NUCLEAR ENERGY INSTITUTE

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Subject: Response to NRC Request for Additional Information (RAI) Regarding Materials Reliability Program (MRP)-169, "Technical Basis for Preemptive Weld Overlays for Alloy 82/182 Butt Welds in PWRS," Report (TAC NO. MD8005), April 07, 2008.

Project Number: 689

The Nuclear Energy Institute (NEI) is pleased to provide the enclosed responses to the NRC's request for additional information (RAI) on EPRI Topical Report MRP-169 (TR), "Technical Basis for Pre-Emptive Weld Overlays for Alloy 82/182 Butt Welds in Pressurized Water Reactors (PWRs)."

EPRI MRP-169 details the methodology and criteria for using preemptive weld overlays (PWOL) to prevent dissimilar metal welds from cracking in PWR primary coolant pipes and nozzles. The NRC issued several requests for additional information on this document. The enclosed RAI responses address all NRC and Battelle questions and comments. MRP-169 Revision 1, also enclosed, includes changes proposed to resolve all the comments and suggestions from NRC and Battelle Staff. The enclosed documents are considered to be non-proprietary.

NEI requests continuance of the NRC safety review of Sections 4 and 7 of MRP-169 Rev 1. NRC staff review of the enclosed report is exempt from the fee recovery provision contained in 10 CFR Part 170. A fee waiver was already granted when the TR was first submitted. This approval is documented in an NRC letter dated August 3, 2006 (ADAMS ML060370431).

As discussed with the NRC staff, the industry plans to use TR MRP-169 for the weld overlay of dissimilar metal welds in the fall 2008 refueling outage. We look forward to working with the Staff towards a successful completion of the safety evaluation.

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If you have any technical questions regarding this matter, please contact me at 202.739.8137; jhr@nei.org or Mike Melton at 202.739.8049; mam@nei.org.

Sincerely,

James H. Riley

James H. Riley

Enclosures

c: Mr. Edmund T. Sullivan, Senior Level Advisor, NRC
Mr. Terrence Chan, Branch Chief, NRC

RESPONSES TO REQUEST FOR ADDITIONAL INFORMATION

Materials Reliability Program (MRP)

Topical Report MRP-169 "Technical Basis for Preemptive Weld Overlays for Alloy 82/182 Butt Welds in PWRs"

NRC RAI Response
Table of Contents

Section I: Original RAIs

General Content

General Question 1: *NEI has requested that the Nuclear Regulatory Commission (NRC) staff review and approve only Section 4, Design Requirements, and Section 7.1, Examination Requirements, of MRP-169. However, the NRC staff review and potential approval of these sections has necessitated the review of the entire report. Accordingly, the NRC staff is transmitting questions on various sections beyond 4 and 7.1 and will need responses to those questions in order to proceed with the review.*

Proposed Response: Comment acknowledged. No response required.

General Question 2 *The treatment of pre-emptive full structural, design, and optimized weld overlays (WOLs) is confusing because in various sections the discussions of the design and optimized pre-emptive weld overlay (PWOL) are intermingled with the discussion of the full structural PWOL. The NRC staff suggests that the report be clarified to (a) provide an introductory section that defines the differences between full structural, design, and optimized WOLs and (b) more clearly separate out the differences in the design and inspection rules for each category of overlay.*

Proposed Response: As suggested, clarification will be added to MRP-169 that defines the function of weld overlays to be either 'repair' or 'mitigation', and that within each function type, a weld overlay may be either an optimized weld overlay (OWOL) or a full structural weld overlay (FSWOL). An OWOL may be used for repair only if an existing flaw can be characterized as less than a prescribed through-wall dimension (i.e., 50% through wall) and justified by design analysis. Table 1 will be included in the revised report to summarize each overlay type with attendant design and inspection requirements from both MRP-139/169 and the ASME draft Code Cases N-740-1 and N-754. The term 'design overlay' will no longer be used in MRP-169.

Cross Reference to MRP-169, Rev. 1

Section 4.1 has been completely rewritten to provide general background information on weld overlay design and its relationship to ASME Section XI flaw evaluation rules. The discussion of FSWOLs and OWOLs is also expanded and clarified. New Figures 4-1 and 4-2 are added to support this background discussion. A new summary Section (4.7) and Table (4-1, which is Table 1 from this response) have been added summarizing the various design and inspection requirements for FSWOLs and OWOLs.

Table 1 – Weld Overlay Design Types and Associated Design and Inspection Requirements

Weld Overlay Type	Pre-WOL Inspection Completed?	Design Basis Flaw for WOL	Crack Growth Design Basis	Post-WOL Exam Volume (PSI and ISI)	Post-WOL Inservice Inspection Schedule (MRP-139/169 vs. ASME Code Cases)
Repair – Full Structural	Yes	100% thru-wall, full circ.	Actual observed flaw shall not exceed design basis flaw size in next inspection interval	WOL + outer 25% of Code DMW Exam Volume	MRP-139/169: (Cat. F) Once in the next 5 years, and then if no growth 100% in subsequent 10 year interval CC N-740-1: Once in the next two RFOs, and then if no growth, a 25% sample population on a 10 year basis
Repair – Full Structural	No	100% thru-wall, full circ.	Assumed 75% flaw shall not exceed design basis flaw size in next inspection interval	WOL + outer 25% of Code DMW Exam Volume	MRP-139/169: (Cat. F) Once in the next 5 years, and then if no growth 100% in subsequent 10 year interval CC N-740-1: Once in the next two RFOs, and then if no growth, a 25% sample population on a 10 year basis
Preemptive – Full Structural	Yes	100% thru-wall, full circ.	Assumed 10% flaw shall not exceed design basis flaw size in next inspection interval	WOL + outer 25% of Code DMW Exam Volume	MRP-139/169: (Cat. B) 100% every interval (10 years) CC N-740-1: A 25% sample population on a 10 year basis
Repair – Optimized	Yes	75% thru-wall, full circ.	Actual observed flaw shall not exceed design basis flaw size in next inspection interval	WOL + outer 50% of Code DMW Exam Volume	*MRP-139/169: (Cat. F) Once in the next 5 years, and then if no growth 100% in subsequent 10 year interval CC N-754: Once in the next two RFOs, and then if no growth, a 25% sample population on a 10 year basis (outer 50%)
Preemptive – Optimized	Yes	75% thru-wall, full circ	Assumed 10% flaw shall not exceed design basis flaw size in next inspection interval	WOL + outer 50% of Code DMW Exam Volume	*MRP-139/169: (Cat. B) 100% every interval (10 years) CC N-754: A 25% sample population on a 10 year basis

* Current MRP-139 requirement is that overlays must be full structural to qualify as Cat. B or F, however, a technical basis statement is being developed to support these categories for optimized overlays (similar to MRP-139, Section 6) and formal "interim guidance" will be issued to reconcile MRP-169/139 until the next revision of MRP-139 is issued

General Question 3 *There may be conflicts between MRP-169 and other MRP reports. Question 3 under "Inspections" illustrates one such example. Sections 4 and 7.1 of MRP-169 contain information that is also in MRP-139, "Primary System Piping Butt Weld Inspection and Evaluation Guideline," which the NRC staff has not been requested to review and approve. Also, MRP-169 may not be consistent with MRP-140, "Leak-Before-Break [LBB] Evaluation for PWR Alloy 82/182 Welds." The NRC staff recommends that additional reviews be performed of these documents for consistency.*

Proposed Response: MRP has performed a consistency review of MRP-169 (in its proposed revised form) with respect to MRP-139 and MRP-140.

An inconsistency currently exists regarding classification of OWOLs due to the fact that the OWOL concept was defined after publication of MRP-139, and therefore was not addressed in it. MRP-139 provides categories for FSWOLs (B if the DMW is inspected and found clean, and F if it is inspected and found cracked prior to WOL application) as well as for DMWs treated by stress improvement (C if the DMW is inspected and found clean, and G if it is inspected and found cracked prior to the stress improvement application). The MRP-139 inspection requirements for these categories are summarized in the following table.

Table 2 – MRP-139 Inspection Requirements for FSWOLs and DMWs treated by Stress Improvement

MRP-139 Inspection Category	Applies to:	Examination Extent and Schedule
B	Inspected, uncracked, reinforced by FSWOL	Existing Code Examination Program or Approved Alternative
C	Inspected, uncracked, mitigated by SI	50% within next 6 years; if clean, then Code program or approved alternative
F	Inspected, cracked, reinforced by FSWOL	Once in next 5 years; if no new indications/growth, then Code program or approved alternative
G	Inspected, cracked, mitigated by SI	100% at 2 RFO intervals. If no new indications/growth after 2 exams then Code program or approved alternative

The following MRP-139 interim guidance and associated technical justification has been proposed to MRP on this topic:

- MRP-139, Category B (not C) is recommended for Alloy 82/182 welds that are inspected in accordance with ASME Section XI, Appendix VIII, prior to OWOL application and found to be free of service-induced defects.
- MRP-139, Category F (not G) is recommended if the weld is found cracked (or a fully qualified inspection is unable to be performed prior to OWOL application) and the OWOL is applied as a repair.

The technical justification for these recommendations is that an OWOL performs not only a stress improvement function, but also provides structural reinforcement with a corrosion resistant material. The assumed design basis flaw size for an OWOL is smaller than for a FSWOL (75% versus 100%), however the post-WOL exam volume and crack growth analysis requirements are adjusted accordingly. The technical justification includes analyses which demonstrate that OWOLs retain structural margin even under the extreme assumption that a PWSCC flaw grows through the entire thickness of the DMW to the overlay (not realistic in view of OWOL design and inspection requirements). This reserve structural margin, which does not exist in the case of stress improvement only, justifies inspection categorization that recognizes both the stress improvement and structural reinforcement attributes of OWOLs.

Cross Reference to MRP-169, Rev. 1

No specific changes are required to MRP-169 to address this issue, since changes to MRP-139 have been proposed that will correct the inconsistency. However, the inconsistency and the proposed MRP-139 action are addressed in a footnote to new Table 4-1.

MRP-140 did not specifically address weld overlays, and thus there are no major inconsistencies between it and MRP-169. MRP-169, Rev. 0 provides some specific requirements for LBB to remain applicable to PWSCC susceptible welds that have been mitigated by pre-emptive weld overlays (FSWOLs or OWOLs). However, the current technical basis for regulatory approval of LBB applications does not provide a path for approval of components with active degradation mechanisms such as PWSCC. Efforts are underway within the NRC and EPRI to develop the tools necessary to evaluate the probability of pipe rupture and to define LBB evaluation criteria for welds susceptible to PWSCC. Pending completion of that effort, discussion of LBB requirements and examples in MRP-169, Rev. 1 will be modified to simply state that "plants applying structural weld overlays (FSWOL or OWOL) to current LBB locations should update the original LBB calculations with an evaluation demonstrating that due to the efficacy of the overlay for PWSCC mitigation, concerns for original weld susceptibility to cracking have been resolved."

Existing Section 4-5 has been revised to wording that references the joint EPRI /NRC project to develop a more robust technical basis for LBB and provides interim guidance regarding treatment of the LBB analysis associated with DM weld locations to be mitigated by WOL. In addition, the LBB example problem (Section 8.5) will be eliminated in its entirety. References to LBB analyses were also deleted in several other sections (Abstract, 2.0 Purpose, and 9.0 Conclusions)

General Question 4 *There appears to be a number of differences between MRP-169 and the corresponding draft code case for PWOLs. For example, the draft code case does not provide a maximum residual stress value for the design. Also, the draft code case does not indicate that if a qualified examination cannot be performed immediately prior to the WOL, the WOL should be assumed to be a full structural examination. Please provide a crosswalk of the design and inspection requirements in MRP-169 and the draft code case and discuss any plans to make these two documents consistent, including a revision of MRP-169.*

Proposed Response: Table 1 provides a summary of the design basis flaw assumptions and crack growth analysis requirements in MRP-169. These are consistent with Code Case N-740-1 for full structural overlays, and presumably with what the requirements will be for optimized overlays when draft Code Case N-754 is eventually published. Although there are no substantive differences in the design and analysis requirements between MRP-169 and the respective Code Cases, MRP-169 provides additional guidance in areas not addressed by the Code Cases, including residual stress analyses and acceptance criteria, fatigue and fatigue crack growth analyses. There are also differences in the future inservice inspection schedules between MRP-169 and the respective Code Cases which are summarized in the last column of Table 1. These are discussed further under Inspection Question 3 below.

MRP will endeavor to promote consistency between MRP-169 and future drafts of related ASME Code Cases. However, Code Committees are consensus bodies, and the MRP cannot guarantee that the versions of the Code Cases that are eventually issued will be entirely consistent with the MRP guidance in MRP-139/169.

Cross Reference to MRP-169, Rev. 1

No specific changes are required to MRP-169 to address the differences in future inspection requirements relative to the Code Cases, since MRP-169 is considered more conservative than the Code Cases in this regard. However, the differences are summarized in the new Table 4-1.

Inspection Questions

Inspection Question 1: *Page 4-2 in Section 4.1 on Weld Overlay Sizing indicates that, "For an optimized structural PWOL,...[t]he pipe will have been inspected, and found to exhibit no evidence of cracking, so there is a high level of assurance that no flaws greater than 10% of the wall thickness exist in the original weld." This wording is not clear as to whether the inspections for an optimized structural PWOL has to be performed immediately prior to the application of the WOL. However, on Pages 7-2 and 7-3 it appears that if a qualified inspection is not performed immediately prior to the application of the PWOL, the weldment must be assumed to be cracked and the WOL repair will be full structural, not optimized structural. Please verify whether the above statement is correct. In other words, please clarify (if possible in both sections of the report) that if a American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (Code), Section XI, Appendix VIII, inspection is not performed immediately prior to the application of the PWOL, the WOL must be full structural, not optimized structural.*

Proposed Response: MRP-169 will be revised to clearly state that a qualified inspection in accordance with ASME Section XI, Appendix VIII, is required immediately prior to application of an OWOL. It will also state that an optimized weld overlay may be used either preemptively or as a repair for observed flaw indications up to 50% through wall, as long as the crack growth analysis demonstrates that the observed flaw would not violate the OWOL design basis in the normal ASME Section XI inspection interval of ten years.

However, there are cases in which the original DMW configuration does not permit full coverage of the pre-overlay exam volume by qualified techniques (i.e. due to cast stainless steel or geometric limitations), or where flaw indications greater than 50% (but less than 75%) through-wall may be detected. MRP-169, Rev. 1 will state that an OWOL may still be applied in such situations, subject to a plant-specific, nozzle-specific technical justification.

Cross Reference to MRP-169, Rev. 1

Section 4.1 has been revised to specifically state that for an OWOL: "The pipe will have been inspected immediately prior to the overlay application, using an inspection technique qualified in accordance with ASME Section XI, Appendix VIII" This paragraph is now consistent with Section 7. Section 4.1 also now allows that OWOLs may be used for repairs of flaws up to 50% through the original pipe wall. Finally, a paragraph has been added stating that OWOLs may be used in the event that the original DMW configuration does not permit full coverage of the pre-overlay exam volume by qualified techniques or where flaw indications greater than 50% (but less than 75%) through-wall are detected, subject to a plant-specific, nozzle-specific technical justification.

Inspection Question 2: *On Page 4-2 in Section 4.1, the ASME Code Case N-504-2 is mentioned. This ASME Code Case lists calculations to be completed under g(1), (2), and (3). Additionally, Page 4-3 states that a joint-specific, overlay-specific weld residual stress analysis is required for each unique PWOL configuration. It has come to the NRC staff's attention that the ASME Code Case N-504-2 analyses are not being completed by the licensees prior to startup. Please discuss what calculations need to be completed for a PWOL prior to startup or provide a technical justification for any calculations not performed until a specified time has elapsed after startup.*

Proposed Response: The structural sizing calculations sufficiently define the design of a weld overlay repair for the purposes of structural integrity and thus safety for plant startup and some short period of plant operation. The remaining calculations (residual stress, crack growth and Section III fatigue analysis) are only to substantiate the life of the design. The time needed to complete these calculations should be decided by utility and approved by NRC. Technically, there is no difference between an emergent (repair) overlay versus a planned (preemptive) overlay on this timing issue. Traditionally, these should be completed within one month of return to power for repair overlay. This timing has been regularly accepted by NRC for repair overlays, performed on an emergent basis, of DMWs in which cracks were discovered during an outage.

Cross Reference to MRP-169, Rev. 1
No specific changes are proposed to address this question.

Inspection Question 3: *In Section 4.4, the last sentence in the section on Fatigue Crack Growth on Page 4-6 states that, "PWOL examinations may not be eliminated or reduced as a result of Risk-Informed [inservice inspection] ISI considerations." Section 7.2 on Inspection Interval and Sample Size for PWOLs indicates that if qualified examinations are performed prior to application of the PWOL and such ISI demonstrates the weld to be absent of any flaws or crack-like indications, future ISI of the welds shall be performed in accordance with the current requirements of Section XI of the ASME Code. This paragraph goes on to say that, "This requirement is consistent with MRP-139 Category B, except that it is independent of whether the PWOL is a full structural or optimized structural overlay." MRP-139, Category B inspections are the existing ASME Code examination program or approved alternative. The staff understands "approved alternatives" to mean alternatives to ASME Code requirements which the NRC has previously approved. Approved alternatives may include risk-informed ISI programs. Risk-informed ISI may lead to certain dissimilar metal (DM) welds never being inspected after the post-mitigated inspection. Please clarify this potential conflict between MRP-169 and MRP-139.*

Proposed Response: As indicated in the response to Inspection Question 1 above, the inspection requirement noted for an optimized weld overlay with a clean pre-inspection is acknowledged as inconsistent with MRP-139 on the subject of subsequent inspection requirements for OWOLs. Interim guidance and associated technical justification have been developed to make MRP-139 consistent with MRP-169 in this regard. We understand that there is also an inconsistency here with respect to Code Case N-740-1, which permits overlays, under some circumstances, to "be placed into a population to be examined on a sample basis. Twenty-five percent of this population shall be examined once every 10 years." MRP-169 will require 100% inspection of the population of weld overlays to be inspected every ten years, and is thus more conservative than the Code Case in this regard.

However, upon reconsideration, MRP would like to retain the option of applying an "approved alternative" (i.e. RI-ISI) to weld overlaid PWR DMWs at some time in the future, pending sufficient experience and technical justification. If this option is pursued, it will be documented in a generic technical justification (similar to BWRVIP-75), and individual RI-ISI updates will explicitly identify any reduction in inspections of weld overlaid DMWs.

Cross Reference to MRP-169, Rev. 1

The sentence disallowing RI-ISI has been deleted from Section 4.4, and additional guidance on the subject has been added in Section 7.3, stating that, at some future time, after inservice inspections have demonstrated successful operating experience with PWR overlays, additional inspection relief may be provided, as was done for BWR overlays in BWRVIP-75.

Inspection Question 4: *In Section 4-4, the discussion of ASME intervals and "that interval" for allowable flaw sizes on Page 4-6 is confusing. Please provide a few examples for subsequent ISIs using the criteria you discuss.*

Proposed Response: The wording of Section 4-4 will be changed for added clarity.

Cross Reference to MRP-169, Rev. 1

The wording in Section 4.4 regarding subsequent inspection intervals has been revised for clarity, and an example, based on new Figure 4-1 is discussed.

Inspection Question 5: *The fourth paragraph in Section 7.1 discusses construction examination of a WOL on piping that is normally examined from the inside surface for ISI. The construction examination is the overlay volume. The criterion is silent on examination of the heat affected zone. Provide an explanation for excluding the heat affected zone from the examination of the WOL. The same paragraph is silent on performing examination from the inside surface prior to applying the WOL. If a crack is located on the inside surface, how effective would depth sizing be after applying the WOL. Discuss why an examination prior to applying the WOL is or is not necessary. Discuss the monitoring of an inside surface crack from the inside surface at a location with an outside surface WOL.*

Proposed Response: The required exam volume for the acceptance (construction) examination of the overlay includes the entire weld overlay (except for the tapered end regions) and the associated HAZ. This inspection is performed from the OD of the overlay regardless of whether pre-and post-overlay inservice inspections are performed from the ID or OD. Section 7.1 and Figure 7-1 of MRP-169 will be clarified on these points.

If ISI examinations are performed from the inside surface, the application of the overlay will not require changes to previously qualified examination procedures. However, some additional qualification may be required to demonstrate that ID connected flaws are still detectable after application of the overlay and associated compressive stresses. The weld overlay mockups discussed in Inspection Question 6 below will be available for such qualification, and will contain flaws of various depths, installed prior to application of the weld overlays.

It is possible that some very shallow ID flaws may not be able to be detected after they are put in compression by the overlay, but if they grow outside of the compressive region, ID examinations will be able to readily detect and size them. Current sizing procedures for examination of DMWs from the ID are not limited to the inner 1/3 of the DMW thickness, but are qualified for the entire DMW thickness.

Cross Reference to MRP-169, Rev. 1

The wording in Sections 7.1 regarding inside surface inspections has been revised to indicate that the WOL acceptance exam must still be performed from the OD and that some additional qualification of the ID technique is required for post-overlay exams. Also, revised Figure 7-1 now indicates that the required exam volume for the overlay acceptance exam includes the HAZ under the WOL.

Inspection Question 6: *The last paragraph in Section 7.1 states that procedures, equipment, and personnel will be qualified for examinations of WOLs in accordance with Appendix VIII of the ASME Code, as amended in Section 50.55a of Title 10 of the Code of Federal Regulations. The ASME Code, Appendix VIII, Supplement 11 qualifications apply to full structural WOL of austenitic piping (WOL thickness plus 25 percent of through-wall (T-W) base metal thickness). For the optimized WOL, the minimum percent T-W inspection volume is the WOL plus base metal necessary for structural integrity including consideration for flaw growth up to the design basis flaw depth plus a 25 percent T-W tolerance. Therefore, the minimum percent T-W inspection volume is a variable and may require inspecting 50 percent T-W of the base metal. For an optimized WOL, discuss the performance demonstration qualifications for similar configurations (same diameter pipe-to-pipe), dissimilar configurations (different diameter pipe-to-flange or nozzle), DM welds, and cast austenitic piping.*

Proposed Response: Criteria and mockup samples are being developed in order to qualify procedures and personnel to examine the required expanded volume for optimized overlays (i.e., the overlay plus outer 50% of original weldment). A demonstration mockup currently exists of a typical surge nozzle weld overlay with ID defects installed at depths ranging from 10% to 75% through the original DMW wall thickness. These defects were installed using standard PDI techniques to simulate service induced flaws, prior to application of the weld overlay, so that any crack closure effects that may occur due to weld overlay compressive stresses are present in the mockup.

A large diameter qualification sample (36 inches) is currently being fabricated using similar flaw depths and fabrication procedures, and has a nozzle configuration representative of an RPV hot leg nozzle, (including different diameter pipe-to-nozzle, DM weld, and cast austenitic safe-end). This mockup will be available for PDI qualification of post-overlay inspection procedures and personnel (from either ID or OD) including the expanded exam volume for optimized overlays.

Cross Reference to MRP-169, Rev. 1

No changes to MRP-169 are required to address this issue. The requirement to perform PDI-qualified inspections of the expanded OWOL exam volume is clearly stated, and it is incumbent on the industry to have qualification criteria and mockups in place in a timeframe consistent with upcoming OWOL applications.

Inspection Question 7: *Section 7.2.1 states that if an ISI examination immediately prior to a full structural or optimized WOL that is absent of any flaws or crack-like indications, then future ISI of the WOL shall be performed in accordance with requirements of Section XI of the ASME Code. What are the specific ASME Code, Section XI non-destructive examination (NDE) methods and volume and/or surface examination requirements? Do the examination requirements of Section XI, Appendix Q of the ASME Code apply?*

Proposed Response: The future ISI coverage requirement include a volume inclusive of ½" from each DM weld toe and from the surface of the weld overlay and to a depth of 25% or 50% (as applicable) of the original base material/weld thickness and the inspections must be qualified in accordance with ASME Section XI, Appendix VIII, as discussed in response to Inspection Question 6 above. A figure will be added to MRP-169 to depict post overlay exam volumes for acceptance examinations as well as PSI/ISI examinations of FSWOLs and OWOLs. ASME Section XI, Appendix Q, as well as Code Case N-460 coverage requirements apply to overlay pre- and inservice inspections.

Cross Reference to MRP-169, Rev. 1

Figure 7-1 has been modified to specifically identify the required inspections and exam volumes for post overlay inspection, including the acceptance examination, and pre- and inservice inspections. The wording in Section 7.1 has also been expanded to specify that ASME Section XI, Appendix Q as well as Code Case N-460 coverage requirements apply to overlay pre- and inservice inspections.

Inspection Question 8: *Section 7.2.2 states that if no ISI examination is performed immediately prior to a full structural WOL, or crack-like indications are detected, then the weld must be assumed cracked. Discuss the application of the requirements of Section XI, Appendix Q of the ASME Code and explain the differences between Appendix Q and the referenced, MRP-139, Category F, examination frequency, examination methods, and examination volume.*

Proposed Response: The requirements of Section XI, Appendix Q, regarding examination methods and examination volume are consistent with those included in MRP-139 Category F and thus with MRP-169. MRP-139 (and MRP-169) differ with Appendix Q only on the subject of examination frequency, which as itemized in Table 1, are as follows:

1. The first subsequent inspection for Category F welds in MRP-139/169 is all welds once in the next 5 years, and then if no growth, 100% are inspected in each successive 10 year interval
2. The first subsequent inspection for cracked, overlaid welds in Appendix Q is all welds once within the next two RFOs, and then if no growth, a 25% sample population is inspected on a 10 year basis.

MRP 139/169 are considered more conservative than Appendix Q in this regard, because the difference in the first inspection schedule (5 years versus 2 RFOs (i.e. 3 to 4 years)) is insignificant compared to the subsequent inspection requirement of 100% versus a 25% sample.

Cross Reference to MRP-169, Rev. 1

No specific changes are proposed to address this issue.

Leak-Before-Break Questions

LBB Question 1: *Section 4.5 indicates that, "Prior to performing the PWOL, a qualified examination of the weld and adjacent base material must be performed to show that no cracking is present." Not all welds previously approved for LBB by the NRC can be inspected by a qualified examination. For example, qualified procedures have not been developed for examination of DM welds between cast austenitic components and ferritic components. How does MRP-169 address the issues discussed in Section 4.5 for these types of welds?*

Proposed Response: We recognize that some DMWs have been approved for LBB that cannot be inspected by a qualified examination and others may inspect and find some cracking. Certainly, applying a WOL to these components (full structural or optimized) and the subsequent NDE can only improve the situation. A key feature of weld overlays is that they improve inspection coverage (relative to the required post-overlay exam volume), in addition to their residual stress improvement and structural reinforcement benefits.

As previously discussed under General Question 2, a new NRC/EPRI program is underway to define LBB criteria for welds susceptible to PWSCC and to develop the tools necessary to evaluate the probability of pipe rupture in systems with active degradation mechanisms. In the interim, pending results of that effort, discussion of LBB requirements in MRP-169, Rev. 1 will be modified to simply state that "plants applying structural weld overlays (FSWOL or OWOL) to current LBB locations should demonstrate the efficacy of the overlay to mitigate PWSCC concerns for original weld susceptibility to cracking."

Cross Reference to MRP-169, Rev. 1

Existing Section 4-5 has been revised to wording that references the joint EPRI /NRC project to develop a more robust technical basis for LBB and provides interim guidance regarding treatment of the LBB analysis associated with DM weld locations to be mitigated by WOL. In addition, the LBB example problem (Section 8.5) will be eliminated in its entirety. References to LBB analyses were also deleted in several other sections (Abstract, 2.0 Purpose, and 9.0 Conclusions)

LBB Question 2: *The application of a PWOL would alter the piping configuration assumed in the LBB critical flaw size and leakage crack size analyses. Section 4.5 is not clear that for PWOLs these LBB analyses need to be performed and verified to satisfy the specified margins in draft Standard Review Plan 3.6.3. Please clarify in both the RAI response and a revision to MRP-169 that these analyses need to be performed for the PWOLs applied to welds in piping systems that were approved for LBB.*

Proposed Response: As previously discussed, pending results of the joint NRC/EPRI program on LBB for welds susceptible to PWSCC, the discussion of LBB in MRP-169 will be revised to the above, agreed-upon wording.

Cross Reference to MRP-169, Rev. 1
Same as for Question LBB 1 above.

Fatigue Questions

Fatigue Question 1: *In Section 4.4, provide the basis for postulating the existing CUF=0.2 as a threshold for not requiring a fatigue analysis per Section III NB-2300 of the ASME Code, since the existing CUF is based on the simplified rules of the ASME Code, Section III NB-3600, which are not applicable to WOL regions. The NRC staff also believes that the appropriate NB-3200 fatigue analysis should be based on the licensing basis design transients, and not on an alternate, less severe, set of design transients.*

Proposed Response: The basis for 0.2 was primarily engineering judgment. MRP-169 also imposes the additional restriction (for not performing a fatigue analysis) that there be no severe thermal transients at the location, beyond normal plant startups and shutdowns. As with the license renewal process, overlay fatigue analyses can be performed with a basis less conservative than the original design basis transient set, so long as the assumptions regarding transients to date can be substantiated by plant records, and assumed future transients are tracked as part of the plant's design basis.

MRP-169 will clarify that some aspects of post-overlay fatigue analyses are performed in accordance with NB-3600, i.e., on the piping side of the overlay; while NB-3200 criteria are applicable for the nozzle side of the weld overlay repair.

Cross Reference to MRP-169, Rev. 1
Section 4.4 was modified to state specific Code paragraphs applicable to the fatigue usage evaluation.

Fatigue Question 2: *Relative to Section 4.4, the NRC staff notes that for those plants that have been approved for license renewal or are considering license renewal application, the license renewal period extends plant life to 60 years. Discuss the time period considered for end of life of the PWOL as evaluated for fatigue crack growth.*

Proposed Response: The required time period for fatigue crack growth (as well as PWSCC crack growth) analysis in MRP-169 is to the end of the next ASME Section XI inspection interval (ten years). A plant may optionally utilize an analysis period to the end of plant life, in which case the license renewal period should be included.

Cross Reference to MRP-169, Rev. 1
Section 4.4 was modified to specifically require inclusion of the license renewal period for FCG analyses that utilize an analysis period to the end of plant life.

Weld Overlay Effectiveness Questions

WOL Effectiveness Question 1: *Section 5.1 on Page 5-4 discusses the "MRP/EPRI PWOL Development Program for Alloy 600 [primary water stress corrosion cracking] PWSCC Mitigation." This section indicates that the program is on-going and that the analysis results are preliminary. Please provide the status of this program and the final results.*

Proposed Response: The final residual stress analysis and measurement results from the PWOL mock-up are available and will be added to the revision of MRP-169. Additional details of the mockup program are documented in MRP-208 (to be published) which will be referenced. Copies of MRP-208 can be provided to the NRC staff, when published, with appropriate proprietary information caveats by EPRI.

Cross Reference to MRP-169, Rev. 1

Section 5.1 (5) was completely re-written and Figures 5-12 thru 5-15 added summarizing the results of the PWOL mockup program.

WOL Effectiveness Question 2: *Section 5.2 on Analytical Programs discusses the effects of WOL without water backing. Given the rapid cooling with relatively thin water backed components, is the temper bead technique always used for WOLs?*

Proposed Response: Weld overlays may be applied with or without water backing, and with or without temperbead welding procedures, depending on the specific nozzle location, nozzle geometry and Code PWHT requirements. Whatever procedure is used, MRP-169, Section 4.2 requires a nozzle-specific residual stress analysis that reflects the actual geometry and conditions under which the overlay welding is performed.

Cross Reference to MRP-169, Rev. 1

No specific changes are proposed to address this issue

WOL Effectiveness Question 3: *A premise of the PWOL design is that the overlay will induce compressive stress in the inside diameter region of the pipe so that PWSCC flaws will not initiate or a small existing PWSCC flaw would not propagate. Discuss the potential adverse impact of a PWOL on a weld with a subsurface flaw considering that the crack tip may experience the tensile component of the T-W stress gradient.*

Proposed Response: Crack growth analysis is required (Section 4.2) for the specific geometry to which the weld overlay is applied with input from the configuration-specific residual stress analysis. The cracktip stress intensity factor (K) is determined, which is a function of the stresses (operational plus residual) integrated over the entire crack face and must be shown to be negative for crack depths up to the applicable overlay design and inspection requirement (i.e. 50% thru-wall for OWOLs, or 75% through-wall for FSWOLs). Then the complementary region (the outer 50% or 25% of the base material, as appropriate) is inspected to demonstrate it to be crack-free. These combined requirements assure that flaws (surface or subsurface) will not grow to a depth that would violate the overlay design basis. In addition the overlays are installed using materials that have been shown to be highly resistant to crack propagation due to PWSCC, adding yet another layer of protection.

Cross Reference to MRP-169, Rev. 1

Specific requirements for the PWSCC crack growth analysis have been added to Section 4.2.

Stress Analysis Questions

Stress Analysis Question 1: *Section 4.2 discusses residual stress improvement and indicates that, "the resulting inside surface stresses, after application of operating pressure and loads must be less than 10 ksi tensile. This target stress level has been selected as a conservatively safe value, below which PWSCC initiation, or growth of small initiated cracks, is unlikely." This criterion appears to be based on the presence of only small preexisting cracks. However, if preexisting cracks extend into a tensile stress region of the original weld, crack propagation may continue to occur. Please justify the appropriateness of this criterion given that MRP-169 indicates that PWOLs may be used without performing examinations prior to application of the WOL and given that the probability of detection even for relatively deep flaws is less than 1.*

Proposed Response: The 10 ksi maximum tensile stress criterion provides protection against new PWSCC initiation. Laboratory data and field observations have shown that high stresses, on the order of the material yield strength, are necessary to initiate PWSCC. Limiting ID surface stress levels less than 10 ksi ensures a very low probability of initiating new PWSCC cracks after application of the weld overlay.

MRP-169 also imposes crack growth criteria (PWSCC and FCG) which, in conjunction with the required pre- and post-overlay inspections, provide protection against propagation of pre-existing cracks that would violate the overlay design basis. Also note that, because of the nature of the fracture mechanics calculations, in which the cracktip stress intensity factor (K) is a function of the stresses integrated over the entire crack surface, the K for a postulated crack in an overlaid weld typically remains compressive (no crack growth) for cracks that extend into the tensile stress region of the post-overlay stress field. Other safety factors are present in the ASME Section XI flaw evaluation rules to address (among other things) the probability of non-detection of NDE techniques. The effect of a probability of detection less than 1 is no different for weld overlays than for any other Section XI flaw evaluation or for any other PWSCC mitigation approach.

Cross Reference to MRP-169, Rev. 1

The requirements for PWSCC crack growth analysis are expanded and clarified in Section 4.2, and together with the 10 ksi surface stress limit, constitute an integral part of the acceptance criteria for post-overly residual stresses.

Stress Analysis Question 2: *Section 4.2 discusses overlay specific weld residual stress analysis and states that these analyses are required for each unique PWOL configuration. This section also notes that most boiling water reactor pipe WOLs did not require weld specific residual stress analyses since the geometric configurations* *were fairly standard. Please provide the criteria that will be used to determine whether or not weld specific residual stress analyses will be performed.*

Proposed Response: Criteria will be added to MRP-169 clarifying when overlay specific residual stress analyses are required. The proposed criteria are that, for any significant geometry, material, or welding process differences from a previously analyzed overlay, beyond standard drawing/fabrication tolerances, nozzle specific residual stress analyses should be performed.

Cross Reference to MRP-169, Rev. 1

Wording has been added to Section 4.2 defining criteria for when an overlay-specific weld residual stress analysis is required.

Stress Analysis Question 3: *Page 4-4 in Section 4-2 indicates that the resultant stresses on the inner diameter (ID), after the application of operating pressures and loads, must be less than 10 ksi tensile. Page 4-3 indicates that, "to adequately demonstrate the favorable residual stress effects of a WOL, one must start with a highly unfavorable, pre-overlay residual stress." Describe how the pre-overlay residual stress will be determined. How will the repair history (or lack of information on the repair history) be taken into account in the stress analysis used to determine the post-overlay stress profile?*

Proposed Response: The example problems in Section 8 of MRP-169 utilize a very conservative starting assumption of a 360° ID repair that is 50% through-wall. This flaw assumption was demonstrated by analysis and measurements on the PWOL mockup (based on a 90° arc repair) to yield very high, tensile residual stresses prior to application of the weld overlay, as discussed above under WOL effectiveness question 1 and new report section 5.1 (5)) . This repair assumption and the resulting residual stresses conservatively bound any repairs that may have been made during plant construction. It is the recommended starting point for residual stress analyses performed in accordance with MRP-169.

Cross Reference to MRP-169, Rev. 1

No specific changes are proposed to address this issue.

Stress Analysis Question 4: *Figures 5-11 and 5-12 show the residual hoop and axial stress distributions for the PWOL mockup. After application of the PWOL, the residual hoop and axial stresses in the WOL appear to be mostly compression. In addition, prior to the application of the PWOL, the figures indicate high tensile hoop and axial stresses that may be beyond the ultimate stresses of the materials. After application of the PWOL, the high tensile regions in the nozzles become compressive, but the compressive regions appear to remain compressive. The stresses in the WOL* *are also shown mostly as compressive. Figures 8-8 and 8-9 show the residual stress distribution for a pressurizer spray nozzle, which appears to be similar to the mock-up geometry. The stress distributions are different from those of the mock-up nozzle. Likewise, the T-W stresses shown in Figures 8-11, 8-13 and 8-15 tend to be tensile towards the outer surface, as expected.*

Proposed Response: The PWOL mockup stress analysis results presented in MRP-169, Rev. 0 were identified as preliminary. Final analysis results along with residual stress measurements on the mockup are reported in MRP-208, and will be included in MRP-169, Rev. 1. The post-overlay axial residual stresses for the PWOL mockup show the expected pattern of compression on the ID of the original weld, transitioning to tension near the OD of the original weld and in the overlay itself.

4.a) Provide a discussion why the stress distributions in the mock-up PWOL are different from those of the nozzle PWOLs in Section 8.

Proposed Response(4a): The PWOL mockup actually more closely simulates a surge nozzle than a pressurizer spray nozzle. The spray nozzle is smaller in diameter and is relatively thicker (smaller radius to thickness ratio). The post-overlay residual stresses for the mockup in Section 5 and the surge nozzle example in Section 8 do not differ significantly, when compared under like conditions.

Note that the residual stresses for the PWOL mockup in Section 5 were reported at room temperature, since their purpose is a comparison to residual stress measurements which were performed on the mockup at room temperature. The stresses for the example nozzles in Section 8 were reported at operating temperature (650°F) and also included operating stresses (pressure plus thermal expansion). Because of the differential thermal expansion effects of the various materials involved, this can result in differences in the post-overlay stress distributions at different temperatures.

Appendix A to this response provides contour plots of axial and hoop post-overlay residual stresses at 70°F for the surge nozzle example of Section 8 and the PWOL mockup of Section 5. Careful examination of these plots indicates that the residual stress distributions for the two are quite similar, when compared under like conditions.

Cross Reference to MRP-169, Rev. 1

No specific changes are proposed to address this issue.

4.b) Provide a table showing the material properties used in the finite element analyses in Section 5 and Section 8.

Proposed Response (4b): Tables of temperature-dependent materials properties used in the residual stress calculations are provided in Appendix B to this response.

Cross Reference to MRP-169, Rev. 1
No specific changes are proposed to address this issue.

Stress Analysis Question 5: In Table 8-5, identify the acronyms HLST, HHST, CLST, and CHST.

Proposed Response: Acronyms will be spelled out in revision to MRP-169, as follows: HLST = Heatup Low Pressure Stratification, HHST = Heatup High Pressure Stratification, CLST = Cooldown Low Pressure Stratification, CHST = Cooldown High Pressure Stratification.

Cross Reference to MRP-169, Rev. 1
Footnote will be added to Table 8-5 defining acronyms.

Stress Analysis Question 6: *Draft ASME Code Cases related to WOLs contain a requirement to evaluate the effects of any changes in applied loads, as a result of weld shrinkage from the entire overlay, on other items in the piping system (e.g., support loads and clearances, nozzle loads, and changes in system flexibility and weight due to the WOL). MRP-169 does not appear to address these conditions. Please address this comment.*

Proposed Response: Analysis requirements similar to those contained in the draft ASME Code Cases will be added to the revision to MRP-169.

Cross Reference to MRP-169, Rev. 1
New section 4.6 has been added addressing these requirements.

Example Analysis

Example Analysis Question 1: *Page 8-5 indicates that, "The final spray nozzle overlay dimensions that produce these results are a WOL thickness of 0.3" and a WOL length of ~7.2", making this effectively a full structural overlay as defined in Table 8-3, ..." As stated in Section 4.1, PWOL thickness is calculated based on the ASME Code maximum flaw depth considerations, IWB-3641 allowable flaw size considerations, and residual stress considerations. Clarify what aspect(s) of this analysis yielded a full structural WOL versus an optimized WOL result.*

Proposed Response: IWB-3641 allowable flaw size evaluations (aka: structural sizing calculations) were performed for each of the example nozzles in Section 8, considering the appropriate design basis flaw size assumption (100% thru-wall for FSWOL and 75% thru-wall for OWOL) and a typical set of applied nozzle loads. This led to the required design thicknesses for full structural and optimized overlays listed in Table 8-3. However, in some cases, residual stress and inspectability considerations interceded, and required greater overlay lengths and thicknesses than the minimums required by the structural sizing calculations. These are tabulated in Table 8-4. For the spray and surge nozzle examples, these considerations produced overlay dimensions that were greater than the minimums required by the structural sizing calculations for OWOLs, and resulted in minimum overlay designs that were essentially the same as those for FSWOLs on these nozzles.

Cross Reference to MRP-169, Rev. 1

No specific changes are proposed to address this issue.

Clarifications

1. *Please clarify the word "consider" in the following statement on Page 4-9: "[I]n meeting the leakage rate requirements, one must consider the potential for more flow resistance through a PWSCC crack morphology."*

Proposed Response: As previously discussed, a new NRC/MRP program is underway to define LBB criteria for welds susceptible to PWSCC and to develop the tools necessary to evaluate the probability of pipe rupture with active degradation mechanisms. In the interim, pending results of that program, the discussion of LBB has been totally revised, as discussed in LBB Questions 1 and 2.

Cross Reference to MRP-169, Rev. 1
Same as for Question LBB 1 above.

2. *The NRC staff has identified the following typographical errors. (a) In the last paragraph in Section 8-1, it appears that Table 8-2 should have been identified as Table 8-3,*
Proposed Response: It *will be* Corrected
(b) References to Tables 8-7 through 8-9 on Pages 8-10 and 8-11 may be incorrect.
Proposed Response: The LBB Section and associated tables have been deleted.

3. *The last "sentence" on Page 4-5 is not a complete sentence. Please clarify.*
Proposed Response: Corrected

4. *As part of the design requirements, the NRC staff requests clarifications regarding how certain parameters may be limitations or conditions, if any, to the application of the PWOL. For example, the following parameters:*

4.a. applicable pipe sizes
4.b. applicable pipe thicknesses
4.c. applicable configurations, e.g., pipe-to-pipe, pipe-to-safe end, pipe to nozzle
4.d. applicable pipe degradation mechanisms
4.e. maximum WOL thickness
4.f. number of times a PWOL can be applied to a location

Proposed Response: Subject to the design and analysis requirements specified in MRP-169, no limitations are envisioned in the above areas on application of PWOLs.

Cross Reference to MRP-169, Rev. 1
No specific changes are proposed to address this issue.

Other Chang to MRP-169, Rev.1

(Not related to RAI Questions)

Fatigue Crack Growth Law MRP-169, Rev. 0 contained a very complex and conservative FCG law taken from a 2001 ANL Report (NUREG/CR-6721, "Effects of Alloy Chemistry, Cold Work, and Water Chemistry on Corrosion Fatigue and Stress Corrosion Cracking of Nickel Alloys and Welds," U.S. Nuclear Regulatory Commission (Argonne National Laboratory), April 2001.) A more recent ANL publication (NUREG/CR-6907, "Crack Growth Rates of Nickel Alloy Welds in a PWR Environment," U.S. Nuclear Regulatory Commission (Argonne National Laboratory), May 2006) published after initial issue of MRP-169 recommended instead that "The (fatigue) CGRs of Alloy 182 in the PWR environment are a factor ~ 5 higher than those of Alloy 600 in air under the same loading conditions." The recommended FCG law and examples will be changed to this recommendation.

Cross Reference to MRP-169, Rev. 1
Environmental Fatigue Crack Growth Law in Section 4.4 and Example FCG Analysis in Section 8.3 were revised to reflect the recommendation of the more recent ANL publication.

Section II: Additional RAIs

Questions from NRC Staff

Question 1: Response to General Question 2. Table 1 (the same as Table 4-1 in MRP-169) summarizes requirements for the design, inspection, and crack growth calculations of the weld overlay (WOL). (a) Discuss whether licensees must follow these requirements or they are guidance that licensees may or may not follow. (b) Discuss whether licensees are allowed to use some but not all requirements (i.e., is cherry picking the requirements allowed?). (3) Licensees have relied on the American society of Mechanical Engineers (ASME) Code Case N-740 in relief requests for NRC approval to install WOLs without using MRP-169. Discuss how MRP-169 will be used in weld overlay relief requests. Discuss how code cases will be sued in conjunction with MRP-169 in performing weld overlay activities.

Proposed Response:

(a) It is anticipated that licensees will commit to performing weld overlays in accordance with MRP-169. Once they do so, the requirements become mandatory.
(b) It is intended that the requirements be met in their entirety. If a licensee plans to not comply with one or more of the requirements, they would have to prepare a relief request, which would be subject to NRC approval.
(c) Installation of the overlays (welding, acceptance examinations, etc.) will be performed in accordance with ASME Code Case N-740-2. MRP-169 addresses design and analysis requirements for preemptive overlays that are generally outside of ASME Code purview.

Question 2: Response to Inspection Question 7. Nuclear Energy Institute (NEI) stated that inservice inspection (ISI) of the weld overlay includes a weld volume of ½ inch from each dissimilar metal weld toe. Figure 7-3 on page 56 shows a sketch of the WOL ISI volume. Figure 7-3 should clarify the ½ inch extension on both sides of the weld toe with a footnote (similar to the footnote in code case N-740-1 or Appendix Q to the ASME Code, Section XI). The footnote should clarify whether butter and heat affected zone, if applicable, will be included in the examination volume.

Proposed Response: The suggested revisions have been made in MRP-169, Rev. 1. (Note: actual Figure number is 7-1.)

Question 3: Stress Analysis Question 1. MRP-169 requires calculations be performed for primary water stress corrosion cracking (PWSCC) and fatigue. Describe the calculation methodology in detail.

Proposed Response: Following is a typical list of calculations that will be prepared for a preemptive weld overlay (OWOL or FSWOL):
A Weld Overlay Structural Sizing

Analyses to establish the minimum overlay dimensions (length and thickness) required to satisfy ASME Section XI, IWB-3640 requirements in the presence of the maximum observed or assumed defect.

B Design Loads for Weld Overlay

A calculation that documents the specific design loads and transients that will be used for the overlay design.

C Finite Element Model of Nozzle with Weld Overlay

A calculation that documents the geometric details of the finite element model(s) to be used in the overlay analyses.

D Thermal and Mechanical Stress Analyses of Nozzle with Weld Overlay

Computes stresses in the nozzle plus weld overlay due to design loads and thermal transients, for use in ASME Code and crack growth evaluations.

E Residual Stress Analysis of Nozzle with Weld Overlay

Nozzle-specific elastic-plastic stress analyses of the nozzle to establish the residual stress distribution after application of the overlay. Severe ID weld repairs are assumed in these analyses that effectively bound any actual weld repairs that may have occurred in the nozzles. The analyses then simulate application of the weld overlays to determine the final residual stress profile.

F Section III Code Evaluation of Nozzle with Weld Overlay

Analyses to demonstrate that application of the weld overlays does not impact the conclusions of the existing nozzle Stress Reports. ASME Code, Section III stress and fatigue criteria will be met for regions of the overlays remote from the observed (or assumed) cracks.

G Crack Growth Evaluation of Nozzle with Weld Overlay

Fracture mechanics analyses performed to predict crack growth, assuming that cracks exist that are equal to or greater than the detected flaw sizes (or the detection thresholds of the applicable NDE, if no flaws are detected). Crack growth is evaluated due to PWSCC as well as due to fatigue crack growth in the original DMW.

H Evaluation of Effects of Weld Overlay on System

Shrinkage stresses at other locations in the piping systems arising from the weld overlays are demonstrated not to have an adverse effect on the systems. Clearances of affected support and restraints are checked after the overlay repair, and reset within the design ranges as required. The total added weight on the piping systems due to the overlays is evaluated for potential impact on piping system stresses and dynamic characteristics.

Question 4:. Section 4.0. NEI revised certain sections of MRP-169, Revision 0, in particular as Section 4, 5, 7, 9 and 10. Please discuss whether any other sections of MRP-169 will be changed as a result of the RAI responses.

Proposed Response: Other sections have been revised as well to address these and previous RAIs. A complete version of MRP-169, Rev. 1, incorporating all changes is included with these responses.

Question 5: On page 33, Section 4.0, NEI states that the minimum WOL thickness is 1/3 of the pipe thickness. (a) Discuss whether there is a limit for the maximum WOL thickness beyond which the WOL will cause detrimental effect on the pipe. Discuss whether this upper bound in WOL thickness will be specified in MRP-169 to avoid over-design of the WOL thickness. (b) The NRC staff has concerns if a WOL is installed on a degraded WOL. Explain the MRP-169 position on the use of WOL for more than one time application to any specific degraded dissimilar metal weld (DMW).

Proposed Response:

(a) There is no general maximum thickness that can be specified for an overlay in MRP-169. However, some of the calculations listed under Question 3 above are adversely affected by excess overlay thickness, and the designer must therefore establish both a maximum and minimum thickness for each specific overlay, and perform his analyses accordingly.

(b) Industry agrees that a WOL should not be applied to repair a WOL that has degraded in service. However, instances may arise in which it is desirable to increase the size of a weld overlay on DMWs for which there is no evidence that the original overlay is ineffective or degraded (e.g. to increase from an OWOL to a FSWOL or to enhance crack propagation life). There is no reason to disallow such an increase, assuming the overlay design calculations are updated accordingly.

Question 6: On page 34, NEI stated that "...There are cases in which the original DMW configuration does not permit full coverage of the pre-overlay exam volume by qualified techniques (i.e. due to cast stainless steel or geometric limitations), or where flaw indications greater than 50% (but less than 75%) through-wall are detected. An optimized weld overlay (OWOL) may still be applied in such situations, subject to a plant-specific, nozzle specific technical justification demonstrating that the observed or postulated worst-case flaw will not violate the OWOL design basis...". Clarify how the OWOL design can be carried out under either of the conditions noted above (i.e., less that complete coverage with a qualified examination or a flaw greater than 50% but less than 75% through wall).

Proposed Response: The intent of this paragraph was to not generically prohibit OWOL applications in such cases, but to allow such special circumstances to be addressed via case-specific technical justification, subject to NRC staff review and approval. One example would be if a flaw is found that is 60% thru-wall. Nozzle-specific analyses may demonstrate that an OWOL (or an overlay that is somewhere between an OWOL and a FSWOL) may effectively meet all of the design and analysis requirements of MRP-169. In the case of CASS material, a post-overlay inspection may be qualified to effectively examine a sufficient portion of the required exam volume such that the missed volume could be addressed via special crack growth analyses. The wording in MRP-169, Rev. 1 has been revised to clarify that technical justifications for such cases are subject to NRC review and approval.

Question 7: On page 34, last sentence, NEI states that the 0.75√Rt recommendation for the axial length of the overlay is only a rule of thumb, and that shorter lengths may be used if justified by stress analysis of the specific preemptive weld overlay (PWOL) configuration, to demonstrate that adequate load transfer and stress attenuation are achieved. In relief requests, the staff would need to review use of shorter lengths than 0.75√Rt and would so state in any safety assessment report on MRP-169. Justify the use of a weld overlay axial length that is shorter than 0.75√Rt.

Proposed Response: Shorter lengths than 0.75√Rt have been used and approved in the past on pressurizer nozzle FSWOL applications. The design and analysis requirements is that there is sufficient shear area to transmit the design loads from the pipe to the overlay and then back into the nozzle without violating applicable ASME Section III stress limits. The overlay length must also provide effective residual stress reversal (per the criteria in MRP-169 Section 4.2) and sufficient length for inspectability of the post overlay PSI/ISI exam volume (per Section 4.3).

Question 8: On page 36, first paragraph, NEI states that if the inside surface stresses are less than 10 ksi tensile, then PWSCC cracks will not be able to initiate. There has not been any evidence of a threshold value of stress intensity factor (K) for PWSCC growth. If we are operating on the basis that there is no threshold value of K for growth, it appears that this may be in contradiction with a premise that cracks can not initiate at stresses less than 10 ksi. Please address the basis for your statement on crack initiation.

Proposed Response: The zero threshold for PWSCC growth in weld metal applies to stress intensity factor, K (ksi√in). The tensile stress limit in MRP-169 applies to ID surface stress (ksi). PWSCC initiation data for both A-600 base metals and A-82/182 weldments indicate that high stresses, greater than 80% of yield strength, are required to initiate PWSCC cracks in these materials [1-3][1]. The 10 ksi limit is very conservative relative to these data. MRP-169, Section 4.2 also imposes a separate PWSCC crack growth requirement that implements the zero stress intensity factor threshold.

Question 9: Section 5.0. Please provide the MRP-208 report.

Proposed Response: NEI has provided MRP-208.

Question 10: Section 7.2 does not appear to have a successive inspection requirement for the case when a new indication or growth of existing indications is observed in either the weld overlay or in the original weld. Code Case N-740-1 provides acceptable inspection strategy for successive examinations. Please address actions to be taken when a new indication or growth of existing indications is observed in either the weld overlay or in the original weld.

[1] Numbers in brackets refer to references listed at the end of these responses.

Proposed Response: Requirements similar to those in Code Case N-740-2 have been added in MRP-169, Rev. 1 Section 7.2. (i.e. If ISI reveals flaw growth into the WOL exam volume, the overlay must be re-examined during first or second RFO following that inspection.)

Question 11: Discuss how users of MPR-169 would inspect cast austenitic stainless steel (CASS) components and how to analyze the CASS components (e.g., postulated flaw size) when the WOL is installed on a CASS component.

Proposed Response: Mockups are being fabricated that include DMWs adjacent to CASS components with and without WOLs. These will be used to develop and qualify UT procedures. The demonstrations will determine the capability of UT techniques to examine the inner 1/3 of DMWs without WOLs and the outer 50% with WOLs. In addition, exam volume coverage requirements have been defined in Section 7.1 which specify that 90% of the required exam volume, but no less than 100% of the PWSCC susceptible material, must be inspectable by PDI qualified exams. The uninspectable CASS material would have to fall within the 90% requirement.

Finally, if the required exam volume coverage cannot be achieved, design of WOLs for such joints will be subject to the case-specific technical justification and NRC staff review and approval, as discussed under Question 6 above.

Question 12: In the recent WOL installations, licensees have been applying a sacrificial layer made of austenitic stainless steel weld metal on the austenitic stainless steel pipe prior to installing the Alloy 52M WOL to prevent potential cracking. Licensees have included this information in their relief requests. Discuss whether this information needs to be included in MRP-169, Revision 1.

Proposed Response: Installation aspects of PWOLs, including an austenitic buffer layer if used, are covered by ASME Code requirements, specifically Code Case N-740-2. The industry does not believe it is necessary to repeat them in MRP-169. In accordance with these requirements, the thickness of these layers shall not be used in meeting weld reinforcement design thickness requirements.

Question 13: The ASME Section XI code cases related to weld overlays (e.g., N-740) provide requirements in the following areas that may not be addressed in MRP-169 to the same level of detail: (a) acceptance, preservice, and inservice examinations of the weld overlay, (b) crack growth calculations, (c) identification of applicable base and weld metal, (d) acceptance criteria for laminar flaws in the weld overlay, and (e) allowable Chromium content in the weld overlay. Please address how the requirements in these areas are addressed by MRP-169 or a user of MRP-169.

Proposed Response: MRP169 should be used in combination with related ASME Code requirements (Code Case N-740-2) for installation of the overlays. Of the items identified in this question, (a) preservice and inservice examinations and (b) crack growth calculations are covered by MRP-169. The remaining items: (c), (d) and (e), as well as the overlay acceptance exam in (a), are installation related and therefore fall under the purview of Code Case N-740-2.

Question 14: For full structural WOL repair without pre-WOL inspection as shown in Table 4-1, MRP-169 states that for crack growth calculation, the assumed 75% flaw shall not exceed the design basis flaw size in next inspection interval. In its relief request reviews, the staff has asked licensees to address a larger initial crack should a flaw be detected in the outer 25% region of the pipe wall. That is, if a flaw is detected in the outer 25% pipe thickness region, the as-found flaw should be added to the assumed 75% through wall flaw in the crack growth calculation. Discuss how MRP-169 addresses the initial flaw size when the post overlay inspection identifies a flaw in the outer 25% of the original pipe wall.

Proposed Response: If a flaw is detected in a pre- or post-overlay inspection that is greater than the standard flaw sizes assumed for crack growth in the overlay calculations (50% or 75% through wall), then the calculations must address that larger flaw. Sections 4.2 and 4.4 have been revised to clarify this requirement.

Question 15: MRP-169 states that the required examination volume for the OWOL includes the weld overlay thickness and outer 50% of the pipe thickness. However, the ASME Code, Section XI, Appendix VIII has not issued a supplement to address the inspection of OWOL, i.e., weld overlay thickness and the outer 50% pipe wall. Please address how the level of inspection qualification for OWOL equivalent to full structural weld overlays (FSWOLs) is to be demonstrated and implemented through ASME or other requirements.

Proposed Response: A PDI mockup of a large diameter DMW with OWOL and FSWOL has been fabricated and will be available for procedure and personnel qualification under the PDI program for extended volume inspections, including the outer 50% of the DMW. The PDI qualification process will include test specimen requirements, conduct of demonstrations and acceptance criteria similar to those in ASME Code, Section XI, Appendix VIII, Supplement 11, and will be used until such a time as an Appendix VIII supplement addressing OWOLs is available.

Question 16: The Proposed Response to Inspection Question 7 notes that Code Case N-460 coverage requirements apply to overlay preservice and inservice inspections. Code Case N-460 was not written to address the situation where an active degradation mechanism exists and where the results of the inspection are to be relied upon for design and flaw evaluation. The staff does not agree to this limitation in N-460 in the context of weld overlay relief requests.

Proposed Response: NEI was unaware of any such restriction on the applicability of Code Case N-460. However, as agreed to in the Feb. 21, 2008 meeting, reference to Code Case N-460 has been deleted and exam volume coverage requirements specific to weld overlays have been added in Section 7.2. These state that:

- for the initial overlay acceptance examination, 100% of the required UT and PT exam volumes shall be examined, and
- for post-overlay pre- and inservice inspections, essentially 100% (>90%) of the required exam volume shall be examined, but shall include no less than 100% of any PWSCC susceptible material within the exam volume.

Question 17: Table 1 on page 2 of the response uses the expression, "WOL + outer 25% of Code DMW exam volume." The staff understands that the aforementioned requirement is based on the examination figures on page 56. However, the DMW examination volume per ASME Code, Section XI does not include the outer 25% of the examination volume. Please correct this discrepancy.

Proposed Response: Table 4-1 in MRP-169 Rev. 1 has been revised to clarify the exam volume requirement via reference to Figure 7-1.

Question 18: The first paragraph of the proposed response to Inspection Question 1 states that "...an optimized weld overlay may be used either preemptively or as a repair for observed flaw indications up to 50% through wall, as long as the crack growth analysis demonstrates that the observed flaw would not violate the OWOL design basis in the normal ASME Section XI inspection interval of ten years ..." The NRC staff recommends that the above statement be revised to read "...an optimized weld overlay may be used either preemptively or as a repair for observed flaw indications up to 50% through wall, as long as the crack growth analysis demonstrates that the observed flaw would not violate the OWOL design basis in the normal ASME Section XI inspection interval of ten years and the WOL + 50% of the outer pipe wall is inspectable with Appendix VIII qualified personnel and procedures."

Proposed Response: NEI concurs with the suggested wording, with the understanding that the OWOL exam volume and coverage requirements are as defined in Section 7.1 and Figure 7-1 of MRP-169 Rev. 1

Question 19: This question relates to question 15 above. The responses to the RAI questions on inspection contain a high level discussion of criteria and mockup samples being developed for qualification of OWOL inspection. The status of the development of OWOL criteria and mockups is not clear. It is not clear whether MRP-169 plans to rely on demonstration as opposed to qualification. Since OWOL inspection requirements have not been developed (or at least NRC staff has not seen any proposed requirements from the industry), clarify what MRP perceives as the regulatory approach for obtaining NRC staff approval of inspection qualification, in so far as it would apply to review and approval of MRP-169.

Proposed Response: MRP-169 states that the "procedures, equipment, and personnel used for examination of preemptive weld overlays shall be qualified" (not demonstrated) in accordance with the PDI qualification process. As discussed under question 15 above, test specimen requirements, conduct of demonstrations and acceptance criteria will be similar to those in Section XI, Appendix VIII Supplement 11. If such qualification is not accomplished, then either OWOLs cannot be used or a special relief request will have to be submitted requesting an alternate approach.

Question 20:. The Proposed Response to Stress Analysis Question 2 is vague and not particularly informative. Please clarify.

Proposed Response: In practice, nozzle specific residual stress analyses have been performed on virtually every pressurizer nozzle weld overlay, and it is expected that this practice will continue for large bore nozzle overlays, especially if they are OWOLs. Section 4.2 of MRP-169, Rev. 1 requires overlay specific weld residual stress analysis for each unique PWOL configuration in which there is a significant geometry, material, or welding process difference from a previously analyzed overlay (beyond standard drawing/fabrication tolerances).

Question 21:. The Proposed Response to Fatigue Question 1 indicates that the cumulative usage factor (CUF) = 0.2 criterion is based primarily on engineering judgment. The staff finds this justification inadequate and insufficient. MRP-169 assumes that there will be no significant differences in the stress distribution under the same plant thermal transients before and after the PWOL. This should be verified by bounding fatigue calculations, which may form an adequate basis for making this judgment. Justify the use of the "CUF = 0.2" criterion.

Proposed Response: MRP-169 does not assume that there will be no significant difference in the stress distributions before and after a PWOL. In fact, analyses are specifically required to address these differences for nozzles in which fatigue usage is considered significant. The intent of this paragraph was to avoid having to perform nozzle-specific analyses on nozzles for which fatigue duty is not significant. A fatigue usage factor of 0.2 is only 20% of the ASME Section III allowable, and in past analyses of high fatigue duty locations (i.e. pressurizer surge and spray nozzles), weld overlays have not been found to cause a five-fold increase in fatigue usage. Note also that the exemption for CUF $\leq$ 0.2 does not apply to the requirement to perform a fatigue crack growth analysis, which is generally a more limiting requirement than the fatigue usage calculation.

Question 22: Section 5 of MRP-169 pertains to verification of weld overlay effectiveness. Figures 5-14 and 5-15 on pages 51 and 52 show comparisons of measured and analytically calculated axial and hoop residual stresses on the inside surface of the mock-up nozzle, both pre- and post-overlay. The results do not indicate good agreement between measured and calculated values. The pre-overlay measurements indicate that both the hoop and the axial stresses are not uniformly distributed around the circumference for the pipe and, therefore, the assumption of axisymmetry in the calculation does not appear to be valid.

The pre-overlay diagram in Figure 5-14 shows significant measured compressive inside diameter (ID) hoop stresses around the circumference and along the length of the pipe, whereas the calculated ID hoop stresses are all tensile. The largest measured compressive hoop stress is about 70 ksi. The post-overlay diagram indicates that the largest measured compressive hoop stress is approximately 55 ksi., *smaller* than the pre-overlay stress. As a result of the overlay, the largest measured compressive hoop stress on the ID appears to have actually decreased.

The pre-overlay diagram in Figure 5-15 shows measured ID residual tensile axial stresses in excess of 100 ksi, considerably larger than the largest calculated tensile axial stress and *higher* than the ultimate stress. Likewise, the post-overlay diagram shows a measured compressive axial stress in excess of 100 ksi.

Therefore, either the measurements are unreliable, or the method of calculating the stresses does not reflect the actual pre-overlay and post-overlay stress states, or both. These results cast doubt on the accuracy of the fatigue crack growth calculations, the predictability of the effectively mitigating PWSCC, and on the proposed inspection frequency. Please address these issues.

Proposed Response: The analytical-experimental agreement, while not perfect, is relatively good for a highly complex problem such as this and it must be recognized that there is a large degree of statistical scatter and uncertainty in actual residual stresses as well as their measurement. More importantly, the post-overlay results demonstrate that the current 2-D method of evaluating weld overlay residual stress improvement is conservative in terms of estimating the residual stress benefits of the overlay process. Weld overlays have been used successfully to repair and mitigate SCC in BWRs for over 25 years, with less analytical rigor than is currently documented in MRP-169 Section 5, and the inspection frequencies imposed in MRP-139 for PWR overlays are the same as (or more frequent than) those currently in place for BWR overlays.

Question 23: Figures A-1 and A-2 on pages 25 and 26 appear to have an editorial error. Based on the SY and SZ notation, it appears that Figure A-1 compares the hoop stress of the Surge Nozzle Example and the axial stress of PWOL Mockup. A similar error appears to have been made on Figure A-2. Please explain the discrepancy.

Proposed Response: There is no error in Figures A-1 and A-2 of the prior RAI response. The mockup stress contour plots are presented in a local coordinate system, rather than the global coordinate system indicated on the figures.

Question 24: There are a couple of cases where the proposed responses discuss case specific justification to extend the conditions laid out in MRP-169. For example, (a) Proposed Response to Inspection Question 1 discusses configurations that do not permit full coverage of the pre-overlay examination volume by qualified techniques or where flaw indications greater than 50% (but less than 75%) through-wall may be detected. It also notes that MRP-169, Rev. 1 will state that an OWOL may still be applied in such situations, subject to a plant-specific, nozzle specific technical justification. (b) Proposed Response to Inspection Question 3 notes that MRP would like to retain the option of applying an "approved alternative" (i.e. Risk Informed-ISI) to weld overlaid

PWR DMWs at some time in the future, pending sufficient experience and technical justification.

For example (a) above, justify why OWOL configurations are allowed for less than full examination coverage or for a degraded weld containing flaws greater than 50% through wall. For example (b) above, justify the use of risk-informed ISI to weld overlays when Code Case N-740 provides specific inspection requirements.

Proposed Response:

(a) Case-specific technical justifications are required for special circumstances such as those described in example (a) in this question. It is not NEI's intent to provide such technical justifications generically, as part of MRP-169, but rather to allow for such circumstances to be addressed in the future, should they arise. As discussed in the responses to questions 6 and 11 above, the wording in MRP-169, Rev. 1 has been revised to clarify that technical justifications for such cases are subject to NRC review and approval.

(b) Regarding example (b), application of RI-ISI, if a licensee commits to performing WOLs in accordance with MRP-169, the applicable ISI requirements are those defined for Category B or F in MRP-139, not Code Case N-740 (per Table 4-1 of MRP-169 Rev. 1). If, in the future, the industry chooses to apply RI-ISI to such WOLs, a technical justification will be prepared, similar to BWRVIP-75, and submitted to NRC for review and approval.

Question 25: Submit the revised MRP-169 (i.e., MRP-169, Revision 1) in its entirety.

Proposed Response: MRP-169, Rev. 1 (Proprietary version and non- proprietary version), in its entirety, is included with these responses.

Questions from Battelle Columbus Laboratory

Question 1: The second paragraph on page 33 says, "Weld overlay sizing requirements are further defined in Code Case N-504-2……ASME Code Section XI allowable flaw size criteria (IWB-3640 and Appendix C) are used for sizing the weld overlay ..."

Code Case N-504-2 was developed for stainless steel piping, and as such Appendix C and IWB-3640 of the ASME Code, Section XI would be appropriate. However, these requirements may not apply for DMWs if the crack is near the fusion line of the butter to the ferritic material. There is a very limited set of J-R curves for these DMWs. There is data developed at Battelle Laboratory for the fusion line as part of the Short Cracks program and for the weld metal itself as part of the Large Break LOCA program. Outside of those data the NRC staff is not aware of any other fracture toughness data. It may be premature to universally say that limit load is the governing fracture criteria based on this limited set of data. Using the Dimensionless Plastic Zone Parameter (DPZP) analysis which was developed to distinguish when limit load was valid and when it was not, and using the Short Cracks fusion line fracture toughness data, we saw as part of our review of MRP-140 that for the hot leg geometry the DPZP maximum predicted stress was only about 60 percent of the limit load stress. Please address this comment.

Proposed Response: Figure 1 below presents a plot of J-R data for A-182 and A-82 weldments from various References [4-6] compared to similar data for wrought SS and Alloy 600 base metal. It is seen from this figure that the weldment toughnesses are comparable to those for the base metals for which limit load is generally considered applicable. The fusion line data from [4] (red chain link curve) are somewhat lower, but still more than a factor or two greater than the "low toughness" flux weld and carbon steel piping toughnesses, indicated by the solid brown and black curves at the bottom of the plot.

For FSWOLs, there is no concern for potentially lower toughness, because no credit is taken for the underlying DMW. The entire load is supported by the WOL itself, which is fabricated from high toughness, PWSCC-resistant GTAW weld metal (Alloy 52).

For OWOLs, credit is taken for load carrying capacity of some of the underlying DMW (outer 25%), so the potential for reduced toughness should be considered. In the AFEA project [7], a Z-Factor approach proposed in Ref. [4] was used to account for potential low toughness of the DMW, and it was also agreed to conservatively ignore the load carrying contribution of the compressive side of the crack. In designing overlays, this latter conservatism is considered unnecessary, because the overlay produces high axial shrinkage and associated compression of the crack face. Therefore, for OWOL designs, it is proposed that the designer include a Z-Factor from [4] in determining allowable flaw size and thus overlay thickness in accordance with ASME Code Section XI allowable flaw size criteria (IWB-3640 and Appendix C), but that the analysis also include the ability of the crack face to support compression where applicable.

The wording in MRP-169, Section 4.1 has been revised to incorporate this requirement for OWOL sizing. The example problems in Section 8 will also be revised accordingly.

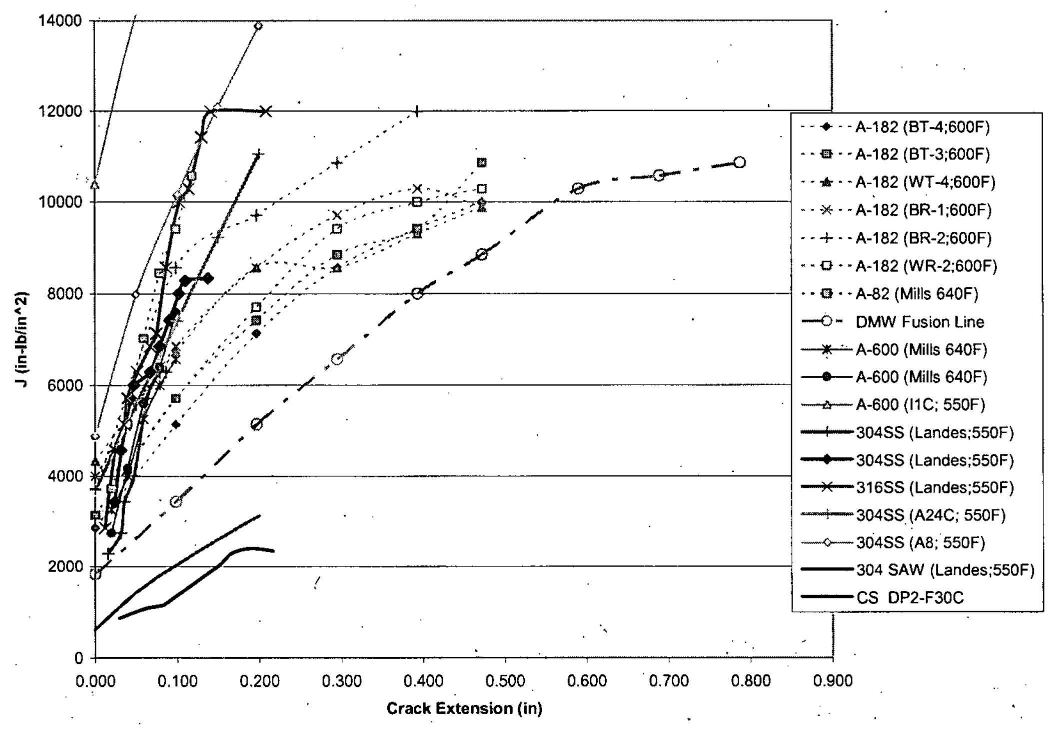


Figure 1 – Comparison of J-R Curves for Alloy-82/182 and DMW Fusion Line to Various Pipe Test Materials. Two "Low Toughness" Materials also plotted for Comparison

Question 2: In the third paragraph of Section 4.2 on page 35 when discussing the need for weld residual stress analysis for each unique PWOL configuration, the last sentence states, "Several tools exist and have been demonstrated to produce residual stress results that are in agreement with experimental measurements (see Section 5)." The NRC staff is aware that the data has a good deal of scatter. The above statement may be premature until such time as we can better validate these models through the mock-ups both NRC and EPRI are planning on fabricating and testing. Clarify the above statement.

Proposed Response: Weld residual stresses will always exhibit a great deal of scatter, due to start-stops in the welding process, permissible ranges of welding parameters, localized repairs, and the fact that 2D residual stress analyses are typically performed as part of the WOL design process while the welding process is complex, 3D phenomenon. However, comparisons to measured residual stresses on weld overlay mockups (including the one discussed in Section 5.1 (5) of MRP-169) have demonstrated that 2D analysis techniques conservatively bound experimental results from the standpoint of the WOL residual stress benefits.

The quoted wording from Section 4.2 has been revised to state that "Several tools exist and have been demonstrated to produce residual stress results that are in agreement with (*or conservatively bound*) experimental measurements (see Section 5)." (*Italicized words added*)

NEI recognizes that there is ongoing research on this topic, and industry representatives are participating in that effort. We will follow this work and incorporate methodology improvements as practical, but at this time industry believes it is prudent to proceed with DMW mitigations using current methodology, which has been shown to be conservative

Question 3: The last sentence of the first full paragraph on page 8-2 of MRP-169, Revision 0, says, "Since the weld overlay is being applied with Alloy 52 GTAW weld metal, the stress ratio is computed as (Pm + Pb)/Sm, where Sm = 23.3 ksi for Alloy 600 and 690 piping material at 650 degrees F."

This implies that one will use the weld metal strength properties to define the Sm (or strength properties) for the fracture analysis. In all of the work done at Battelle Laboratory over the years in comparing pipe fracture experiments with analytical results, Battelle obtains the best agreement between the experimental results and analytical results when the base metal strength properties and the weld metal fracture toughness properties are used in analyzing experiments where cracks were in the weld metal. In these types of analyses it would be more conservative to use the lower strength base metal properties in these types of fracture analyses. EPRI agreed with this approach during the work on Advanced Finite Element Analysis. Discuss why this approach is not being used herein.

Proposed Response: As was the case in Battelle question #1, this is not a concern for FSWOLs, since no credit is taken for the underlying DMW. The entire load is supported by the WOL itself, which is fabricated from Alloy 52 weld metal that possesses weld metal strength properties. For OWOLs, however, a portion of the original DMW is being credited (outer 25%).

The Battelle experiments and analyses referred to in the question addressed non-overlaid, cracked pipes, in which the A-182 weld and the SS base metal were "in series", such that the load needs to be transferred first into the base metal adjacent to the weld and then through the weld at the cracked section (which could be near the SS to A-182 fusion line). With an OWOL, the outer 25 percent of the original pipe weld is doing this, but "in parallel" we have the overlay material taking a larger fraction of the load. Thus, it is not necessary to assume the lower strength of the SS base metal for the entire section. A more precise limit load analysis of this two-material situation is presented in [8], considering both the lower strength base material and the higher strength A-52 weld overlay. In response to this question, the design analysis requirements in Section 4.1 have been revised to require either a two-material analysis approach for OWOLs, or the more conservative assumption of SS strength properties for the entire thickness. The example problems in Section 8 will also be revised accordingly.

An aspect of this response also relates to the above response to Question 1, regarding reduced toughness concerns and Z-factors. The concern for lower strength material properties in the limit load analysis applies primarily to cracks at or near the fusion line of the DMW with the lower strength stainless steel pipe or safe end. Conversely, as illustrated in Figure 1, the concern for reduced fracture toughness, and thus the use of Z-factors in the design, applies to cracks at or near the fusion line with the LAS or CS nozzle. These two conservatisms need not be applied simultaneously. The following dual analyses approach is thus proposed:

- One sizing calculation is performed incorporating a Z-factor from [4] with uniform strength properties applicable to the Alloy 182 and Alloy 52 weld metal (which in practice equate to the Code properties for Alloy 600)
- A second calculation is performed assuming the lower strength of the SS base metal, either for the entire thickness, or implemented via the two-material approach of [8], but with the Z-factor set equal to 1.0.

The larger OWOL thickness requirement resulting from these two analyses would apply.

Question 4: The bottom of page 8-2 and the top of page 8-3 of MRP-169, Revision 0, says,
"The desired result is that post-WOL residual stress on the inside surface of the nozzle, over the entire region of PWSCC susceptible material, in both the axial and circumferential directions, be sufficiently compressive, such that the total stress, when sustained operating loads are added, remain less than 10 ksi tension. This result will inhibit PWSCC initiation in any direction."

Discuss the consequence where there is already PWSCC in the weld and the 10 ksi tension with operating loads is high enough to open the existing crack faces and allow in corrosive liquid which acts on the more highly stressed crack tip. Is this acceptable?

Proposed Response: Section 4.2, as revised in MRP-169, Rev. 1, requires a crack growth evaluation <u>in addition</u> to the 10 ksi initiation criterion for acceptability of post-WOL residual stresses. Specifically, Section 4.2 states:
"A separate PWSCC crack growth criterion must also be satisfied to demonstrate the acceptability of the post-weld overlay residual stress distribution. This criterion requires that any cracks detected in the pre- or post-overlay inspections, or that are not within the examination volumes in the PWSCC susceptible material, would not grow by PWSCC to the point that they would violate the overlay design basis (75% through-wall for OWOLs or 100% through-wall for FSWOLs). Since there is no generally accepted PWSCC crack growth threshold for Alloy 82/182 weld metals, satisfying this criterion generally requires that the cracktip stress intensity factor due to residual stresses, operating pressure and sustained, steady-state loads, be compressive up to the greater of the maximum flaw size detected (either pre- or post-overlay) or the maximum flaw size in PWSCC susceptible material that could be missed by the applicable inspections."

Question 5: Page 8-11 of MRP-169, Revision 0, includes the expression, "Phase = base material property." Is that the carbon steel or stainless steel base properties for the dissimilar metal welds?

Proposed Response: Based on agreement with the staff, the LBB example case to which this comment applies has been completely eliminated in MRP-169, Rev. 1, pending completion of the EPRI/NRC joint program on LBB in SCC susceptible components. Thus the question is no longer relevant.

Question 6: MRP-169, Revision 0, Table 8-9, 4th column, implies that Crack Opening Displacement (COD) values are provided but they are not included. Please clarify.

Proposed Response: Similar to the previous response, this question is no longer relevant since the LBB example problem will be deleted.

Question 7: MRP-169, Revision 0, Figures 8-2 and 8-6 do not show the thermal sleeve on the ID surface that is typically used for this application. Please clarify.

Proposed Response: The effect of thermal sleeves in residual stress analyses of weld overlays is typically addressed through a heat transfer coefficient adjustment for the inside surface of the pipe during welding.

Question 8: For Figure 8-11 of MRP-169, Revision 0, if the thickness of the weld is 0.875 inches (Figure 8-1) and the overlay thickness is 0.3 inches (Page 8-5), then the combined thickness is 1.175 inches, but Figure 8-11 shows through thickness stresses out to 1.3+ inches from the inside surface. Similarly for Figure 8-13, if the thickness of the weld is 1.28 inches (Figure 8-2) and the overlay thickness is 0.44 inches (Page 8-6), the combined thickness is 1.72 inches but Figure 8-13 shows through thickness stresses out to almost 2 inches. Please clarify this discrepancy.

Proposed Response: In Figures 8-1 and 8-2, the 0.875" and 1.28" dimensions used for structural sizing do not include the vessel ID cladding thickness. However, ID cladding is included in residual stress modeling (Figures 8.5 and 8.6), and thus results in the greater total thru-wall thicknesses reported.

Question 9: Regarding Chapter 8 of MRP-169, Revision 0, the welding direction was from the safe end side toward the nozzle for the hot leg and surge nozzle. The spray nozzle was done with the opposite progression from the nozzle side to the safe end side. No mention is made of differences in results with different weld pattern direction. This appears to be a very important issue with weld overlays working properly. Please comment.

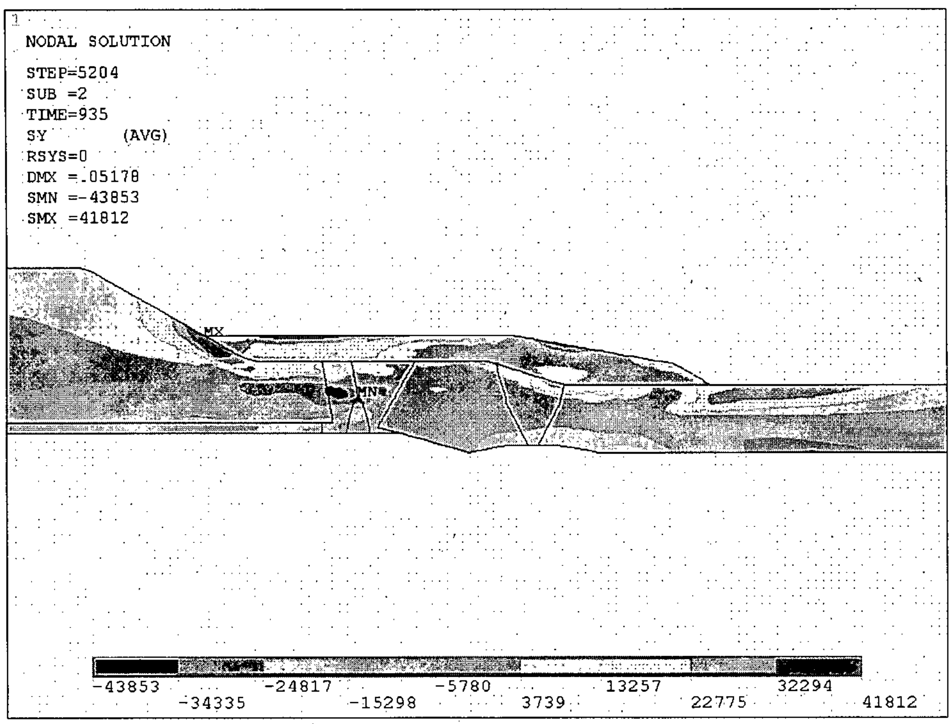
Proposed Response: Section 8 presents example problems, for which no welding was actually performed. Welding parameters (including welding direction) were therefore assumed that are typical for that type of nozzle. However, in real WOL applications, the residual stress analyses should incorporate actual welding parameters (including direction) for the specific nozzle. Wording has been added in Section 4.2 clarifying this requirement.

References:

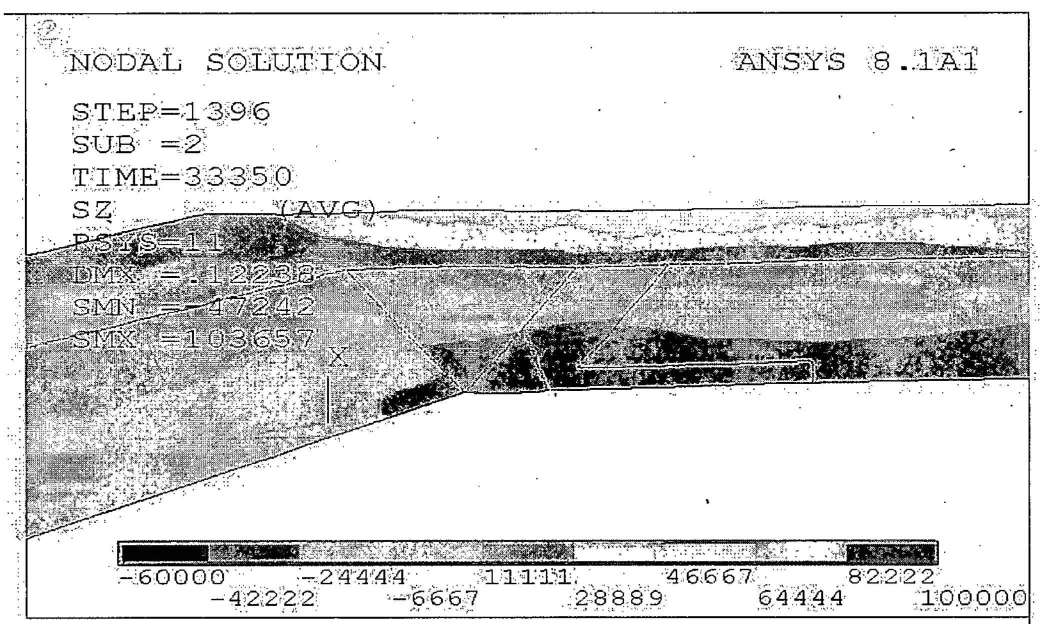
1. W. Hübner, B. Johansson, and M. de Pourbaix, Studies of the Tendency to Intergranular Stress Corrosion Cracking of Austenitic Fe-Cr-Ni Alloys in High Purity Water at 300°C, Studsvik report AE-437, Nykoping, Sweden, 1971.
2. W. Debray and L. Stieding, Materials in the Primary Circuit of Water-Cooled Power Reactors, International Nickel Power Conference, Lausanne, Switzerland, May 1972, Paper No. 3.
3. C. Amzallag, et al., "Stress Corrosion Life Assessment of 182 and 82 Welds used in PWR Components," Proceedings of the 10th International Symposium on Environmental Degradation of Materials in Nuclear Power Systems - Water Reactors, NACE, 2001.
4. G. Wilkowski, H. Xu, D.-J. Shim, and D. Rudland, "Determination of the Elastic-Plastic Fracture Mechanics Z-factor for Alloy 82/182 Weld Metal Flaws for Use in the ASME Section XI Appendix C Flaw Evaluation Procedures," PVP2007-26733, Proceedings of ASME-PVP 2007: 2007 ASME Pressure Vessels and Piping Division Conference, San Antonio, TX, 2007.
5. W.J. Mills, C.M. Brown, "Fracture Toughness of Alloy 600 and EN82H Weld in Air and Water", B-T-3264, Bettis APL,
6. J.D. Landes, J. McCabe, "Toughness of Austenitic Stainless Steel Pipe Welds", EPRI NP-4768, October, 1988
7. G.A. White et al, Materials Reliability Program: "Advanced FEA Evaluation of Growth of Postulated Circumferential PWSCC Flaws in Pressurizer Nozzle Dissimilar Metal Welds" (MRP-216), EPRI Report 1015383, August, 2007.
8. A.F. Deardorff et al, "Net Section Plastic Collapse Analysis of Two-Layered Materials and Application To Weld Overlay Design", ASME PVP 2006 Pressure Vessels and Piping Division Conference, Vancouver, Canada, July 2006, PVP2006-ICPVT11-93454

Appendix A

Comparison of Residual Stress Analyses Results for PWOL Mockup and Surge Nozzle Example in MRP-169

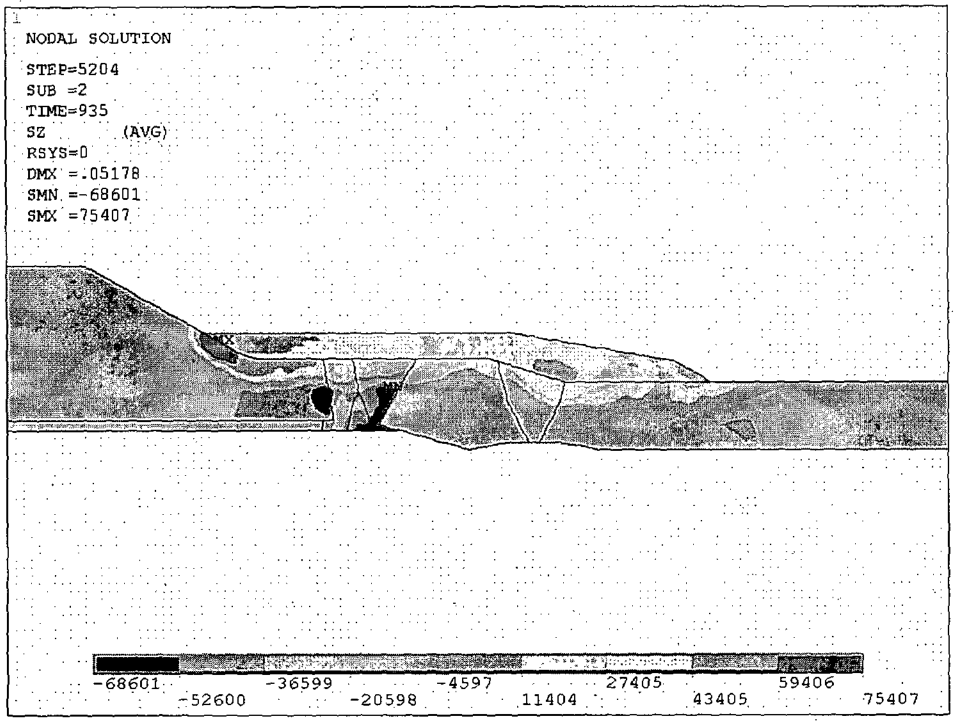


Surge Nozzle Example (Section 8)

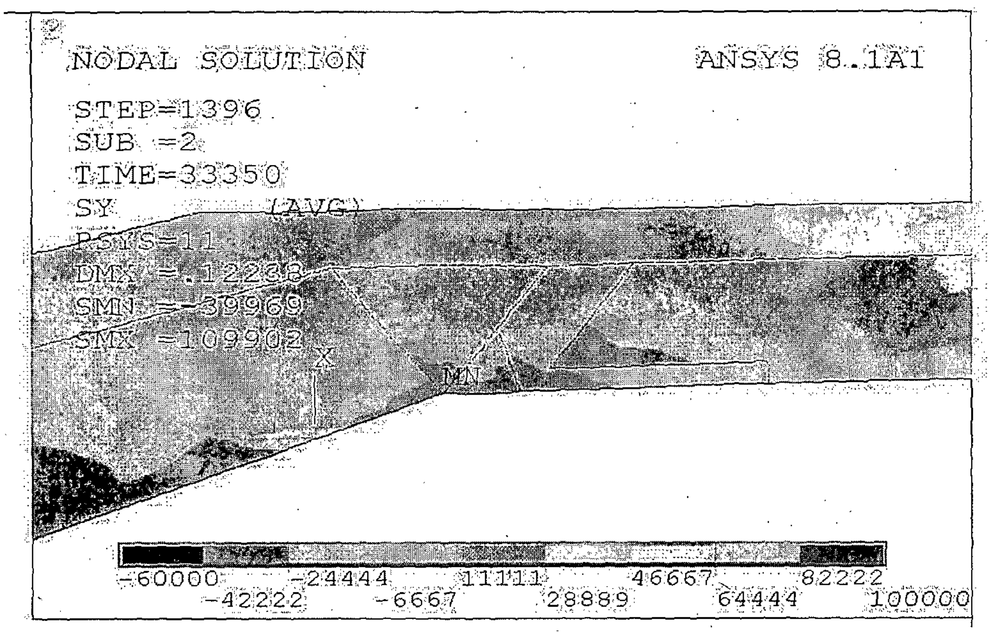


PWOL Mockup (Section 5)

Figure A-1 – Post-Overlay Axial Residual Stress Comparison (Surge Nozzle vs. PWOL Mockup) at 70°F



Surge Nozzle Example (Section 8)



PWOL Mockup (Section 5)

Figure A-2 – Post-Overlay Hoop Residual Stress Comparison (Surge Nozzle vs. PWOL Mockup) at 70°F

Appendix B

Tables of Material Properties Used in Residual Stress Analyses

Table B-1: Material Properties

Material 7 (Nozzle): SA-508, Class 2 (3/4 Ni-1/2 Mo-1/3 Cr-V)

Temperature (°F)	Young's Modulus ($x10^6$ psi)	Thermal Expansion ($x10^{-6}$ in/in/°F)	Thermal Conductivity ($x10^{-4}$ Btu/sec-in-°F)	Specific Heat (Btu/lb-°F)
70	27.8	6.4	5.44	0.105
200	27.1	6.7	5.46	0.114
400	26.1	7.1	5.35	0.125
600	25.2	7.4	5.14	0.135
700	24.6	7.6	5.00	0.140
800	23.9	7.8	4.86	0.147
1000	22.4	8.1	4.56	0.163
1200	20.4	8.3	4.21	0.186
1400	17.7	8.4	3.54	0.406
1600	12.65	8.4	3.50	0.154
1800	7.59	8.4	3.50	0.154
2000	2.54	8.4	3.50	0.154
2100	0.01	8.4	3.50	0.154
2500	0.01	8.4	3.50	0.154
3000	0.01	8.4	3.50	0.154

Materials 5, 6, 9 (Original Nozzle Weld, Weld Butter, Weld Repair): Alloy 82/182/600 (N06600)

Temperature (°F)	Young's Modulus ($x10^6$ psi)	Thermal Expansion ($x10^{-6}$ in/in/°F)	Thermal Conductivity ($x10^{-4}$ Btu/sec-in-°F)	Specific Heat (Btu/lb-°F)
70	31.0	6.8	1.99	0.107
200	30.2	7.1	2.11	0.112
400	29.5	7.5	2.34	0.118
600	28.7	7.8	2.57	0.123
700	28.2	7.9	2.69	0.125
800	27.6	8.1	2.80	0.128
1000	26.4	8.3	3.06	0.134
1200	25.3	8.6	3.31	0.141
1400	23.9	8.9	3.59	0.146
1600	19.3	9.0	3.70	0.148
1800	11.6	9.0	3.70	0.148
2000	3.9	9.0	3.70	0.148
2100	0.01	9.0	3.70	0.148
2500	0.01	9.0	3.70	0.148
3000	0.01	9.0	3.70	0.148

Table B-1 Material Properties (cont'd)

Materials 1, 3, 8 (Cladding, Safe-end Weld, Piping): SA-376 Type 304 (18 Cr-8 Ni)

Temperature (°F)	Young's Modulus ($x10^6$ psi)	Thermal Expansion ($x10^{-6}$ in/in/°F)	Thermal Conductivity ($x10^{-4}$ Btu/sec-in-°F)	Specific Heat (Btu/lb-°F)
70	28.3	8.5	1.99	0.116
200	27.6	8.9	2.15	0.122
400	26.5	9.5	2.41	0.129
600	25.3	9.8	2.62	0.133
700	24.8	10.0	2.73	0.135
800	24.1	10.1	2.82	0.136
1000	22.8	10.3	3.06	0.139
1200	21.2	10.6	3.24	0.141
1400	19.2	10.8	3.45	0.144
1600	15.1	10.8	3.54	0.145
1800	9.1	10.8	3.54	0.145
2000	3.0	10.8	3.54	0.145
2100	0.01	10.8	3.54	0.145
2500	0.01	10.8	3.54	0.145
3000	0.01	10.8	3.54	0.145

Material 4 (Safe-end): SA-182 Type F-316L (16 Cr-12 Ni-2 Mo)

Temperature (°F)	Young's Modulus ($x10^6$ psi)	Thermal Expansion ($x10^{-6}$ in/in/°F)	Thermal Conductivity ($x10^{-4}$ Btu/sec-in-°F)	Specific Heat (Btu/lb-°F)
70	28.3	8.5	1.90	0.121
200	27.6	8.9	2.04	0.124
400	26.5	9.5	2.27	0.129
600	25.3	9.8	2.48	0.133
700	24.8	10.0	2.59	0.135
800	24.1	10.1	2.69	0.136
1000	22.8	10.3	2.89	0.139
1200	21.2	10.6	3.10	0.141
1400	19.2	10.8	3.31	0.145
1600	15.1	10.8	3.40	0.145
1800	9.10	10.8	3.40	0.145
2000	3.00	10.8	3.40	0.145
2100	0.01	10.8	3.40	0.145
2500	0.01	10.8	3.40	0.145
3000	0.01	10.8	3.40	0.145

Table B-1 Material Properties (cont'd)

Material 2 (Weld Overlay): Alloy 52/152/690 (N06690)

Temperature (°F)	Young's Modulus ($x10^6$ psi)	Thermal Expansion ($x10^{-6}$ in/in/°F)	Thermal Conductivity ($x10^{-4}$ Btu/sec-in-°F)	Specific Heat (Btu/lb-°F)
70	30.3	7.7	1.57	0.105
200	29.5	7.9	1.76	0.109
400	28.8	8.0	2.04	0.115
600	28.1	8.2	2.31	0.119
700	27.6	8.3	2.45	0.122
800	27.0	8.3	2.59	0.124
1000	25.8	8.3	2.89	0.129
1200	24.7	8.3	3.17	0.134
1400	23.3	8.3	3.45	0.140
1600	18.8	8.3	3.59	0.143
1800	11.3	8.3	3.59	0.143
2000	3.8	8.3	3.59	0.143
2100	0.01	8.3	3.59	0.143
2500	0.01	8.3	3.59	0.143
3000	0.01	8.3	3.59	0.143

Table B-2: Material Yield Stresses (YS) and Tangent Moduli (TM)

Temperature (°F)	SA 508 Class 2		Alloy 82/182/600		SA-182, Type F-316L		SA 376 Type 304		Alloy 52/152/690	
	YS (ksi)	TM (ksi)	YS (ksi)	TM (ksi)	YS (ksi)	TM (ksi)	YS (ksi)	TM (ksi)	YS (ksi)	TM (ksi)
70	63.6	191.9	53.9	531.1	40.2	680.1	35.8	531.1	49.2	531.1
550	56.3	132.3	50.0	361.5	24.8	415.0	26.5	361.5	36.4	361.5
1000	47.2	79.5	45.7	216.1	20.9	357.1	19.1	216.1	32.7	216.1
1300	36.5	49.6	41.6	138.6	19.3	333.0	15.5	138.6	30.5	138.6
1600	24.2	30.2	24.7	80.5	14.6	247.1	10.5	80.5	27.0	80.5
≥2500	2.0	5.0	2.0	5.0	2.0	5.0	2.0	5.0	2.0	5.0