: Thursday, June 03, 2010 6:15 PM
To: 'Tesfaye, Getachew'
Cc: DELANO Karen V (AREVA NP INC); ROMINE Judy (AREVA NP INC); BENNETT Kathy A (OFR) (AREVA NP INC); WELLS Russell D (AREVA NP INC)
Subject: Response to U.S. EPR Design Certification Application RAI No. 265, FSAR Ch 3, Supplement 2

Getachew,

The proprietary and non-proprietary versions of the response to RAI No. 265 Supplement 2 are submitted via AREVA NP Inc. letter, "Response to U.S. EPR Design Certification Application RAI No. 265, Supplement 2" NRC 10:051, dated June 3, 2010. The enclosure to that letter responds to NRC comments on the AREVA NP response to Questions 03.06.03-20 and 03.06.03-21 that were provided in RAI No. 265 Supplement 1. The NRC comments were provided in a telecon with AREVA NP on April 7, 2010. An affidavit to support withholding of information from public disclosure, per 10CFR2.390(b), is provided as an enclosure to that letter.

The following table indicates the respective pages in the response document, "RAI 265 Supplement 2 Response US EPR DC.pdf" that contain AREVA NP's response to the subject questions.

Question #	Start Page	End Page
RAI 265 — 03.06.03-20	2	4
RAI 265 — 03.06.03-21	5	10

Sincerely,

Martin (Marty) C. Bryan
U.S. EPR Design Certification Licensing Manager
AREVA NP Inc.
Tel: (434) 832-3016
702 561-3528 cell
Martin.Bryan.ext@areva.com

From: WELLS Russell D (AREVA NP INC)
Sent: Friday, December 18, 2009 2:27 PM
To: 'Getachew Tesfaye'
Cc: Pederson Ronda M (AREVA NP INC); BENNETT Kathy A (OFR) (AREVA NP INC); DELANO Karen V (AREVA NP INC); DUNCAN Leslie E (AREVA NP INC)
Subject: Response to U.S. EPR Design Certification Application RAI No. 265, FSAR Ch 3, Supplement 1

Getachew,

The proprietary and non-proprietary versions of the response to RAI No. 265 are submitted via AREVA NP Inc. letter, "Response to U.S. EPR Design Certification Application RAI No. 265, Supplement 1" NRC 09:132, dated December 17, 2009. The enclosure to that letter provides technically correct and complete responses the remaining 6 questions in RAI No. 265. An affidavit to support withholding of information from public disclosure, per 10CFR2.390(b), is provided as an enclosure to that letter.

The following table indicates the respective pages in the response document, "RAI 265 Response US EPR DC.pdf" that contain AREVA NP's response to the subject questions.

Question #	Start Page	End Page
RAI 265 — 03.06.03-20	2	3
RAI 265 — 03.06.03-21	4	7
RAI 265 — 03.06.03-22	8	9
RAI 265 — 03.06.03-23	10	12
RAI 265 — 03.06.03-25	13	14
RAI 265 — 03.06.03-26	15	15

Also enclosed with this response are the following documents which support the responses to Questions 03.06.03-22 and 03.06.03-26:

- Updated Moment Versus Leakage Crack Lengths
- Leak-Before-Break (LBB) Finite Element Analysis (FEA) for the U.S. EPR Surge Line (SL)
- Updated Flaw Stability Analysis

This concludes the formal AREVA NP response to RAI 265, and there are no questions from this RAI for which AREVA NP has not provided responses.

Sincerely,

(Russ Wells on behalf of)
Ronda Pederson
ronda.pederson@areva.com
Licensing Manager, U.S. EPR Design Certification
New Plants Deployment
AREVA NP, Inc.
An AREVA and Siemens company
3315 Old Forest Road
Lynchburg, VA 24506-0935
Phone: 434-832-3694
Cell: 434-841-8788

From: Pederson Ronda M (AREVA NP INC)
Sent: Friday, October 16, 2009 5:38 PM
To: Tesfaye, Getachew
Cc: BENNETT Kathy A (OFR) (AREVA NP INC); DELANO Karen V (AREVA NP INC); WELLS Russell D (AREVA NP INC)
Subject: Response to U.S. EPR Design Certification Application RAI No. 265, FSARCh. 3

Getachew,

Attached please find AREVA NP Inc.'s response to the subject request for additional information (RAI). The attached file, "RAI 265 Response US EPR DC.pdf" provides a technically correct and complete response to 1 of the 7 questions.

Appended to this file are affected pages of the U.S. EPR Final Safety Analysis Report in redline-strikeout format which supports the response to RAI 265 Question 03.06.03-24.

The following table indicates the respective page in the response document, "RAI 265 Response US EPR DC.pdf," that contains AREVA NP's response to the subject questions.

Question #	Start Page	End Page
RAI 265 — 03.06.03-20	2	2
RAI 265 — 03.06.03-21	3	3
RAI 265 — 03.06.03-22	4	4
RAI 265 — 03.06.03-23	5	5
RAI 265 — 03.06.03-24	6	6
RAI 265 — 03.06.03-25	7	7
RAI 265 — 03.06.03-26	8	8

A complete answer is not provided for 6 of the 7 questions. The schedule for a technically correct and complete response to these questions is provided below.

Question #	Response Date
RAI 265 — 03.06.03-20	December 18, 2009
RAI 265 — 03.06.03-21	December 18, 2009
RAI 265 — 03.06.03-22	December 18, 2009
RAI 265 — 03.06.03-23	December 18, 2009
RAI 265 — 03.06.03-25	December 18, 2009

Sincerely,

Ronda Pederson

ronda.pederson@areva.com
Licensing Manager, U.S. EPR Design Certification
AREVA NP Inc.
An AREVA and Siemens company
3315 Old Forest Road
Lynchburg, VA 24506-0935
Phone: 434-832-3694
Cell: 434-841-8788

From: Tesfaye, Getachew [mailto:Getachew.Tesfaye@nrc.gov]
Sent: Wednesday, September 16, 2009 1:52 PM
To: ZZ-DL-A-USEPR-DL
Cc: Reichelt, Eric; Miernicki, Michael; Patel, Jay; Terao, David; Colaccino, Joseph; ArevaEPRDCPEm Resource
Subject: U.S. EPR Design Certification Application RAI No. 265 (3358), FSARCh. 3

Attached please find the subject requests for additional information (RAI). A draft of the RAI was provided to you on August 3, 2009, and discussed with your staff on August 17, 2009. Draft RAI Questions 03.06.03-21 and 03.06.03-22d were modified as a result of that discussion. 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: 2071

Mail Envelope Properties (1F1CC1BBDC66B842A46CAC03D6B1CD41036D8F74)

Subject: Response to U.S. EPR Design Certification Application RAI No. 265, FSAR Ch 3, Supplement 5
Sent Date: 9/30/2010 5:17:44 PM
Received Date: 9/30/2010 5:18:00 PM
From: WELLS Russell (AREVA)

Created By: Russell.Wells@areva.com

Recipients:
"BRYAN Martin (EXTERNAL AREVA)" <Martin.Bryan.ext@areva.com>
Tracking Status: None
"BENNETT Kathy (AREVA)" <Kathy.Bennett@areva.com>
Tracking Status: None
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Tracking Status: None

Post Office: AUSLYNCMX02.adom.ad.corp

Files	**Size**	**Date & Time**
MESSAGE	12972	9/30/2010 5:18:00 PM
RAI 265 Supplement 5 Response US EPR DC.pdf		234421

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

Response to

Request for Additional Information No. 265, Supplement 5

9/16/2009

U. S. EPR Standard Design Certification
AREVA NP Inc.
Docket No. 52-020
SRP Section: 03.06.03 - Leak-Before-Break Evaluation Procedures
Application Section: 03.06.03

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

Original NRC Question 03.06.03-20:

Follow-up to RAI Question 03.06.03-3

During the 6/09/2009, audit, the staff reviewed information related to Dynamic Strain Aging (DSA) and recommendations regarding metallurgical and heat treatment specifications as well as improvements to production welding procedures for ferritic base metals that would minimize the concern for dynamic strain aging. AREVA is requested to formally submit this material so the staff can review the recommendations and AREVA's approach.

Original AREVA NP Response to Question 03.06.03-20:

The AREVA NP presentation material from the NRC audit related to impact of DSA on leak-before-break (LBB) analysis was formally submitted to the NRC on July 1, 2009 (reference Accession Number ML091900197). Additional information as requested by the NRC regarding DSA is provided in this response.

Based on Reference 1, DSA can be minimized in carbon steel by minimizing the amount of nitrogen and carbon dissolved in the ferrite, which depends on the steel grade, the deoxidation practice, and the heat treatment.

The steel grade controls the chemical composition of the material, which affects the final properties. One method of minimizing the amount of nitrogen and carbon in solution is to limit the amount in the heat of material. Carbon cannot be reduced without decreasing the strength of the material because it is the main hardening agent. However, SA-106 typically contains a small amount of strong carbide formers (i.e., chromium, vanadium and molybdenum), which remove some of the free carbon from solution, decreasing its role in strain aging. Nitrogen does not provide a significant benefit to the mechanical properties, so it should be held as low as reasonably achievable through modern steel making practices to minimize its role in strain aging (Reference 2).

Carbon steel is killed by adding deoxidizing agents such as silicon and aluminum, which form nitrides and remove nitrogen from the ferrite lattice. This deoxidation practice decreases nitrogen’s contribution to strain aging. Steels that are deoxidized with both aluminum and silicon are most resistant to dynamic strain aging (Reference 2). ASME SA-106 requires that the steel be killed with silicon. Based on Reference 2, the SA-106 Grade C piping will be killed with 0.15-0.25 wt percent silicon and 0.03-0.08 wt percent aluminum. This will reduce the susceptibility to strain aging while not significantly affecting the mechanical properties.

The strain aging response of carbon steel is also a function of heat treatment. For the SA-106 Grade C carbon steel to meet the minimum mechanical property requirements of the MSL piping, it must be quenched and tempered. The rapid cooling during the quenching process traps carbon and nitrogen interstitials in sites too small for the size of these atoms, straining the crystal lattice. At operating temperatures, these interstitial atoms may segregate to dislocations and impede their movement, which contributes to DSA. Tempering causes carbon atoms to form carbide precipitates, which, unlike carbon interstitials, do not increase DSA susceptibility. Tempering temperature has a larger role in carbide precipitation compared to time. The same is true for the stress relief heat treatment because the stress relief temperature is the same as the tempering temperature. As stated in Reference 1, the lowest susceptibility will be associated with treatments that provide precipitation of nitrides and carbides, namely, extended treatment near 600°C (1110°F) followed by slow cooling.

The impact of the welding process on the DSA susceptibility of the base metal was also considered. DSA susceptibility could potentially be increased if a sharp notch near the weld was formed due to a fabrication defect. This is not a concern because such a defect would be found and removed during required post weld inspection. The adverse impact of the welding process on the DSA susceptibility of the base metal is the creation of residual stress in the weld heat affect zone. These stresses will be removed during the post fabrication stress relief heat treatment or the post weld heat treatment. The welding process will not adversely impact base metal DSA susceptibility.

Additionally, the following actions will further minimize the potential for DSA:

- The composition of SA-106 Grade C that will be used for the U.S. EPR MSL piping to reduce the susceptibility to dynamic strain aging is:

  Si: 0.15-0.25 percent.
  Al: 0.03-0.08 percent.
  N: As low as reasonably achievable.

  This composition will decrease the total amount of nitrogen in the material and minimize the amount of free nitrogen by encouraging the formation of nitrides.

- The SA-106 Grade C heat treatment that will be used for the U.S. EPR (MSL) piping is:

Heat Treatment:	1600-1650°F held for two to three hours and water quenched.
Temper:	1100-1150°F held for four hours and air cooled.
Stress Relief:	1100-1150°F held for 30 hours and furnace cool to 600°F.

  This heat treatment is consistent with the recommendations for minimizing susceptibility to DSA in Reference 1 and is also consistent with heat treatment of SA-106 Grade C pipe in service at operating nuclear facilities.

References for Original AREVA NP Response to Question 03.06.03-20:

1. Marschall, C. W., et al., “Effect of Dynamic Strain Aging on Fracture Resistance of Carbon Steels Operating at Light-Water Reactor Temperatures,” Fracture Mechanics: Twenty-First Symposium, ASTM STP 1074, J. P. Gudas, J. A. Joyce, and E. M. Hackett, Eds., American Society for Testing and Materials, Philadelphia, 1990, pp. 339-360.

2. Leslie, W. C., et al., “Influence of Aluminum and Silicon Deoxidation on the Strain Aging of Low-Carbon Steels,” Transactions AIME, Journal of Metals, Aug. 1953, pp. 1021-1031.

NRC Comment on AREVA NP Response to Question 03.06.03-20:

Based on a telecon with NRC on April 7, NRC provided the following comment regarding the AREVA NP Response to Question 03.06.03-20:

One issue of potential concern is that a fabrication defect (a sharp notch near a weld) could increase DSA susceptibility. AREVA does not perceive this to be a problem as they indicate that it will be found and removed during post weld inspection. The MSL is ASME Code Class 2 and Section III rules apply with Radiography as the primary NDE technique required for fabrication inspection. Appendix VIII of Section XI is not applicable. How effective is the required Section III inspection at detecting sharp notches?

AREVA NP Response to NRC Comment:

Radiography performed in accordance with ASME, Section III is able to detect sharp notches or other abrupt discontinuities. Therefore, it is unlikely that such a flaw would go undetected during fabrication.

Additionally, AREVA NP has revised the Response to Question 03.06.03-20. A description of the changes and the revised response (with change bars) is provided below:

- The recommended silicon content was changed from a range of 0.15-0.25 wt% to a minimum of 0.16 wt%. This change was made to be more consistent with Reference 2 of the Response to Question 03.06.03-20, which shows that carbon steel killed with both silicon and aluminum is most resistant to DSA when the silicon content is at least 0.16 wt%. This is illustrated in figure 5 of Reference 2. Providing a maximum limit for the silicon content is not necessary for this response because increasing the silicon content beyond 0.16 wt% will not increase DSA susceptibility.
- The recommended aluminum content was changed from a range of 0.03-0.08 wt% to a minimum of 0.03 wt%. This change was made because providing a maximum limit for the aluminum content is not necessary for this response since increasing the aluminum content beyond 0.03 wt% will not increase DSA susceptibility.
- The recommended time for the stress relief heat treatment was changed from 30 hours to a minimum of 5 hours. This change was made because a 30 hour heat treatment is not required for reducing susceptibility to DSA since heat treatment temperature has a larger role in carbide and nitride precipitation compared to time. This is supported by Reference 3 of the Response to Question 03.06.03-20 that showed the benefit from thermal aging was similar for aging times between 0.5 and 1000 hours. The minimum stress relief time of 5 hours was selected to remain conservative.

Revised AREVA NP Response to Question 03.06.03-20:

The AREVA NP presentation material from the NRC audit related to impact of DSA on leak-before-break (LBB) analysis was formally submitted to the NRC on July 1, 2009 (reference Accession Number ML091900197). Additional information as requested by the NRC regarding DSA is provided in this response.

Based on Reference 1, DSA can be minimized in carbon steel by minimizing the amount of nitrogen and carbon dissolved in the ferrite, which depends on the steel grade, the deoxidation practice, and the heat treatment.

The steel grade controls the chemical composition of the material, which affects the final properties. One method of minimizing the amount of nitrogen and carbon in solution is to limit the amount in the heat of material. Carbon cannot be reduced without decreasing the strength of the material because it is the main hardening agent. However, SA-106 typically contains a small amount of strong carbide formers (i.e., chromium, vanadium and molybdenum), which remove some of the free carbon from solution, decreasing its role in strain aging. As stated in U.S. EPR FSAR Tier 2, Section 10.3.6.3, the minimum allowable chromium content for the main steam line (MSL) piping is 0.10 percent, which helps to remove excess carbon from solution and to protect against flow assisted corrosion. Nitrogen is unspecified (not required) by SA-106 Grade C, but small amounts are typically present. Therefore, nitrogen is recommended to be held as low as reasonably achievable through modern steel making practices to minimize its role in strain aging (Reference 2).

Carbon steel is killed by adding deoxidizing agents such as silicon and aluminum, which form nitrides and remove nitrogen from the ferrite lattice. This deoxidation practice decreases nitrogen's contribution to strain aging. Steels that are deoxidized with both aluminum and silicon are most resistant to dynamic strain aging (Reference 2). ASME SA-106 requires that the steel be killed with a minimum silicon content for Grade C of 0.10 wt%. Aluminum is unspecified by SA-106 Grade C. Based on the results of various grades of low carbon steel tested for strain aging (Reference 2), it is recommended that the SA-106 Grade C piping for the MSL be killed with a minimum of 0.16 wt% silicon and 0.03 wt% aluminum. This will reduce the susceptibility to strain aging while not significantly affecting the mechanical properties.

The strain aging response of carbon steel is also a function of heat treatment. In order for the SA-106 Grade C carbon steel to meet the minimum mechanical property requirements of the MSL piping, it must be quenched and tempered. The rapid cooling during the quenching process traps carbon and nitrogen interstitials in sites too small for the size of these atoms, straining the crystal lattice. At operating temperatures, these interstitial atoms may segregate to dislocations and impede their movement, which contributes to DSA. Heat treatments, such as tempering and stress relief, cause carbon and nitrogen atoms to form carbide and nitride precipitates, which, unlike interstitials, do not increase DSA susceptibility. Heat treatment temperature has a larger role in carbide and nitride precipitation compared to time. This is supported by an Reference 3 which showed the benefit from thermal aging was similar for aging times between 0.5 and 1000 hours. As stated in Reference 1, the lowest susceptibility will be associated with treatments that provide precipitation of nitrides and carbides, namely, extended treatment near 600°C (1110°F) followed by slow cooling. Based on this information and the heat treatment parameters of piping at operating nuclear facilities, the recommended stress relief heat treatment for the SA-106 Grade C MSL piping is 1100-1150°F for a minimum of 5 hours followed by furnace cooling to 600°F.

The impact of the welding process on the DSA susceptibility of the base metal was also considered. DSA susceptibility could potentially be increased if a sharp notch near the weld was formed due to a fabrication defect. This is not a concern because such a defect would be found and removed during required post weld inspection. The adverse impact of the welding process on the DSA susceptibility of the base metal is the creation of residual stress in the weld heat affect zone. These stresses will be removed during the post fabrication stress relief heat treatment or the post weld heat treatment. The welding process will not adversely impact base metal DSA susceptibility.

Additionally, the following actions will further minimize the potential for DSA:

- The composition of SA-106 Grade C that will be used for the U.S. EPR MSL piping to reduce the susceptibility to dynamic strain aging is:

  Si: 0.16 percent minimum.
  Al: 0.03 percent minimum.
  N: As low as reasonably achievable.

- The SA-106 Grade C heat treatment that will be used for the U.S. EPR (MSL) piping is:

  Heat Treatment: 1600-1650°F held for two to three hours and water quenched.
  Temper: 1100-1150°F held for four hours and air cooled.
  Stress Relief: 1100-1150°F held for at least five hours and furnace cooled to 600°F.

References for Question 03.06.03-20:

1. Marschall, C. W., et al., "Effect of Dynamic Strain Aging on Fracture Resistance of Carbon Steels Operating at Light-Water Reactor Temperatures," Fracture Mechanics: Twenty-First Symposium, ASTM STP 1074, J. P. Gudas, J. A. Joyce, and E. M. Hackett, Eds., American Society for Testing and Materials, Philadelphia, 1990, pp. 339-360.
2. Leslie, W. C., et al., "Influence of Aluminum and Silicon Deoxidation on the Strain Aging of Low-Carbon Steels," Transactions AIME, Journal of Metals, Aug. 1953, pp. 1021-1031.
3. Pense, A., "HPS Corrugated Web Girder Fabrication Innovations, Final Report, Part 4: Literature and Experimental Study of Strain Aging in HPS and Other Bridge Steels," Lehigh University, Center for Advanced Technology for Large Structural Systems, April 9, 2004.

FSAR Impact:

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

Original NRC Question 03.06.03-26

During the audit on 06/09/2009 between the NRC and AREVA, AREVA stated that the material properties of ASME SA-106 was being used to obtain the moment vs. crack length curves for the surge line in the EPR design. However, the material that is to be used for construction is identified as ASME SA-508. In the staff's confirmatory analysis, the stress-strain curves for ASME SA-508 were higher, which would result in a greater amount of constraint of the plasticity. This was confirmed by the staff's Finite Element analysis. AREVA is requested to:

a. Verify that ASME SA-508 is the material to be used in construction for the nozzles and specify which grade or class of SA-508.

b. Provide a confirmatory analysis on ASME SA-508 and justify that ASME SA-106 is more conservative.

Perform a Finite Element analysis between the two materials much like what the staff has performed and discussed during the 06/09/2009 audit.

Original AREVA NP Response to Question 03.06.03-26:

a As noted in U.S EPR FSAR Tier 2, Table 5.2-2, ASME SA-508 Grade 3, Class 2 is the material used for the pressurizer surge nozzle. Prior to the June 9, 2009 audit between the NRC and AREVA NP, AREVA NP was utilizing material properties of ASME SA-106, Grade C for leak-before-break (LBB) analysis of the low alloy pressurizer surge nozzle of the U.S. EPR, even though the actual material for this component is SA-508 Grade 3, Class 2. This is because the stress-strain and J-R data for SA-508 Grade 3, Class 2 is not available. Instead, the material properties for SA -106, Grade C were used because it was representative and conservative compared to the use of actual low alloy steel material properties.

b. Since the June 9, 2009 audit, AREVA NP has obtained the material data for low alloy steel material. SA-508 Grade 3, Class 3 (which is currently classified by ASME Code as SA 508 Grade 3 Class 1) is considered more comparable to the actual SA-508 Grade 3, Class 2 material. As a result, the LBB analysis of the surge line was performed using these sets of material properties. The results of this reevaluation are discussed in the Response to Question 03.06.03-22. Because of this reanalysis, the justification for SA-106 is no longer needed.

c. A finite element analysis (FEA) has been performed and is provided in Attachment 2. As discussed in Item b, a separate FEA using SA-106, Grade C material properties is not required.

NRC Comment on AREVA NP Response to Question 03.06.03-26:

Based on a telecon with NRC on April 7, 2010, NRC provided the following comment regarding the AREVA NP Response to Question 03.06.03-26:

The FE analysis was carefully performed and the equivalent material properties obtained look fine. Sensitivity studies showing that the equivalent properties are nearly independent of crack size were performed. Analysis using both AREVA codes and the NRC code, NRCPIPE, validated the solutions obtained. The estimates for J using modified GE/EPRI and LBB.ENG2 are very close, which shows validation of the method in Figure 5 of Attachment 2 of the RAI 265 supplement. AREVA did a careful job developing the ALL diagrams using both AREVA and NRC type methods. This provides a good check and appears well done.

Based on the analysis the NRC requests that AREVA redo all the ALL diagram calculations based on the approach identified above.

AREVA NP Response to NRC Comment:

U.S. EPR FSAR Tier 2, Figures 3.6.3-18, 3.6.3-19, and 3.6.3-20 will be revised to update the allowable load limit (ALL) diagrams as requested in the above NRC Comment on the original AREVA NP Response to Question 03.06.03-26. The revised ALL diagrams that are in revised U.S. EPR FSAR Tier 2, Figures 3.6.3-19, and 3.6.3-20 also provide results at additional SL locations and also reflect that the leak rate analysis considers fatigue (air) crack morphology with applicable number of turns and roughness values reported in NUREG/CR-6004. Additional U.S. EPR FSAR changes that reflect these revised figures and the leak-before-break (LBB) methodology described in References 1 through 9 are as follows:

- U.S. EPR FSAR Tier 2, Figure 3.6.3-6 will be revised to add an additional location (i.e., the remainder of the pressurizer surge line) and to reflect the revised fatigue (air) crack morphology. This information is provided in tabular form in revised U.S. EPR FSAR Tier 2, Table 3.6.3-10.
- U.S. EPR FSAR Tier 2, Table 3.6.3-2 will be revised to reflect the precise dimensional information for the three surge line (SL) locations.
- U.S. EPR FSAR Tier 2, Table 3.6.3-5 will be revised to reflect the revised tensile properties for the SL piping, the dissimilar weld (DMW) location, and the hot leg nozzle based on the finite element analysis (FEA).
- U.S. EPR FSAR Tier 2, Table 3.6.3-6 will be revised to reflect the revised Rm/t parameters for the SL and to revise the thickness for the Pressurizer Surge Nozzle and the SL piping near the Pressurizer consistent with the changes to U.S. EPR FSAR Tier 2, Table 3.6.3-2.
- U.S. EPR FSAR Tier 2, Table 3.6.3-7 will be revised to correct the reference strain values.
- U.S. EPR FSAR Tier 2, Table 3.6.3-11 and Table 3.6.3-24 will be revised to reflect the revised fatigue (air) crack morphology.
- U.S. EPR FSAR Tier 2, Table 3.6.3-21, Table 3.6.3-22, and Table 3.6.3-23 will be revised to include the revised tabulated resulted for the ALL diagrams depicted in U.S. EPR FSAR Tier 2, Figure 3.6.3-18, Figure 3.6.3-19, and Figure 3.6.3-20.
- U.S. EPR FSAR Tier 2, Table 3.6.3-26 will be added for the air fatigue crack morphology parameters.
- U.S. EPR FSAR Tier 2, Section 3.6.3.4.3.6 will be revised to add information regarding the FEA that was performed for the DMW.
- U.S. EPR FSAR Tier 2, Section 3.6.3.4.3.7 will be revised to delete the sentence that the tensile properties and the Ramberg-Osgood parameters were not readily available for the pressurizer surge nozzle material, because a FEA has been performed.

- U.S. EPR FSAR Tier 2, Section 3.6.3.5.2 will be revised to add the additional SL locations and to state that the leak rate analysis considers fatigue (air) crack morphology with applicable number of turns and roughness values reported in NUREG/CR-6004 (U.S. EPR FSAR Tier 2, Section 3.6.3.8, Reference 29 will be added).
- U.S. EPR FSAR Tier 2, Section 3.6.3.5.3 will be revised to change the title of U.S. EPR FSAR Tier 2, Table 3.6.3-12 from "Minimum Moment versus Circumferential Crack Leakage Sizes for 1 gpm in the Main Steam Line Piping" to "Minimum Moment versus Circumferential Leakage Crack Sizes for 1 gpm in the Main Steam Line Piping" to be consistent with the title change of U.S. EPR FSAR Tier 2, Figure 3.6.3-6.

References for Response to Question 03.06.03-26:

1. Letter, Sandra M. Sloan (AREVA NP Inc.) to Document Control Desk (NRC), "Presentation Materials from the NRC - AREVA NP Audit regarding the U.S. EPR Leak-Before-Break (LBB) Methodology," NRC:08:049, July 2, 2008 (ML081900623).
2. Letter, Sandra M. Sloan (AREVA NP Inc.) to Document Control Desk (NRC), "Response to U.S. EPR Design Certification Application RAI No. 48," NRC:08:072, September 18, 2008 (ML082680039).
3. Letter, Sandra M. Sloan (AREVA NP Inc.) to Document Control Desk (NRC), "Response to U.S. EPR Design Certification Application RAI No. 48, Supplement 1," NRC:08:089, November 7, 2008 (ML083170589).
4. Letter, Sandra M. Sloan (AREVA NP Inc.) to Document Control Desk (NRC), "Additional Information in Support of NRC Confirmatory Analysis Regarding the U.S. EPR Leak- Before-Break (LBB) Methodology," NRC:08:101, December 18, 2008 (ML083170589).
5. Letter, Sandra M. Sloan (AREVA NP Inc.) to Document Control Desk (NRC), "Additional Information in Support of NRC Confirmatory Analysis Regarding the U.S. EPR Leak- Before-Break (LBB) Methodology," NRC:09:003, January 23, 2009 (ML090300651).
6. E-mail, Ronda M. Pederson (AREVA NP Inc.) to Getachew Tesfaye (NRC), "Response to U.S. EPR Design Certification Application RAI No. 265, FSARCh. 3," October 16, 2009 (ML092920048).
7. E-mail, Ronda M. Pederson (AREVA NP Inc.) to Getachew Tesfaye (NRC), "PROPRIETARY - Revised Finite Element Analysis for leak-before-break (LBB) analyses on FSAR Section 3.9.6," November 5, 2009.
8. Letter, Sandra M. Sloan (AREVA NP Inc.) to Document Control Desk (NRC), "Response to U.S. EPR Design Certification Application RAI No. 265, Supplement 1," NRC:09:132, December 17, 2009 (ML093620034).
9. Letter, Sandra M. Sloan (AREVA NP Inc.) to Document Control Desk (NRC), "Response to U.S. EPR Design Certification Application RAI No. 265, Supplement 2," NRC:10:0512, June 3, 2010 (ML101600259).

FSAR Impact:

U.S. EPR FSAR Tier 2, Section 3.6.3, Tables 3.6.3-2, 3.6.3-5, 3.6.3-6, 3.6.3-7, 3.6.3-10, 3.6.3-11 ,3.6.3-12, 3.6.3-21, 3.6.3-22, 3.6.3-23, 3.6.3-24, 3.6.3-26, Figures 3.6.3-6, 3.6.3-18, 3.6.3-19, and 3.6.3-20 will be revised as described in the response and indicated on the enclosed markup.

U.S. EPR Final Safety Analysis Report Markups

materials are made to account for operating conditions and anticipated aging effects. The J-R curves for SA-508 Grade 3, Class 2 material are determined using the correlation between upper shelf energy and upper shelf J-R properties for SA-508 Grade 3 Class1 material. Based on the correlation, the SA-508 Grade 3 Class 1 curves are reduced by 30 percent to approximate the J-R curves for SA-508 Grade 3 Class 2 material.

3.6.3.4.3.4 RCP Casing Nozzles

The RCP casings (including the nozzles) are fabricated from static CASS. The RCP casings are fabricated using SA-351 CF-3 material specification with additional restrictions on silicon (1.5 percent maximum) and niobium (restricted to trace amounts). In addition, the ferrite number is restricted to <20 percent. The lower bound J-R curves for the saturated condition are determined based on a predictive model developed in NUREG/CR-6177 (Reference 16).

3.6.3.4.3.5 Surge Line Weld and Base Metal Properties

The SL weld and base metal properties are determined from the same test program described in Section 3.6.3.4.3. The testing was conducted using compact tension specimens cut from the full thickness of the SL pipe weld geometry. The lower bound SL weld and base metal J-R curves are developed using the same approach as provided in Section 3.6.3.4.3 for the MCL. Therefore, the thermal aging effects of the SL weld metal are considered. The tensile properties with associated Ramberg-Osgood parameters of the various SL piping materials are shown in Table 3.6.3-5—Tensile Properties for the Surge Line Piping.

3.6.3.4.3.6 Dissimilar Metal Weld between Pressurizer Surge Nozzle and Surge Line Piping

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The Alloy 52 fusion line toughness J-R properties, determined in Section 3.6.3.4.3.2, are used in the analysis. The equivalent material tensile properties for the dissimilar metal weld (DMW) at the fusion line location are determined using finite element based elastic-plastic fracture mechanics analysis and provided in Table 3.6.3-5. These material properties at the DMW fusion line region are determined considering the adjoining base metal materials which are F304LN and SA-508 Grade 3 Class 2. The material properties for SA-508 Grade 3 Class 2 are approximated by the material properties for SA-508 Class 3 which are obtained from NUREG/CR-6837, Volume 2 (Reference 25).

3.6.3.4.3.7 Pressurizer Surge Nozzle

The pressurizer surge nozzle is fabricated from SA-508 Grade 3 Class 2 material. The lower bound J-R properties, considering the effects of thermal aging, for SA-508 Grade 3 Class 2, addressed in Section 3.6.3.4.3.3 are also applicable to the pressurizer surge nozzle. The tensile properties and the Ramberg-Osgood parameters for SA-106 Grade C material are conservatively used in the analysis since these properties are not readily available for the pressurizer surge nozzle material. In the region of the pressurizer nozzle it is the dissimilar metal weld location that is limiting for LBB application, as shown in Table 3.6.3-6—Surge Line Piping Locations Based on Key Geometry, Operating Conditions & Lower Bound Material Toughness.

3.6.3.4.3.8 Main Steam Line Weld and Base Metal Properties

The tensile and fracture material properties for ASME SA-106 Grade C carbon steel material and associate weld material used in this analysis are based on a piping material test program that examined six heats of weld metals. Three heats were manual weld metals (one E7015 SMAW and two E8015 SMAW), and the other three heats were automatic submerged weld metals (High Mn-Mo SAW). The properties used in the analysis are the lower bound properties obtained from the test program. The tensile properties are provided in terms of the yield stress, ultimate strength, flow stress, and Young's modulus and are shown in Table 3.6.3-7—Tensile Properties for the Main Steam Line Piping. The Ramberg-Osgood material model parameters are also summarized in Table 3.6.3-7. The fracture toughness properties are provided in terms of the J-R curve. The lower bound material J-R curves for the SA106, Grade C and the weld metals are determined and used in the flaw stability analysis of Section 3.6.3.5.4.1.

3.6.3.5 General Methodology

The load combination methods described in Section 3.6.3.5.1 are applicable to the LBB analyses. For the MCL and the SL piping, the leak rate calculations, performed considering fatigue crack morphology, are determined using AREVA NP computer code KRAKFLO (see Section 3.6.3.5.2). For the MSL LBB analysis, computer code SQUIRT Version 1.1 (see Section 3.6.3.5.3) is used. Since the MCL and SL piping materials are highly ductile austenitic stainless steels, both the limit load analysis and the flaw stability analysis methodology are considered appropriate. For the MCL and SL piping, the flaw stability analysis methodology is used. Since the MSL is made of ferritic steel, the flaw stability methodology is also used in that analysis.

3.6.3.5.1 Load Combination Methods

SRP 3.6.3 addresses two load combination methods: the absolute sum load combination method and the algebraic sum load combination method. The absolute sum load combination method is provided in SRP 3.6.3. The algebraic sum load combination method is shown below:

$$M_{XMAX} = \left| M_{Xdw} + M_{Xth} + M_{Xpress} \right| + \left| M_{Xsse} \right| + \left| M_{Xsam} \right|$$

pressure and minimum moment at a constant leak rate (gallons per minute), the crack length necessary to produce the same leak rate is actually smaller, since higher stress enlarges the crack width.

Maximum Moment

The maximum moment to be evaluated combines the minimum moment with the moments due to seismic and seismic anchor motions. The SSE loadings include the seismic anchor motion loads. As previously noted, the maximum moment is determined using the absolute sum load combination method.

Loadings on Main Coolant Loop, Surge Line, and Main Steam Line

A bounding analysis in the form of LBB allowable load window approach is used in this analysis. Once the allowable load window for a given piping system is generated, the loads for the piping system can then be plotted on the allowable load window. If the applied loading points lie within the allowable load window, LBB is justified for the pipe with appropriate safety margins already included in the window.

3.6.3.5.2 Leak Rate Determination Method for Main Coolant Loop and Surge Line

Leak rate calculations for MCL and SL piping are performed using AREVA NP computer code KRAKFLO, which is similar to the NRC code LKRATE. The leak flow calculations used in KRAKFLO are benchmarked against the Battelle Columbus Laboratories data as presented in EPRI Report NP-3395 (Reference 17). KRAKFLO is based on the LEAK-01 program documented in Reference 17 but has improved ability to determine pressure drops for initially subcooled, non-flashing liquid. KRAKFLO's crack geometry methodology is based on NUREG/CR-3464 (Reference 18); and its flow rate calculation is based on NUREG/CR-1319 (Reference 19). This code has been benchmarked and is in agreement with experimental data.

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Leakage crack sizes associated with a leak rate of 5 gpm are determined in the analysis. This leak rate provides a factor of ten to the leak detection system (LDS) capability. The leakage rate calculations are performed for straight pipe with both axial and circumferential through-wall cracks. For the axial through-wall crack orientations, pressure-only loading is considered, while external bending and pressure loadings are considered for the circumferential through-wall cracks. ~~The leakage rate calculations are determined at the following locations in the MCL piping:~~

Main Coolant Loop

The leakage rate calculations are determined at the following locations in the MCL piping:

- Reactor pressure vessel (RPV) outlet nozzle region at the hot leg.

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- SG inlet nozzle region at the hot leg.
- SG outlet nozzle region.
- Crossover leg, RCP outlet nozzle region, cold leg pipe, and RPV inlet.
- RCP inlet nozzle region.

Surge Line

For the SL piping, the leakage rate calculations are determined at the following locations:

- Pressurizer surge nozzle end of the SL.
- Pressurizer SL
- Hot leg nozzle end of the SL.

The leak rate analysis considers fatigue (air) crack morphology with applicable number of turns and roughness values reported in NUREG/CR-6004 (Reference 29) and shown in Table 3.6.3-26. The leakage crack lengths versus minimum moment at each of the above five locations for the MCL are shown in Table 3.6.3-8—Minimum Moment versus Circumferential Crack Leakage Sizes for 5 gpm at Various Main Coolant Loop Piping Locations and are illustrated in Figure 3.6.3-5—Minimum Moment versus Circumferential Crack Leakage Sizes for 5 gpm at Various Main Coolant Loop Locations. For the through-wall axial cracks, the leakage crack sizes are shown in Table 3.6.3-9—Axial Through-Wall Leakage Crack Sizes for 5 gpm at Various Main Coolant Loop Piping Locations. For SL piping, the leakage crack lengths versus moment at each of the above ~~two~~three locations are shown in Table 3.6.3-10—Minimum Moment versus Circumferential Leakage Crack ~~Leakage~~ Sizes for 5 gpm at ~~Two~~Three Surge Line Piping Locations and are illustrated in Figure 3.6.3-6—Minimum Moment versus Circumferential Leakage Crack ~~Leakage~~ Sizes for 5 gpm at ~~Two~~Three Surge Line Locations. For the through-wall axial cracks, the leakage crack sizes are shown in Table 3.6.3-11 Axial Through-Wall Leakage Crack Sizes for 5 gpm at Two Surge Line Piping Locations.

3.6.3.5.3 Leak Rate Determination Method for Main Steam Line

The leak rate calculations for the MSL piping are performed using SQUIRT Code Version 1.1. The SQUIRT Code is described in NUREG/CR-5128 (Reference 20) and the SQUIRT User's Manual (Reference 21) and has been benchmarked to the experimental steam data developed in Japan, as described in NUREG/CR-6861 (Reference 22). The SQUIRT code has been updated with technical enhancements as part of the NRC large break LOCA program. The SQUIRT Code is used to calculate the leakage rate through the cracked pipe for single phase steam conditions.

Leakage crack sizes associated with a leak rate of one gpm are determined in the analysis. This leak rate provides a factor of ten to the LDS capability. The leakage rate calculations are performed for straight pipe with both axial and circumferential through-wall cracks. Similar to MCL, for the axial through-wall crack orientation, pressure-only loading is considered while external bending and pressure loading is considered for the circumferential through-wall crack. The results of the pressure-only case, as depicted in Figure 3.6.3-7—Pressure Only Leakage Rate versus Crack Length for Both Axial and Circumferential Crack Morphologies, show that for a given crack size the axial through-wall cracks produced a higher leakage rate. As a result, the circumferential leakage crack sizes are conservatively used when analyzing axial leakage cracks. The results of the leak rate calculations provided in Table 3.6.3-12—Minimum Moment versus Circumferential Leakage Crack ~~Leakage~~ Sizes for 1 gpm in the Main Steam Line Piping. The results are also shown in Figure 3.6.3-8—Minimum Moment versus Circumferential Crack Leakage Sizes for 1 gpm in Main Steam Line Piping, in terms of the minimum moment diagrams for a leakage rate of one gpm. The external axial load is set equal to zero in the leak rate calculations. This is considered conservative, since the crack size required to produce a given leakage rate will actually be smaller in the presence of external axial tensile loads. The leakage crack sizes calculated from the circumferential through-wall crack in straight pipe are also used for analyzing circumferential through-wall extrados crack in an elbow.

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3.6.3.5.4 Flaw Stability Analysis Method

The method employed for the flaw stability analysis is the tearing instability analysis method, using a J versus T diagram. The inputs for the flaw stability analysis include the applied J and the material J-R curves. The applied J ($J_{applied}$) depends on the geometry, material, and the applied loads. The material properties are described in terms of the J-R fracture resistance curves which are obtained from tests in accordance with Reference 15 as well as industry data of comparable materials.

To estimate the $J_{applied}$, a J-integral solution is needed. The J-integral solution is a function of geometry, material, and crack size and orientation. Each J-integral solution is usually tabulated in terms of influence coefficients that are calculated based on finite element analyses. The stability analysis covers the following crack geometries:

- Circumferential through-wall crack in a straight pipe.
- Axial through-wall crack in straight pipe.
- Circumferential through-wall extrados crack in an elbow.

A J-integral solution is used for each of the above crack orientations. The following sections address the J-integral solution for each of the crack geometries. For the circumferential through-wall cracks in a straight pipe, the EPRI/GE method reported

21. SQUIRT: Seepage Quantification of Upsets in Reactor Tubes, User's Manual, Windows Version 1.1, Battelle, March 24, 2003.

22. NUREG/CR-6861, "Barrier Integrity Research Program," U.S. Nuclear Regulatory Commission, December 2004.

23. EPRI NP-5596, "Elastic-Plastic Fracture Analysis of Through-Wall and Surface Flaws in Cylinders," Electric Power Research Institute, January 1988.

24. NUREG/CR-4878, "Analysis of Experiments on Stainless Steel Flux Welds," Nuclear Regulatory Commission, April 1987

25. NUREG/CR-6837, Volume 2, "The Battelle Integrity of Nuclear Piping (BINP) Program Final Report Summary and Implications of Results," Appendices, U.S. Nuclear Regulatory Commission, June 2005.

26. EPRI NP-6301-D, Volumes 1–3, "Ductile Fracture Handbook," Electric Power Research Institute, June 1989.

27. NRC letter dated November 9, 1998, D.G. McDonald to M.L. Bowling, "Application of Leak-Before-Break Status to Portions of the Safety Injection and Shutdown Cooling System for the Millstone Nuclear Power Station, Unit No 2 (TAC NO MA2367)."

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28. NUREG-1793, "Final Safety Evaluation Report Related to Certification of the AP1000 Standard Design," U.S. Nuclear Regulatory Commission, September 2004.

29. NUREG/CR-6004, "Probabilistic Pipe Fracture Evaluations for Leak-Rate-Detection Applications," Nuclear Regulatory Commission, April 1995.

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Table 3.6.3-2—Surge Line Piping Dimensions and Operating Condition

Location	Description of Pipe Geometry	Temperature (°F)	Pressure (psia)	ID[1] (iv)	Pipe Wall[2] Thickness (in)
1	Pressurizer Surge Nozzle	653	2250	~~12.81~~ 13.61	~~1.59~~2.055
2	Surge Line Piping near Pressurizer	653	2250	12.81	1.595
3	Hot Leg Nozzle	624	2250	12.~~8~~91	1.5~~9~~45

Notes:

1. ID of the pipe. At the weld prep location, the ID of the pipe is 12.91 in.
2. For ~~detailed J-T analysis the weld prep thickness is conservatively~~consistency, the pipe wall thickness is used in both the leak rate and flow stability analysis. ~~For leak rate analysis the pipe wall thickness is conservatively used.~~

Table 3.6.3-3—Main Steam Line Dimensions and Operating Condition

Location	Description of Pipe Geometry	Temperature (°F)	Pressure (psia)	ID (iv)	Pipe Wall[1] Thickness (in)
1	Main Steam Line Piping	556	1111	27.5	1.86

Note:

1. Pipe wall thickness is used for both the J-T analysis and the leak rate analysis.

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Table 3.6.3-5—Tensile Properties for the Surge Line Piping

Tensile Properties (ksi)			
	SL Piping near Pressurizer	Pressurizer Nozzle DMW[1]	Hot Leg Nozzle
Yield Stress (σ_y)	18.0	~~39.0~~22.9	18.21
Ultimate Strength (σ_{ult})	59.2	~~81.0~~62.6	59.2
Flow Stress (σ_f)	38.6	~~60.0~~42.8	38.7
Young's Modulus (E)	25,0~~5~~00	~~26,500~~25,400	25,180
Ramberg-Osgood Parameters ($\frac{\varepsilon}{\varepsilon_o} = \frac{\sigma}{\sigma_o} + \alpha\left(\frac{\sigma}{\sigma_o}\right)^n$)			
	SL Piping near Pressurizer	Pressurizer Nozzle	Hot Leg Nozzle
α	~~16.0~~5.90	~~1.48~~5.38	~~16.0~~6.13
n	~~7.0~~3.50	~~5.08~~4.28	~~7.0~~3.50
Reference Stress (σ_o)	~~19.4~~ 18.0 ksi	~~39.0~~22.9 ksi	~~19.4~~18.21 ksi
Reference Strain (ε)	0.000~~17~~72	~~0.0147~~0.000901	0.000~~17~~723

Note:

1. Dissimilar metal weld (DMW) at fusion line determined using elastic-plastic fracture mechanics (EPFM) and finite element method.

Table 3.6.3-6—Surge Line Piping Locations Based on Key Geometry Operating Conditions & Lower Bound Material Toughness

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LBB Piping Location	Description of Pipe Geometry	Temperature (°F)	Thickness (in)	R_m/t	Lower Bounding Material
1	Pressurizer Surge Nozzle	653	~~1.545~~2.005	~~4.68~~ 3.81	Alloy 52
2	Surge Line Piping near Pressurizer	653	~~1.545~~1.595	4.~~68~~52	SS Base Metal
3	Hot leg Nozzle	624	1.545	4.68	SS Base Metal

Table 3.6.3-7—Tensile Properties for the Main Steam Line Piping

Tensile Properties (ksi)		
	Base Metal	Weld Metal
Yield Stress (σ_y)	39.0	76.0
Ultimate Strength (σ_{ult})	81.0	89.5
Flow Stress (σ_f)	60.0	82.75
Young's Modulus (E)	26,750	26,750
Ramberg-Osgood Parameters ($\frac{\varepsilon}{\varepsilon_o} = \frac{\sigma}{\sigma_o} + \alpha\left(\frac{\sigma}{\sigma_o}\right)^n$)		
	Base Metal	Weld Metal
α	1.12	0.897
n	9.54	14.8
Reference Stress (σ_o)	39.0 ksi	76.0 ksi
Reference Strain (ε)	~~0.01470~~0.00146	~~0.02870~~0.00284

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Table 3.6.3-10 Minimum Moment versus Circumferential Crack Leakage Sizes for 5 gpm at Two Surge Line Piping Locations

Surge Nozzle		Hot Leg Nozzle	
Leakage Size (in)	Minimum Moment (in-kips)	Leakage Size (in)	Minimum Moment (in-kips)
8.760	0	8.261	0
7.850	200	7.435	200
7.310	400	6.920	400
6.867	600	6.490	600
6.495	800	6.130	800
6.170	1000	5.822	1000
5.891	1200	5.553	1200
5.644	1400	5.320	1400
5.425	1600	5.110	1600
5.230	1800	4.920	1800
5.051	2000	4.750	2000
4.890	2200	4.596	2200
4.741	2400	4.455	2400
4.606	2600	4.325	2600
4.481	2800	4.206	2800
4.370	3000	4.095	3000
4.257	3200	3.994	3200
4.157	3400	3.900	3400
4.065	3600	3.810	3600
3.974	3800	3.725	3800
3.891	4000	3.645	4000
3.703	4500	3.467	4500
3.540	5000	3.311	5000
3.394	5500	3.174	5500
3.265	6000	3.051	6000
3.149	6500	2.941	6500
3.042	7000	2.842	7000
2.948	7500	2.751	7500
2.852	8000	2.668	8000
2.778	8500	2.591	8500
2.702	9000	2.519	9000

Table 3.6.3-10—Minimum Moment versus Circumferential Leakage Crack Sizes for 5 gpm at Three Surge Line Piping Locations

Surge Nozzle		Surge Line		Hot Leg Nozzle	
Leakage Size (in)	**Minimum Moment (in-kips)**	**Leakage Size (in)**	**Minimum Moment (in-kips)**	**Leakage Size (in)**	**Minimum Moment (in-kips)**
12.318	0	9.459	0	8.776	0
11.094	500	8.536	500	7.897	500
10.142	1000	7.639	1000	7.039	1000
9.353	1500	6.652	1500	6.089	1500
8.634	2000	5.616	2000	5.102	2000
8.006	2500	4.650	2500	4.193	2500
7.377	3000	3.826	3000	3.429	3000
6.758	3500	3.158	3500	2.817	3500
6.152	4000	2.628	4000	2.336	4000
5.565	4500	2.210	4500	1.958	4500
5.008	5000	1.878	5000	1.660	5000
4.493	5500	1.612	5500	1.417	5500
4.021	6000	1.397	6000	1.228	6000
3.597	6500	1.221	6500	1.074	6500
3.219	7000	1.077	7000	0.945	7000
2.883	7500	0.956	7500	0.839	7500
2.587	8000	0.854	8000	0.749	8000
2.326	8500	-	-	-	-
2.098	9000	-	-	-	-
1.897	9500	-	-	-	-
1.719	10000	-	-	-	-

~~Table 3.6.3-11 Axial Through-Wall Leakage Crack Sizes for 5 gpm at Two Surge Line Piping Locations~~

~~SL Location~~	~~Leakage Crack Size (in)~~
~~Surge Nozzle End~~	~~5.429~~
~~Hot Leg Nozzle End~~	~~5.140~~

Table 3.6.3-11—Axial Through-Wall Leakage Crack Sizes for 5 gpm at Three Surge Line Piping Locations

SL Location	Leakage Crack Size (in)
Pressurizer Surge Nozzle at Alloy 52 weld	7.635
Surge Line Piping	6.665
Hot Leg Nozzle	6.526

Table 3.6.3-12—Minimum Moment versus Circumferential Leakage Crack ~~Leakage~~ Sizes for 1 gpm in the Main Steam Line Piping

Leakage Size (in)	Minimum Moment (in-kips)
13.85	2400
12.05	4820
10.73	7270
9.75	9620
8.93	12,100
8.25	14,700
7.70	17,200
7.20	19,800
6.76	22,500
6.33	25,600
5.94	28,800

Table 3.6.3-21 ALL for Pressurizer Surge Nozzle at Alloy 52 Weld

With Axial Load of:			1.5 kips	15 kips	30 kips	40 kips	50 kips
Set No.	Flaw Size (in)	Min Moment (in-kips)	Max Moment (in-kips)	Max Moment (in-kips)	Max Moment (in-kips)	Max Moment (in-kips)	Max Moment (in-kips)
1	8.760	0	2720	2660	2590	2550	2510
2	7.850	200	3420	3370	3300	3260	3220
3	7.310	400	3870	3810	3750	3710	3670
4	6.867	600	4250	4190	4130	4090	4050
5	6.495	800	4570	4520	4460	4420	4380
6	6.170	1000	4860	4810	4750	4710	4670
7	5.891	1200	5110	5060	5000	4960	4920
8	5.644	1400	5340	5290	5230	5190	5150
9	5.425	1600	5540	5490	5430	5390	5350
10	5.230	1800	5720	5670	5610	5570	5530
11	5.051	2000	5890	5840	5780	5740	5700
12	4.890	2200	6040	5990	5930	5890	5860
13	4.741	2400	6180	6130	6070	6040	6000
14	4.606	2600	6310	6260	6200	6160	6130
15	4.481	2800	6430	6380	6320	6280	6250
16	4.370	3000	6540	6490	6430	6390	6350
17	4.257	3200	6650	6590	6540	6500	6460
18	4.157	3400	6740	6690	6630	6600	6560
19	4.065	3600	6830	6780	6720	6690	6650
20	3.974	3800	6920	6870	6810	6770	6740
21	3.891	4000	7000	6950	6890	6860	6820
22	3.703	4500	7190	7130	7080	7040	7000
23	3.540	5000	7350	7300	7240	7200	7160
24	3.394	5500	7490	7440	7390	7350	7310
25	3.265	6000	7620	7570	7510	7480	7440
26	3.149	6500	7740	7690	7630	7590	7560
27	3.042	7000	7850	7800	7740	7700	7670
28	2.948	7500	7940	7890	7840	7800	7760
29	2.852	8000	8040	7990	7940	7900	7860
30	2.778	8500	8120	8070	8010	7980	7940
31	2.702	9000	8200	8150	8090	8060	8020

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Table 3.6.3-21—ALL for Pressurizer Surge Nozzle at Alloy 52 Weld
(Sheet 1 of 2)

With Axial Load of:			0 kips	1.5 kips	15 kips	30 kips	40 kips	50 kips	60 kips	70 kips
Set No.	Max Moment (in-kips)	Max Moment (in-kips)	Max Moment (in-kips)	Max Moment (in-kips)	Max Moment (in-kips)	Max Moment (in-kips)	Max Moment (in-kips)	Max Moment (in-kips)	Max Moment (in-kips)	Max Moment (in-kips)
1	12.318	0	2,076	2,068	1,993	1,910	1,855	1,800	1,745	1,690
2	11.094	500	2,934	2,927	2,855	2,779	2,728	2,676	2,625	2,573
3	10.142	1000	3,710	3,702	3,636	3,562	3,513	3,464	3,415	3,366
4	9.353	1500	4,435	4,428	4,363	4,292	4,245	4,197	4,150	4,103
5	8.634	2000	5,152	5,145	5,083	5,014	4,968	4,921	4,875	4,829
6	8.006	2500	5,819	5,813	5,752	5,684	5,639	5,594	5,549	5,504
7	7.377	3000	6,524	6,517	6,458	6,392	6,347	6,303	6,259	6,215
8	6.758	3500	7,251	7,244	7,185	7,120	7,077	7,034	6,990	6,947
9	6.152	4000	7,992	7,986	7,928	7,864	7,821	7,779	7,736	7,693
10	5.565	4500	8,737	8,731	8,674	8,611	8,569	8,527	8,485	8,442
11	5.008	5000	9,469	9,463	9,407	9,344	9,303	9,261	9,219	9,178
12	4.493	5500	10,168	10,162	10,106	10,044	10,003	9,962	9,920	9,879
13	4.021	6000	10,830	10,824	10,768	10,707	10,666	10,625	10,584	10,543
14	3.597	6500	11,445	11,439	11,384	11,323	11,282	11,241	11,201	11,160
15	3.219	7000	12,014	12,008	11,953	11,892	11,852	11,811	11,771	11,730

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Table 3.6.3-21—ALL for Pressurizer Surge Nozzle at Alloy 52 Weld
(Sheet 2 of 2)

With Axial Load of:			0 kips	1.5 kips	15 kips	30 kips	40 kips	50 kips	60 kips	70 kips
Set No.	Max Moment (in-kips)	Max Moment (in-kips)	Max Moment (in-kips)	Max Moment (in-kips)	Max Moment (in-kips)	Max Moment (in-kips)	Max Moment (in-kips)	Max Moment (in-kips)	Max Moment (in-kips)	Max Moment (in-kips)
16	2.883	7500	12,540	12,534	12,479	12,419	12,378	12,338	12,298	12,257
17	2.587	8000	13,024	13,018	12,963	12,903	12,863	12,823	12,783	12,743
18	2.326	8500	13,471	13,465	13,411	13,351	13,311	13,271	13,231	13,191
19	2.098	9000	13,882	13,876	13,822	13,762	13,722	13,682	13,642	13,602
20	1.897	9500	14,264	14,258	14,204	14,145	14,105	14,065	14,025	13,985
21	1.719	10000	14,622	14,616	14,562	14,503	14,463	14,423	14,383	14,344

Table 3.6.3-22 ALL for Surge Line Piping

With Axial Load of:			1.5 kips	15 kips	30 kips	40 kips	50 kips	60 kips	70 kips
Set No.	Flaw Size (in)	Min Moment (in-kips)	Max Moment (in-kips)	Max Moment (in-kips)	Max Moment (in-kips)	Max Moment (in-kips)	Max Moment (in-kips)	Max Moment (in-kips)	Max Moment (in-kips)
1	8.760	0	2870	2810	2750	2700	2660	2620	2570
2	7.850	200	3640	3580	3520	3480	3440	3390	3350
3	7.310	400	4120	4070	4010	3960	3920	3880	3840
4	6.867	600	4530	4480	4410	4370	4330	4290	4250
5	6.495	800	4880	4820	4760	4720	4680	4640	4600
6	6.170	1000	5190	5130	5070	5030	4990	4950	4920
7	5.891	1200	5450	5400	5340	5300	5260	5220	5180
8	5.644	1400	5690	5640	5580	5540	5500	5460	5420
9	5.425	1600	5900	5850	5790	5750	5710	5670	5630
10	5.230	1800	6090	6030	5970	5940	5900	5860	5820
11	5.051	2000	6260	6200	6150	6110	6070	6030	5990
12	4.890	2200	6410	6360	6300	6260	6220	6180	6150
13	4.741	2400	6550	6500	6440	6400	6370	6330	6290
14	4.606	2600	6680	6630	6570	6530	6490	6460	6420
15	4.481	2800	6800	6750	6690	6650	6610	6580	6540
16	4.370	3000	6900	6850	6800	6760	6720	6680	6640
17	4.257	3200	7010	6960	6900	6860	6830	6790	6750
18	4.157	3400	7110	7050	7000	6960	6920	6880	6850
19	4.065	3600	7190	7140	7080	7050	7010	6970	6930
20	3.974	3800	7280	7230	7170	7130	7090	7060	7020
21	3.891	4000	7360	7310	7250	7210	7170	7140	7100
22	3.703	4500	7530	7480	7430	7390	7350	7310	7280
23	3.540	5000	7690	7640	7580	7540	7510	7470	7430
24	3.394	5500	7830	7780	7720	7680	7640	7610	7570

With Axial Load of:			1.5 kips	15 kips	30 kips	40 kips	50 kips	60 kips	70 kips
Set No.	Flaw Size (in)	Min Moment (in-kips)	Max Moment (in-kips)	Max Moment (in-kips)	Max Moment (in-kips)	Max Moment (in-kips)	Max Moment (in-kips)	Max Moment (in-kips)	Max Moment (in-kips)
25	3.265	6000	7950	7900	7840	7800	7770	7730	7690
26	3.149	6500	8060	8010	7950	7910	7880	7840	7800
27	3.042	7000	8160	8110	8050	8020	7980	7940	7900
28	2.948	7500	8250	8200	8140	8110	8070	8030	7990
29	2.852	8000	8340	8290	8240	8200	8160	8120	8090
30	2.778	8500	8410	8360	8310	8270	8230	8200	8160
31	2.702	9000	8490	8440	8380	8340	8310	8270	8230

Table 3.6.3-22—ALL for Surge Line Piping

With Axial Load of:			0 kips	1.5 kips	15 kips	30 kips	40 kips	50 kips	60 kips	70 kips
Set No.	Flaw Size (in)	Min Moment (in-kips)	Max Moment (in-kips)	Max Moment (in-kips)	Max Moment (in-kips)	Max Moment (in-kips)	Max Moment (in-kips)	Max Moment (in-kips)	Max Moment (in-kips)	Max Moment (in-kips)
1	9.459	0	2,547	2,539	2,468	2,388	2,335	2,281	2,227	2,172
2	8.536	500	3,386	3,378	3,311	3,236	3,186	3,135	3,084	3,033
3	7.639	1000	4,257	4,250	4,187	4,117	4,070	4,023	3,975	3,927
4	6.652	1500	5,228	5,222	5,167	5,106	5,065	5,025	4,984	4,944
5	5.616	2000	6,287	6,281	6,227	6,169	6,129	6,090	6,051	6,011
6	4.650	2500	7,358	7,352	7,300	7,243	7,204	7,166	7,127	7,089
7	3.826	3000	8,343	8,337	8,286	8,229	8,192	8,154	8,116	8,078
8	3.158	3500	9,144	9,140	9,104	9,062	9,034	9,006	8,977	8,941
9	2.628	4000	9,744	9,740	9,707	9,669	9,643	9,617	9,591	9,564
10	2.210	4500	10,214	10,211	10,180	10,145	10,122	10,097	10,073	10,048
11	1.878	5000	10,585	10,582	10,553	10,521	10,499	10,476	10,453	10,430
12	1.612	5500	10,880	10,877	10,850	10,820	10,799	10,778	10,756	10,734
13	1.397	6000	11,117	11,114	11,089	11,060	11,040	11,020	10,999	10,978
14	1.221	6500	11,309	11,307	11,283	11,255	11,236	11,216	11,197	11,176
15	1.077	7000	11,466	11,464	11,440	11,414	11,395	11,377	11,358	11,338
16	0.956	7500	11,597	11,595	11,572	11,546	11,529	11,511	11,492	11,473
17	0.854	8000	11,707	11,705	11,683	11,658	11,641	11,623	11,605	11,587

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Table 3.6.3-23 ALL for Hot Leg Nozzle

With Axial Load of:			1.5 kips	15 kips	30 kips	40 kips	50 kips	60 kips	70 kips
Set No.	Flaw Size (in)	Min Moment (in-kips)	Max Moment (in-kips)	Max Moment (in-kips)	Max Moment (in-kips)	Max Moment (in-kips)	Max Moment (in-kips)	Max Moment (in-kips)	Max Moment (in-kips)
1	8.261	0	3320	3260	3200	3150	3110	3070	3030
2	7.435	200	4050	3990	3930	3890	3830	3810	3760
3	6.920	400	4520	4470	4410	4370	4310	4280	4240
4	6.490	600	4930	4870	4810	4770	4720	4690	4650
5	6.130	800	5270	5220	5160	5120	5060	5040	5000
6	5.822	1000	5570	5510	5450	5420	5360	5340	5300
7	5.553	1200	5830	5770	5710	5680	5620	5600	5560
8	5.320	1400	6050	6000	5940	5900	5850	5820	5780
9	5.110	1600	6250	6200	6140	6100	6050	6030	5990
10	4.920	1800	6440	6380	6330	6290	6240	6210	6170
11	4.750	2000	6600	6550	6490	6450	6400	6370	6340
12	4.596	2200	6750	6690	6640	6600	6550	6520	6480
13	4.455	2400	6880	6830	6770	6730	6680	6660	6620
14	4.325	2600	7000	6950	6900	6860	6810	6780	6740
15	4.206	2800	7120	7070	7010	6970	6920	6900	6860
16	4.095	3000	7220	7170	7120	7080	7030	7000	6960
17	3.994	3200	7320	7270	7210	7170	7130	7100	7060
18	3.900	3400	7410	7360	7300	7260	7220	7190	7150
19	3.810	3600	7490	7440	7390	7350	7300	7270	7240
20	3.725	3800	7580	7520	7470	7430	7390	7360	7320
21	3.645	4000	7650	7600	7540	7510	7460	7430	7390
22	3.467	4500	7820	7770	7710	7680	7630	7600	7560
23	3.311	5000	7970	7920	7860	7830	7780	7750	7710
24	3.174	5500	8100	8050	7990	7960	7910	7880	7840

With Axial Load of:			1.5 kips	15 kips	30 kips	40 kips	50 kips	60 kips	70 kips
Set No.	Flaw Size (in)	Min Moment (in-kips)	Max Moment (in-kips)	Max Moment (in-kips)	Max Moment (in-kips)	Max Moment (in-kips)	Max Moment (in-kips)	Max Moment (in-kips)	Max Moment (in-kips)
25	3.051	6000	8220	8170	8110	8070	8030	8000	7960
26	2.941	6500	8320	8270	8220	8180	8140	8110	8070
27	2.842	7000	8420	8370	8310	8280	8240	8200	8160
28	2.751	7500	8510	8460	8400	8360	8330	8290	8250
29	2.668	8000	8590	8540	8480	8450	8410	8370	8330
30	2.591	8500	8660	8610	8560	8520	8480	8450	8410
31	2.519	9000	8730	8680	8630	8590	8550	8520	8480

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Table 3.6.3-23—ALL for Hot Leg Nozzle

With Axial Load of:			0 kips	1.5 kips	15 kips	30 kips	40 kips	50 kips	60 kips	70 kips
Set No.	Flaw Size(in)	Min Moment (in-kips)	Max Moment (in-kips)	Max Moment (in-kips)	Max Moment (in-kips)	Max Moment (in-kips)	Max Moment (in-kips)	Max Moment (in-kips)	Max Moment (in-kips)	Max Moment (in-kips)
1	8.776	0	3,060	3,052	2,984	2,907	2,855	2,803	2,751	2,698
2	7.897	500	3,883	3,876	3,812	3,740	3,691	3,642	3,593	3,544
3	7.039	1000	4,733	4,726	4,666	4,599	4,554	4,508	4,462	4,416
4	6.089	1500	5,657	5,651	5,597	5,538	5,498	5,458	5,418	5,378
5	5.102	2000	6,691	6,685	6,633	6,574	6,535	6,496	6,457	6,418
6	4.193	2500	7,719	7,713	7,661	7,604	7,566	7,528	7,489	7,451
7	3.429	3000	8,623	8,618	8,579	8,535	8,499	8,462	8,424	8,386
8	2.817	3500	9,302	9,298	9,263	9,223	9,196	9,168	9,140	9,112
9	2.336	4000	9,833	9,829	9,797	9,761	9,736	9,711	9,685	9,659
10	1.958	4500	10,247	10,244	10,214	10,181	10,158	10,134	10,110	10,086
11	1.660	5000	10,572	10,569	10,541	10,509	10,487	10,465	10,443	10,420
12	1.417	5500	10,834	10,831	10,805	10,775	10,755	10,734	10,712	10,691
13	1.228	6000	11,037	11,034	11,009	10,981	10,961	10,941	10,921	10,900
14	1.074	6500	11,201	11,199	11,175	11,147	11,128	11,109	11,089	11,069
15	0.945	7000	11,338	11,335	11,312	11,286	11,268	11,249	11,230	11,210
16	0.839	7500	11,450	11,447	11,425	11,399	11,381	11,363	11,345	11,326
17	0.749	8000	11,545	11,542	11,520	11,495	11,478	11,460	11,442	11,424

Table 3.6.3-24—Critical Axial Crack Size at Surge Line Piping Locations

LBB Piping Location	Description of Pipe Geometry	Leakage Crack Size (in)	Critical Crack Size (in)	Safety Margin
1	Pressurizer Surge Nozzle at Alloy 52 weld	~~5.429~~7.635	~~31.30~~33.65	~~5.76~~4.41
2	Surge Line Piping	~~5.429~~6.665	~~22.80~~23.83	~~4.20~~3.58
3	Hot Leg Nozzle	~~5.140~~6.526	~~22.87~~22.55	~~4.45~~3.46

Table 3.6.3-25—ALL for the Main Steam Line Piping with Safety Factor of 2 on Flaw Size (Base Metal)

Minimum Moment (in-kips)	Maximum Allowable Moment with Moment Plus Axial Load					
	0 kip (in-kips)	100 kips (in-kips)	200 kips (in-kips)	300 kips (in-kips)	451 kips (in-kips)	600 kips (in-kips)
2402	25,153	24,495	23,892	23,214	22,047	20,720
4815	29,053	28,321	27,664	27,084	26,085	24,955
7270	32,379	31,626	30,859	30,241	29,339	28,320
9618	34,845	34,116	33,377	32,634	31,799	30,856
12,122	37,002	36,288	35,569	34,833	33,926	33,041
14,661	38,858	38,159	37,453	36,734	35,746	34,904
17,169	40,352	39,722	39,026	38,318	37,259	36,449
19,805	41,751	41,186	40,496	39,798	38,707	37,887
22,550	43,016	42,509	41,825	41,134	40,058	39,181
25,628	44,285	43,837	43,158	42,473	41,411	40,474
28,822	45,466	45,056	44,398	43,718	42,667	41,673

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Table 3.6.3-26—~~Table Deleted~~Air Fatigue Crack Morphology Parameters

Material	Roughness μ_G, µinch	90-degree Turns per inch n, inch^{-1}
Carbon Steel	1325	51
Stainless Steel	1325	64

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Figure 3.6.3-6—Minimum Moment versus Circumferential Leakage Crack ~~Leakage~~ Sizes for 5 gpm at T~~wo~~hree Surge Line Locations

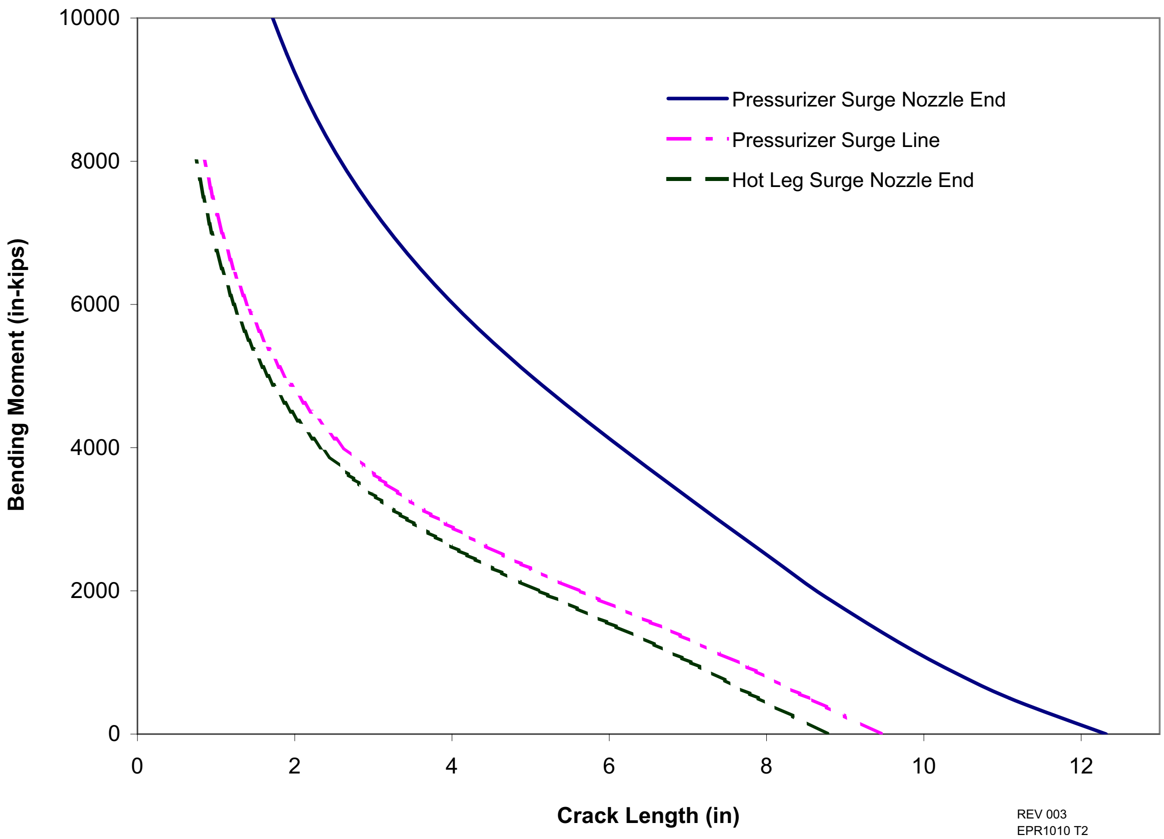

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Figure 3.6.3-18—ALL for Pressurizer Surge Nozzle at Alloy 52 Weld

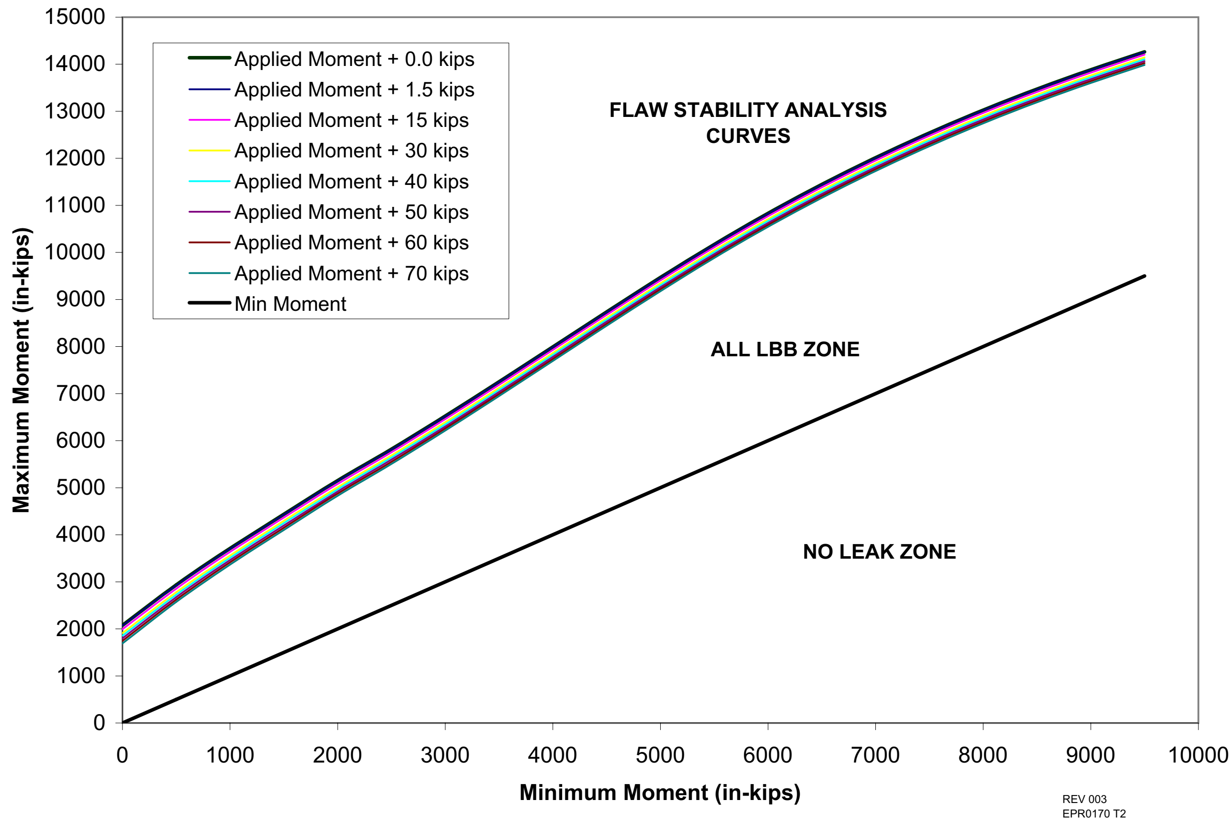

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Figure 3.6.3-19—ALL for Surge Line Piping

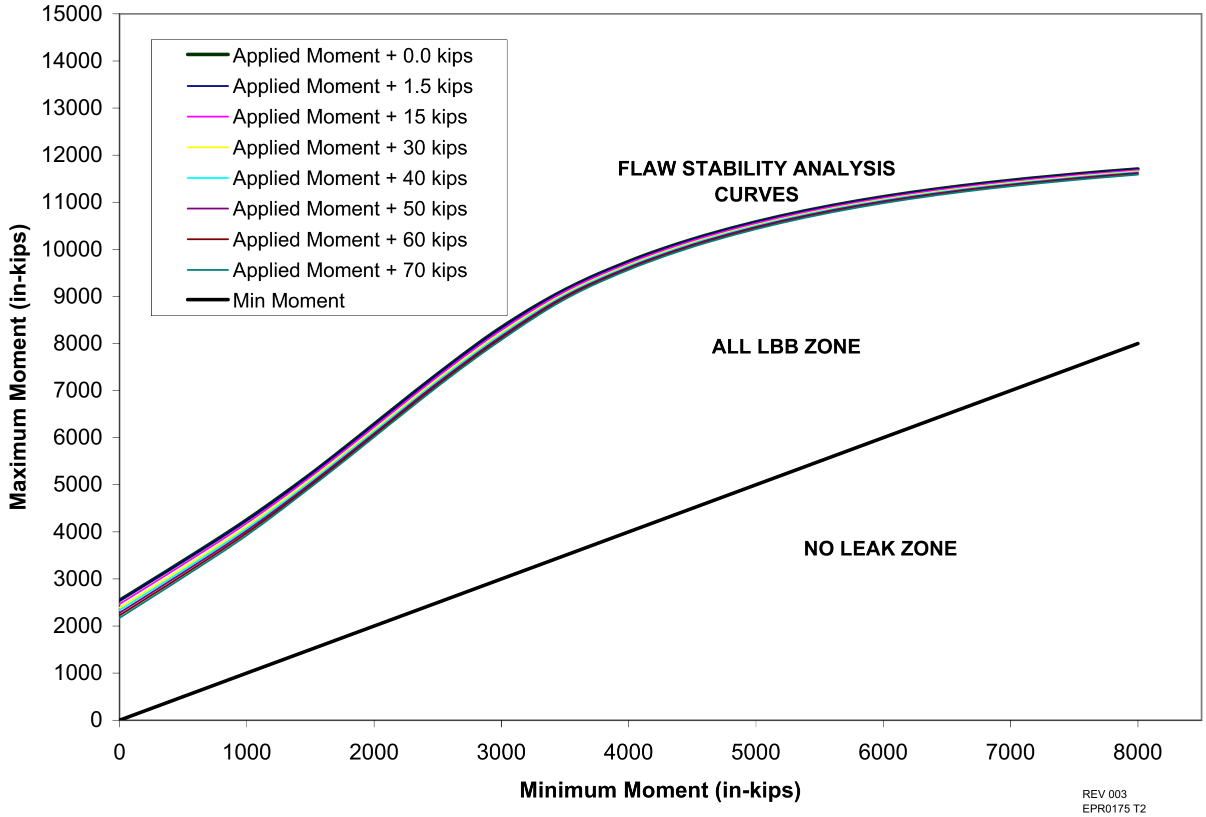

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Figure 3.6.3-20—ALL for Hot Leg Nozzle