Technical Basis for Minimizing Inspection Volume for BWR RPV Shell Welds and Nozzle-to-Shell Welds

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NRC Question

- In Response to a presentation on this same subject NRC Staff asked the question "why should the nozzle-to-shell weld be treated any differently than any other vessel shell weld".
- For the BWR RPV the answer is that they should be treated the same i.e., the examination volume may limited to the Inner 15% or one inch whichever is greater. The position for PWR units it is likely the same. However, the appropriate technical basis calculations are not yet available.

VIP 05

- Investigations by the BWR Vessel and Internals Project demonstrated very low failure probability for BWR Vessel Shell Welds.
- Conclusion
  - Circumferential welds need not be examined
  - Only inner inch need be inspected due to the very low probability of failure resulting from embedded and outer surface flaws

NRC Generic Letter 98-05

- Use of VIP 05 GL 98-05
  - NRC calculated a failure probability for Axial welds at less than 5.0×10^{-6} /yr
  - For circumferential welds 8.2×10^{-8}/yr
  - Approved removing circumferential welds from BWR examination program as the failure probability was well below the 5.0×10^{-6} /yr established in Regulatory Guide 1.154.

VIP 108

- Calculated total failure probability for nozzle-to-shell welds using conservative event frequency of 1.0×10^{-3} /yr, for surface connected flaws in the most conservative location.
- Calculated total failure probability of 2.5×10^{-11}/yr for surface connected nozzle to shell welds.

Embedded Defects

- F. Simonen and others have calculated that a flaw removed one inch from the surface is 1,000 times less likely to fail as compared to an inside surface connected flaw.
- This would result in a failure probability of less than 5×10^{-9}/yr for axial shell welds and 2.5×10^{-14}/yr for nozzle-to-shell welds flaws removed from the inside surface by one inch or more.

Conclusion

- BWR embedded or outside surface flaws are less likely to fail, (5×10^{-9}/yr for axial shell welds and 2.5×10^{-14}/yr for nozzle-to-shell welds), than are surface connected flaws in the circumferential welds.
- 100% of the volume of Circumferential welds are allowed to be removed from examination consideration as a result of their low failure probability (8.2×10^{-8}/yr), NRC Generic Letter 98-05.
- This position is also consistent with Code Case N-526.

Proposed Action

- PDI had requested a clarification of this issue prior to November 22, 2002 relative to the September 22, 1999 Rule.
- NRC is requested to take action to remove the ambiguity in the Federal regulation.
- It is the PDI position that examination for transverse flaws in the outer 85% need not be performed for BWR vessels and that 10CFR50.55a does not require this examination for PWR units that are inspected from the bore of the nozzle.

White Paper

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Background

The Performance Demonstration Initiative (PDI) has had several discussions with NRC Staff, relative to the examinations to be performed in the outer 85% of BWR and PWR RPV nozzle-to-shell welds, reference White Paper dated September 27, 2002 [1]. The NRC asked for additional justification as to why the nozzle-to-shell should be considered any differently than other RPV welds. This document compares the basis for elimination of examinations for 100% of the volume of BWR circumferential welds with that for the outer 85% of BWR nozzle-to-shell and axial welds.

Proposal

It is proposed that the inspection volume for BWR Units Category BA, RPV, longitudinal and circumferential welds and Category BD, RPV, nozzle-to-shell welds be limited to the inner one inch or 15% of the section thickness, whichever is greater. It should be noted that elimination of examinations for 100% of the volume of circumferential welds has previously been granted.

Basis

BWRVIP-05

Analysis by the Boiling Water Reactor Vessel and Internal Project contained in BWRVIP-05 [2] has demonstrated very low probability of failure for BWR RPV longitudinal and circumferential welds. The NRC performed similar calculations and provided slightly more conservative estimates of RPV circumferential weld failure probabilities in NRC Generic Letter 98-05 [3]. The NRC staff estimated the probability of failure of a BWR circumferential weld at 8.2×10^{-8}/yr [(1 x1 0^{-3} event frequency) x (8.2×10^{-5} P(F|E))]. The NRC staff agreed with the industry that vessel failure frequency for axial welds was less than 5.0×10^{-6} /yr [4]. NRC has agreed [3, 4] that circumferential welds in BWR units need not be examined as the failure probability (8.2×10^{-8}) is well below the limit of 5×10^{-6} established by Regulatory Guide 1.154 [5].

BWRVIP-05 also recommended that the inspection volume be limited to the inner 10% of the volume for the axial welds. This recommendation is based on the low safety significance of embedded flaws.

BWRVIP 108

Analysis by the Boiling Water Reactor Vessel and Internal Project contained in BWRVIP-108 [6] extends the VIP– 05 analyses to BWR RPV Category BD nozzle-to-shell welds and the nozzle inner-radius region. The results of this analysis demonstrated the probability of vessel failure at less than 2.5 $x10^{-11}$/yr for surface connected flaws oriented in the direction of maximum stress. The low probability of failure for nozzle-to-shell welds results primarily from the low neutron fluence at the nozzle locations. The total failure probability for nozzle-to-shell welds (2.5 x 10^{-11}/yr) is less than that of BWR circumferential welds (8.2 x 10^{-8}/yr).

Both VIP-05 and 108 considered only surface connected flaws as they overwhelmingly predominate vessel failure probability assessment. Simonen of PNNL has demonstrated that flaws located one inch from the inside surface would be 1000 times less likely to result in vessel failure compared to surface breaking flaws [7]. A flaw located two inches from the inside surface would reduce the probability of failure by a factor of $1x10^{6}$. Flaws located one inch or more from the inside surface would have an expected probability of failure of less than $5x10^{-9}$/yr for the limiting RPV axial shell welds and less than $2.5x10^{-14}$/yr for nozzle-to-vessel welds, assuming the reduction factor of 1000 from Simonen. Both of these probabilities are less than the probability of failure calculated for surface connected flaws in BWR RPV circumferential shell welds (8.2 x 10^{-8}/ yr) stated in Generic letter 98-05 [3].

Conclusion

Flaws located one inch or more from the inside surface of BWR nozzle-to-shell and axial shell welds are less likely to result in a vessel failure than a flaw located at the surface of a weld. NRC has previously accepted elimination of the entire examination volume for BWR circumferential welds based on their low probability of contribution to a possible vessel failure [4, 5]. A flaw located in the outer 85% of the BWR nozzle-to-vessel or axial shell weld would contribute to an even lower probability of failure. The low failure probability of embedded flaws stated here is consistent with the Technical Basis of Code Case N-526 [8].

References

1. L. Becker, "White Paper, RPV Nozzle-to-Shell Examination Coverage and Scan Directions", Submitted to NRC by cover letter R. Linden to T. Chan, dated October 4, 2002.

2. BWR Vessel and Internals Project, "BWR Reactor Pressure Vessel Shell Weld Inspection Recommendations", BWRVIP-05, TR-105697, EPRI, September 1995.

3. NRC Generic Letter 98-05: Boiling Water Reactor Licensees Use of the BWRVIP-05 Report to Request Relief from Augmented Examination Requirements on Reactor Pressure Vessel Circumferential Shell Welds, 11,10,1998.

4. Letter from J. Strosnider to C. Terry, "Supplement to Final Safety Evaluation of the BWR Vessel and Internals Project BWRVIP-05 Report" (TAC NO. MA3395), NRC, March 7, 2000.

5. Regulatory Guide 1.154, "Format and Content of Plant-Specific Pressurized Thermal Shock Safety Analysis Reports for Pressurized Water Reactors", US Nuclear Regulatory Commission, 01, 1987.

6. BWR Vessel and Internals Project, "Technical Basis for the Reduction of Inspection Requirements for the Boiling Water Reactor Nozzle-to-Vessel Shell welds and Nozzle Blend Radii", VIP-108, EPRI, September, 2002.

7. Dr. F. A. Simonen, "Fracture Mechanics Evaluation of surface Versus Interior Flaws in Reactor Pressure Vessels", Meeting Minutes from ASME Section XI Task Group on application of NDE to Operating Plant Criteria, May, 1993.

8. ASME Code Case N-546, "Alternative Requirements for Successive Inspection of class 1 and 2 Vessels", Section XI, Div 1, August 9, 1996.