ATTACHMENT 2

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AREVA DOCUMENT 51-5049676-002, "PALISADES VENT LINE NOZZLE REPAIR ANALYSIS SUMMARY," DATED APRIL 2007

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Title PALISADES VENT LINE NOZZLE REPAIR ANALYSIS SUMMARY

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Technical Manager Statement: Initials BD

Reviewer is Independent.

Remarks:

A weld repair procedure has been developed for the Palisades reactor vessel head vent line nozzle wherein degraded Alloy 182 J-groove weld material is partially removed and Alloy 52/52M/152 weld metal is used to fill the cavity, leaving an embedded flaw between the low alloy steel head and the new weld.

Based on the conservative fatigue analysis, the maximum usage factor for 27 years of operation of the repair design is 0.2079 for the nozzle, 0.1588 for the weld, and 0.0497 for the RV head, compared to the ASME Code allowed maximum of 1.0.

The sub-critical embedded flaw analysis is acceptable for 27 years of operation with the following restrictions:

1. Plant cooldown must be considered to terminate before the coolant temperature reaches 72°F.
2. A design safety factor of $\sqrt{2}$ on the K_{Ic} fracture toughness must be utilized as a flaw acceptance criterion near the end of cooldown when the system pressure is less than 20 percent of the design pressure and the coolant temperature is not less than the RT_{NDT} of the vessel head (72°F at the location of the vent nozzle).

Based on the results of the OD axial flaw evaluation, it is concluded that a maximum allowable initial axial flaw size that is 50% of the nozzle wall thickness is acceptable for a 27 year design life with the repaired Palisades vent line nozzle configuration.

Record of Revisions:

Revision 001 has been created to address changes in References 2-5. The ASME Section XI Code year has been updated. Alloy 52M has been included.

Revision 002 had pages 1a and 1b removed and the proprietary statement on this page was removed.

Introduction

Due to the susceptibility of Alloy 600 reactor vessel head partial penetration nozzles to primary water stress corrosion cracking (PWSCC), a weld repair procedure has been developed for the Palisades reactor vessel head vent line nozzle wherein degraded Alloy 182 J-groove weld material is removed and Alloy 52/52M/152 weld metal is used to fill the cavity, leaving an embedded flaw between the low alloy steel head and the new weld, as shown in Figure 1. The repair is more fully described by the design drawing [1] and the technical requirements document [2].

Three analyses were performed to show the suitability of the repair design.

1. The stress analysis was performed to verify whether the repair design meets the applicable requirements of the ASME Code, Section III, Subsection NB, 1989 edition [3].

2. A flaw analysis was performed on the remaining flaw in the butter, which cannot be sized by currently available non-destructive examination techniques. Therefore, it is assumed that the "as-left" condition of partial penetration weld includes degraded or cracked material throughout that portion of the original Alloy 182 butter material that is not removed by excavation. The remaining flaw is termed a sub-critical embedded flaw (SCEF) since the weld is excavated to a depth that reduces the size of the embedded flaw, after welding, to an acceptable size per Section XI of the ASME Code, considering fatigue crack growth over the life of the repair. A fracture mechanics analysis was performed to demonstrate that the remaining embedded flaw after a vent line nozzle weld repair satisfies the acceptance standards of Section XI of the ASME Code 2001 Edition with 2003 addenda [4].

3. A flaw growth analysis was performed considering a leak path that existed between the OD of the nozzle and the original J-groove weld [5]. After the weld repair, an axial flaw that could follow this leak path is postulated to be present on the OD surface of the modified vent nozzle. The length of the axial flaw corresponds to at least the height of the remnant weld. The analysis is performed using the NRC flaw evaluation guidelines [6, 7] and ASME Code Section XI, 2001 Edition with 2003 addenda.

Results

Stress analysis of the vent nozzle repair necessitated creation of a 2-D finite element model and stress analysis of the nozzle configuration. The model is subjected to the temperature and pressure conditions of the various Palisades reactor vessel loads. The vent pipe is modeled to be perpendicular to the reactor vessel head surface since it is very close to the apex. The model only includes a section of the vent piping which is enough to account for the stress concentration at the nozzle. The analysis demonstrates the repair design meets the stress and fatigue requirements of ASME Code, Section III, Subsection NB, 1989 edition. Based on the conservative fatigue analysis, the maximum usage factor for 27 years of operation of the repair design is 0.2079 for the nozzle, 0.1588 for the weld, and 0.0497 for the RV head, compared to the ASME Code allowed maximum of 1.0 [3].

Based on an evaluation of fatigue crack growth of the SCEF flaw in the original J-groove butter material into the low alloy steel head and the new Alloy 52/52M/152 weld filler and weld overlay, it has been demonstrated that the remaining flaw would satisfy Section XI flaw acceptance criteria for a 27 year design life with the following restrictions:

1. Plant cooldown must be considered to terminate before the coolant temperature reaches 72°F.

2. A design safety factor of $\sqrt{2}$ on the K_{Ic} fracture toughness must be utilized as a flaw acceptance criterion near the end of cooldown when the system pressure is less than 20 percent of the design pressure and the coolant temperature is not less than the RT_{NDT} of the vessel head (72°F at the location of the vent nozzle) [4].

Based on the results of the OD axial flaw evaluation, it is concluded that a maximum allowable initial axial flaw size that is 50% of the nozzle wall thickness is acceptable for a 27 year design life with the repaired Palisades vent line nozzle configuration [5].

Conclusion

Based on the conservative fatigue analysis, the maximum usage factor for 27 years of operation of the repair design is 0.2079 for the nozzle, 0.1588 for the weld, and 0.0497 for the RV head, compared to the ASME Code allowed maximum of 1.0.

The sub-critical embedded flaw analysis is acceptable for 27 years of operation with the following restrictions:

1. Plant cooldown must be considered to terminate before the coolant temperature reaches 72°F.

2. A design safety factor of $\sqrt{2}$ on the K_{Ic} fracture toughness must be utilized as a flaw acceptance criterion near the end of cooldown when the system pressure is less than 20 percent of the design pressure and the coolant temperature is not less than the RT_{NDT} of the vessel head (72°F at the location of the vent nozzle).

Based on the results of the OD axial flaw evaluation, it is concluded that a maximum allowable initial axial flaw size that is 50% of the nozzle wall thickness is acceptable for a 27 year design life with the repaired Palisades vent line nozzle configuration.

References

1. AREVA Drawing 02-5041137C-02, "Palisades Vent Line Modification," September 2004.
2. AREVA Document 51-5041379-003, "Palisades RV Head Vent Line Nozzle Weld Repair Requirements," September 2006.
3. AREVA Document 32-5042025-03, "Palisades RV Head Vent Line Nozzle Stress Analysis," September 2006.
4. AREVA Document 32-5047487-001, "Palisades Vent Line Nozzle J-Groove Weld SCEF Evaluations," September 2006.
5. AREVA Document 32-5048936-001, "Palisades Vent Line Nozzle Axial Flaw Evaluation," September 2006.
6. NRC Letter from Richard Barrett, Director Division of Engineering, Office of NRR to Alex Marion of Nuclear Energy Institute, "Flaw Evaluation Guidelines," April 11, 2003, Accession Number ML030980322.
7. Attachment 2 to Reference 6, "Enclosure 2 Appendix A: Evaluation of Flaws in PWR Reactor Vessel Upper Head Penetration Nozzles," April 11, 2003, Accession Number ML030980333.

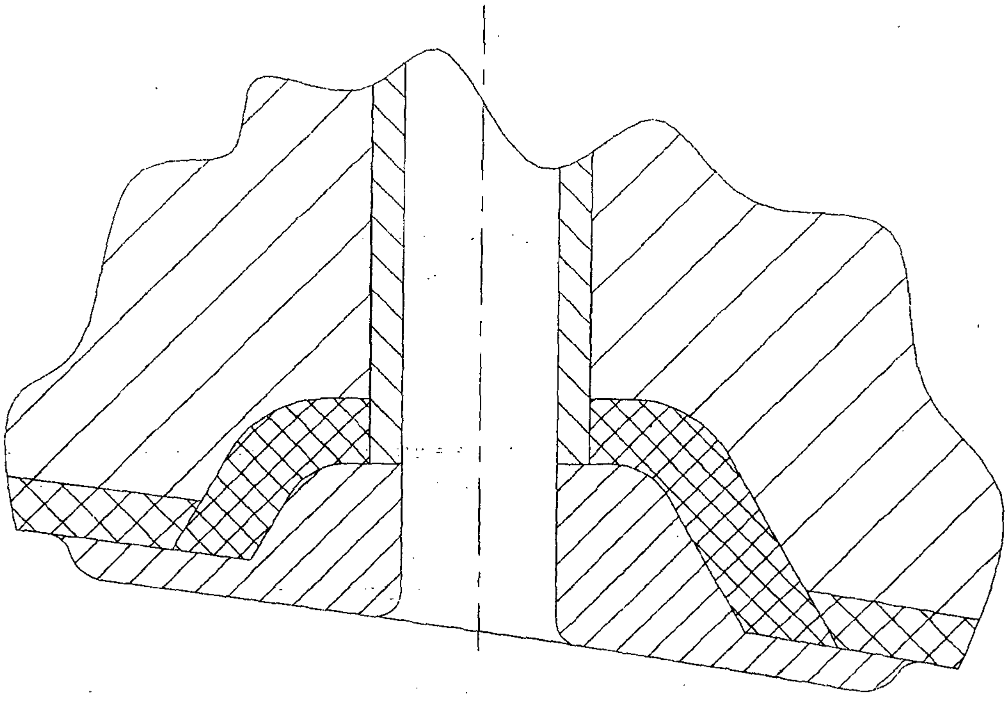

Figure 1. Vent Line Nozzle Weld Repair