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# MRP-169 Discussion
# NRC Meeting

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# Presentation Outline

- Introduction
  - Background
  - Proposed Schedule
- Additional clarification & discussion
- Conclusions

# Introduction

# Weld Overlay : BWRs and PWRs

- Over 800 overlays applied in BWRs during 25 year period, many still operating
- Numerous in-service inspections performed of overlaid BWR welds
- No evidence of flaws growing in overlays or underlying base metal or welds
- PWR Pressurizer nozzle mitigation status
    - End of Fall 2007: 70% of total were mitigated
    - End of Spring 2008: 89% of total will be mitigated

# NRC RAI Background

- In 2005, EPRI developed guidelines for PWOL mitigation strategy, MRP-169 which provides technical basis for Full-size and Optimized WOL
- MRP-169 was submitted to NRC for review in 2005
- NRC requested additional information on August 3, 2006
- NRC met with MRP members on August 23rd 2007
- RAI responses submitted to NRC in January 2008

# NRC RAI Background (Cont'd)

- OWOL application(s) planned during the Fall 2008 refueling outages
- Approval of SER of MRP-169 before 2008 summer was requested during 2007 NRC meeting to support the applications of OWOL
- MRP-208 (PWOL mock-up for pressurizer surge line) was published in 2007 to validate WOL residual stresses

# MRP-169 Proposed Project Schedule

| Timeframe | Milestones |
| --- | --- |
| September 2005 | Submission of MRP169 to NRC |
| August 2006 | Receive NRC RAI |
| August 2007 | NRC meeting to Present and Discuss Draft RAI Responses |
| December 2007 | Formal RAI responses to NRC |
| February 2008 | NRC Public Meeting |
| Summer 2008 (planned) | SER from NRC |
| Fall 2008 (planned) | MRP-169 revision 1 in support of OWOL applications |

# Additional clarification & discussion on RAI responses and MRP-169 revision

# CONTENTS

- Part I: Additional clarification & discussion of RAI responses
- Part II: Comments on MRP-169 revision

# Additional RAI clarifications & discussion Question 1

- Q1. Response to General Question 2. Table 1 (the same as Table 4-1) 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.
  - A: *Licensees will commit to performing weld overlays in accordance with MRP-169. Once they do so, the requirements become mandatory.*

# Additional RAI clarification & discussion Question 1

- (b) Discuss whether licensees are allowed to use some but not all requirements (i.e., is cherry picking the requirements allowed?).
- *A: It is intended that the requirements be met in their entirety. If a utility plans to skip one or more of the requirements, they would have to prepare a relief request, which would become subject to NRC approval.*





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# Additional RAI clarification & discussion Question 1

- (c) Licensees have relied on ASME Code Case N-740 in requests for NRC approval to install WOLs. Discuss how MRP-169 will be used by licensees in weld overlay relief requests. Will any code cases be cited in conjunction with MRP-169? If so, how would the two documents be used together?
- A: *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 the preemptive overlays in areas that are typically outside of ASME Code purview.*

# Additional RAI clarification & discussion Question 3

- Q3. Stress Analysis Question 1. MRP-169 requires calculations be performed for PWSCC and fatigue. During our meeting on February 21, 2008, please outline the calculations performed to ensure that the staff's understanding of the calculations is correct.
  - 1) 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.
  - 2) Design Loads for Weld Overlay

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

# Additional RAI clarification & discussion Question 3

– 3) 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.

– 4) 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.

– 5) 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.

# Additional RAI clarification & discussion Question 3

- 6) Section III Code Evaluation of Nozzle with Weld Overlay

  Analyses to demonstrate that application of the weld overlays does not invalidate 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.

- 7) 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.

- 8) 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.

# Comments on MRP-169 revision Question 5

- Q 5. On page 33, Section 4.0, NEI states that the minimum WOL thickness is 1/3 of the pipe thickness.
  - (a) whether there is a limit for the maximum WOL thickness beyond which the WOL will cause detrimental effect on the pipe. Whether this upper bound in WOL thickness be specified in MRP-169 to avoid over-design of the WOL thickness.
  - 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.

# Comments on MRP-169 revision Question 5 (Cont'd)

- (b) Please explain the MRP-169 position on the use of WOL for more than one time application to any specific degraded DMW. It is not clear to us why it would be appropriate to reinstall a WOL on a degraded WOL.
- *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). There is no reason to disallow such an increase.*





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# Comments on MRP-169 revision Question 6

- Q 6. On page 34, "…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 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…" The staff would like to hear MRP's basis for these statements. It is not clear to the staff how the OWOL design can be carried out under either of the conditions noted above (i.e., less than complete coverage with a qualified examination or a flaw greater than 50% but less than 75% through wall.)

# Comments on MRP-169 revision Response to Question 6

- A : The intent of this paragraph was to not generically prohibit OWOL applications in such cases, but that such special circumstances would require case-specific 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 the entire required exam volume.

# Comments on MRP-169 revision Question 7

- Q 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 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-139.
- A: Shorter lengths than 0.75√Rt have been approved and used in the past on pressurizer nozzle FSWOL applications. The design and analysis requirements are that there is effective 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).





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# Comments on MRP-169 revision Question 8

- Q 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 is evidence that there is no threshold value of 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.
- A: 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 stress (ksi). PWSCC initiation data for both A-600 base metals and weldments indicate that high stresses, on the order of 80% of yield strength, are required to initiate PWSCC cracks. The 10 ksi limit is very conservative relative to these data. MRP-169 also imposes a separate PWSCC crack growth requirement that implements the zero stress intensity factor threshold.

# Comments on MRP-169 revision Question 10

- Q 10. Section 7.2 does not appear to have an inspection requirement for the case when a new indication is observed 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 is observed or growth of existing indications is observed in either the weld overlay or in the original weld.
- A: Requirements similar to those in Code Case N-740-2 can be added. (If ISI reveals flaw growth or new flaws the WOL will be re-examined during first or second RFO following that inspection.)

# Comments on MRP-169 revision Question 11

- Q 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
- A: Mockups are being fabricated that include CASS 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 CASS without WOLs and the outer 50% with WOLs. The examination volume would not include the CASS until UT procedures are qualified for this portion of the examination volume.

# Comments on MRP-169 revision Question 12

- Q 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 install the Alloy 52M WOL. This is 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.
- Answer: *Installation aspects of PWOLs, including an austenitic buffer layer if required, are covered by ASME Code requirements, specifically in Code Case N-740-2. The industry does not believe it is necessary to repeat them in MRP-169*





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# Comments on MRP-169 revision Question 13

- Q 13. The code cases related to weld overlays 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. For example, is MRP-169 to be used in combination with some aspects of ASME code cases?
- A: MRP169 should be used in combination with related ASME Code requirements (Code Case N-740-2).

# Comments on MRP-169 revision Question 14

- Q 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. Please address 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.
- A: 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, then the calculations must address that larger flaw. That is the intent of the penultimate paragraph of Section 4.2, but that paragraph can be revised to clarify this intent.

# Comments on MRP-169 revision Question 15

- Q 15. MRP-169 states that the required examination volume for the OWOL includes the weld overlay thickness and outer 50% of the pipe thickness. An Appendix VIII supplement addressing OWOL, i.e., weld overlay thickness and the outer 50% pipe wall, has not been issued. Please address how the level of inspection qualification for OWOL equivalent to FSWOLs is to be demonstrated and implemented through ASME or other requirements.
- Answer: A PDI mockup of a large diameter DMW with OWOL and FSWOL has been fabricated and will be available for procedure and personnel qualification for extended volume inspections down to 50% thru-wall under the PDI program. The PDI process will be used until such a time as an Appendix VIII supplement addressing OWOLs is available.

# Comments on MRP-169 revision Question 16

- Q 16: The Proposed Response to Inspection Question 7 notes that Code Case N-460 coverage requirements apply to overlay pre- 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 has not agreed to this limitation in the context of weld overlay relief requests.
- A: Code Case N-460 is accepted in RG-1.147 without restriction.

# Comments on MRP-169 revision Question 18

- Q 18. 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 have not seen any proposed requirements), it is not clear what MRP is viewing 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. Please clarify.
- A: MRP-169 clearly 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. 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.

# Comments on MRP-169 revision Question 19

- Q 19: The Proposed Response to Stress Analysis Question 2 is vague and not particularly informative. Please clarify.
- A: In practice, nozzle specific residual stress analyses have been performed on virtually every pressurizer nozzle weld overlay, and it is certainly expected that this practice will continue for large bore nozzle overlays, especially if they are OWOLs.

# Comments on MRP-169 revision Question 20

- Q 20: The Proposed Response to Fatigue Question 1 indicates that the 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.
- A: MRP-169 does <u>not</u> assume that there will be no significant differences 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 considered 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 demanding requirement than the fatigue usage calculation.

# Comments on MRP-169 revision Question 21

- Q 21: 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 measurement and calculation. The pre-overlay measurements indicate that both the hoop and the axial stresses are not uniformly distributed around the circumference 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 ID hoop stresses around the circumference and along the length, 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 this comment.

# Comments on MRP-169 revision Question 21

- A: 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 for over 25 years, with less analytical rigor than is currently documented in MRP-169 Section 5, and the inspection frequencies proposed in MRP-169 are the same as those currently in place for those overlays.

# Comments on MRP-169 revision Question 22

- 22. 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.
- There is no error in Figures A-1 and A-2. The mockup stress contour plots are presented in a local coordinate system, rather than the global coordinate system indicated on the figures. The coordinate notations will be corrected in MRP-169 Rev. 1.

# Comments on MRP-169 revision Question 23

- 23. There are a couple of cases where the proposed responses discuss case specific justification to extend the conditions laid out in MRP-169. Any NRC staff acceptance of MRP-169 would indicate the need for review of case specific justifications.
- Comment acknowledged. It is expected that case-specific review and approval by the NRC staff would be required for these exceptions to the MRP-169 requirements.

# Other Comments

- Other minor comments are acknowledged and will be included in MRP-169 revision 1 accordingly.

# Conclusions

- Responses prepared to all NRC RAIs
- Some RAIs plus field experience with PWOLs have resulted in suggested changes to original MRP-169 requirements
- After reaching agreement with NRC on RAI responses, they will be finalized and submitted
- MRP-169 will be revised accordingly and submitted Requesting NRC approval (SER) of Revised MRP-169 by Spring 2008 to support potential Fall 2008 RPV Nozzle Applications





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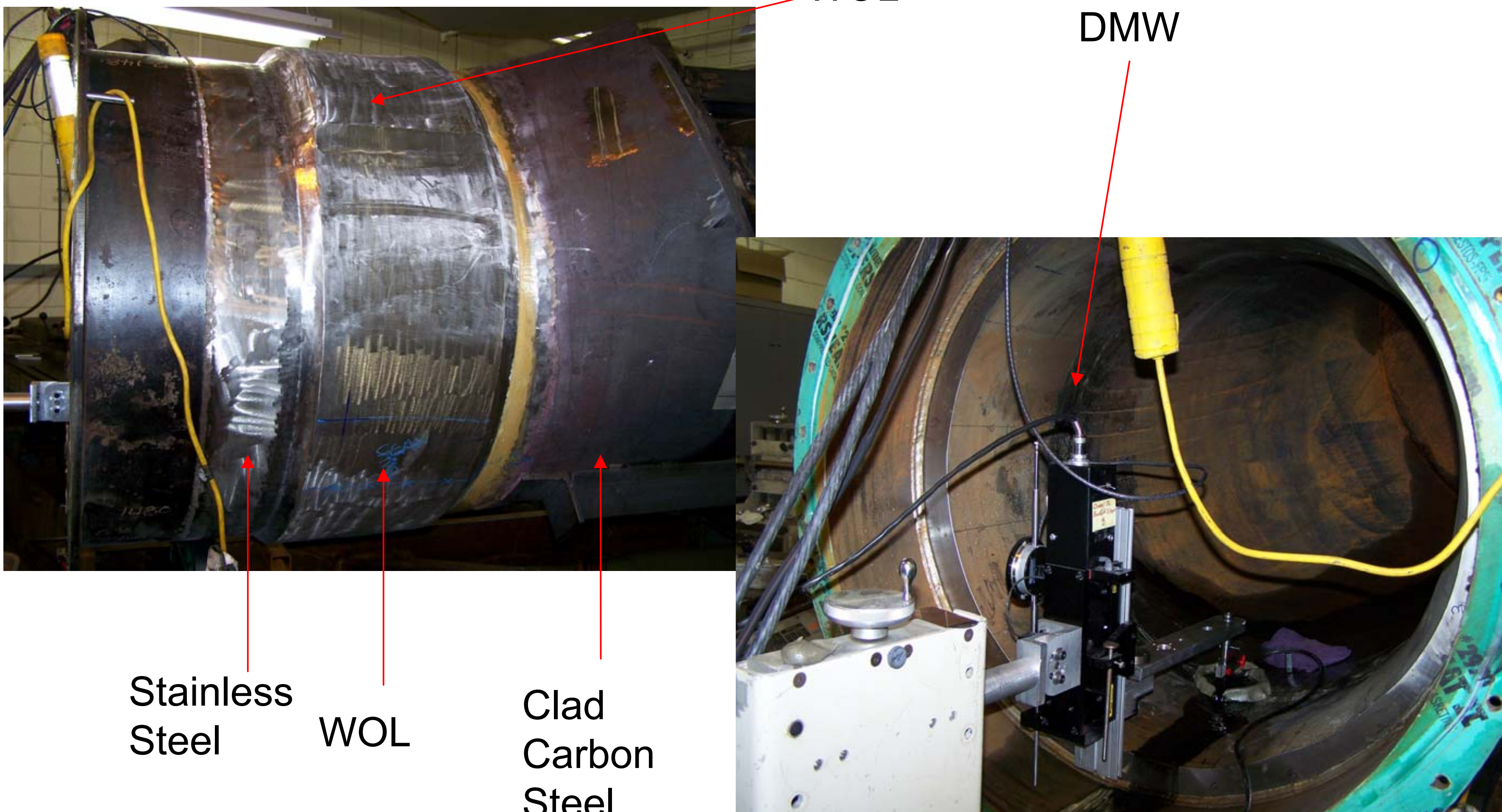
# Thanks!
# Questions and Comments?

# 36-inch mockup status

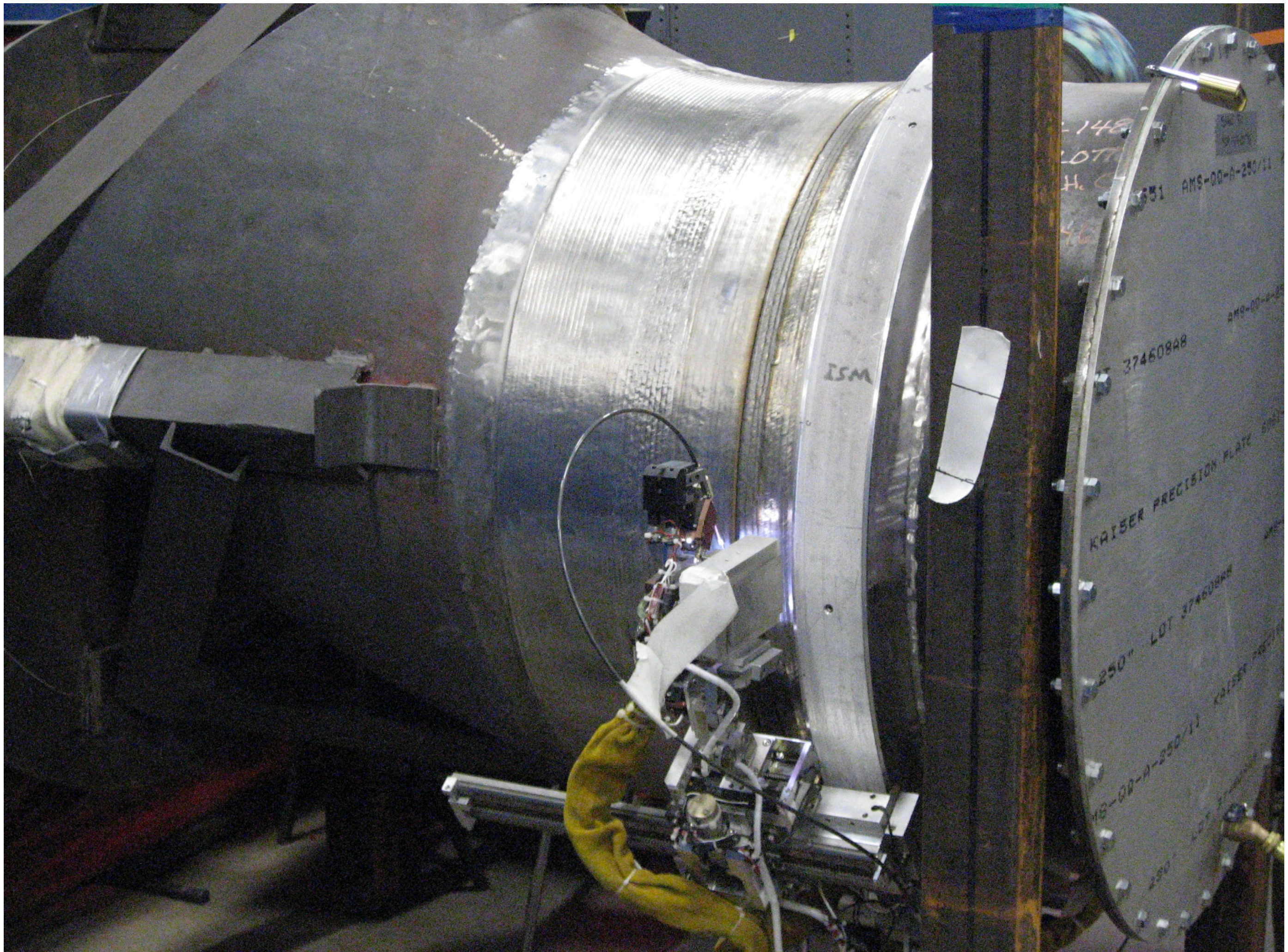
# 36-inch mockup status

- 36-inch mock up built in NDE center.  Stress Results being processed.
  - Residual stress measurements performed
  - FEA modeling in progress

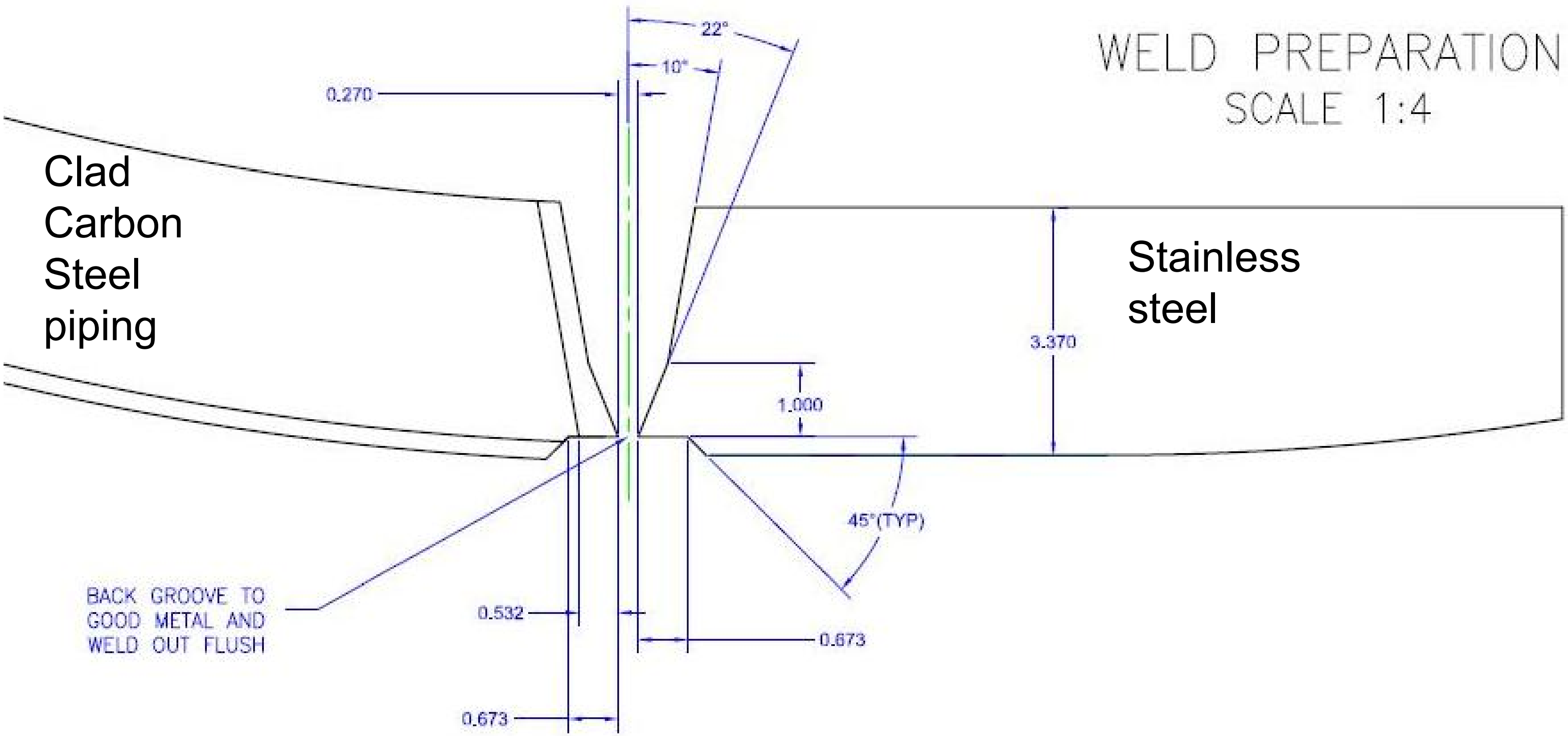
# 36-inch mockup with WOL



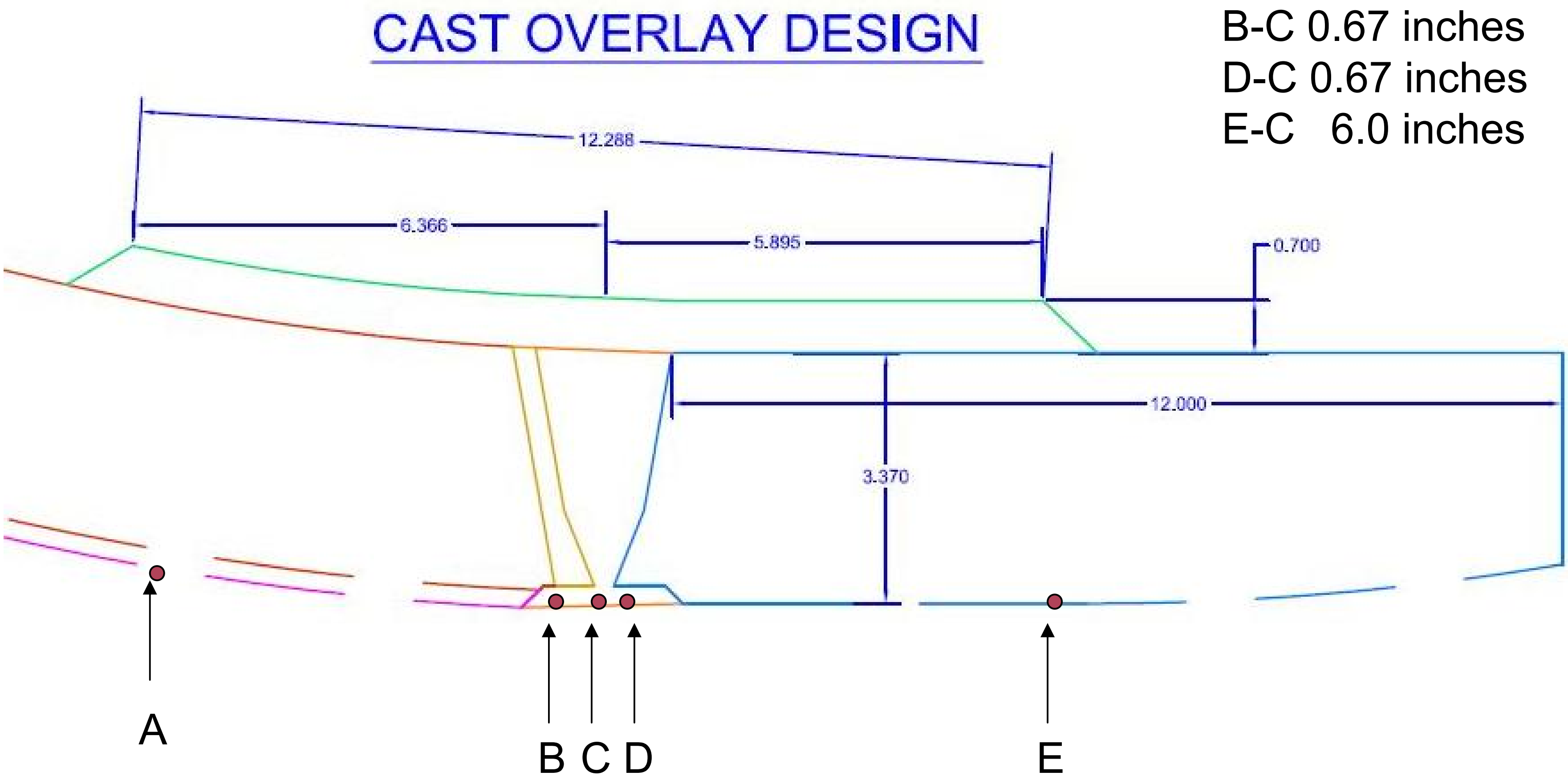
# Mockup Overlay Welding



# Dissimilar Metal Weld



# Partial Weld Overlay Design (Showing Measurement Locations)




A-C 6.0 inches
B-C 0.67 inches
D-C 0.67 inches
E-C 6.0 inches





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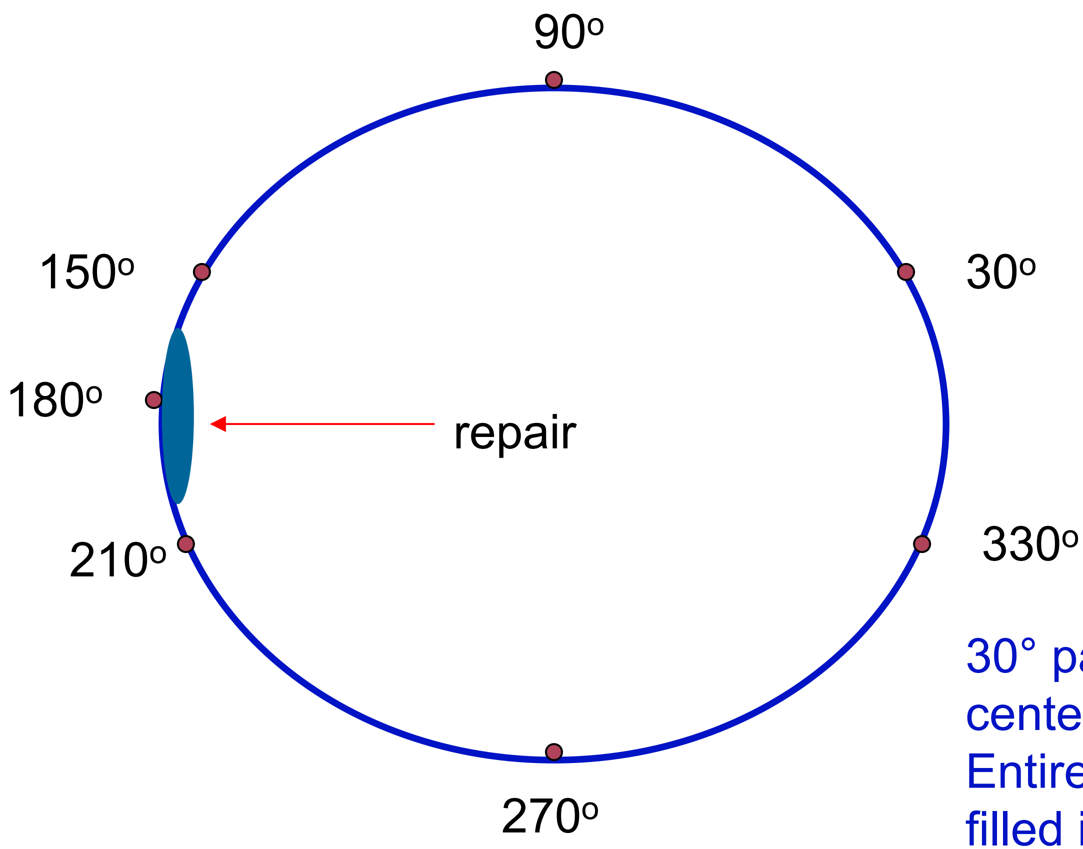
# Measurement Locations (azimuthal)




30° partial arc ID repair centered at 180°;
Entire counterbore then filled in 360°





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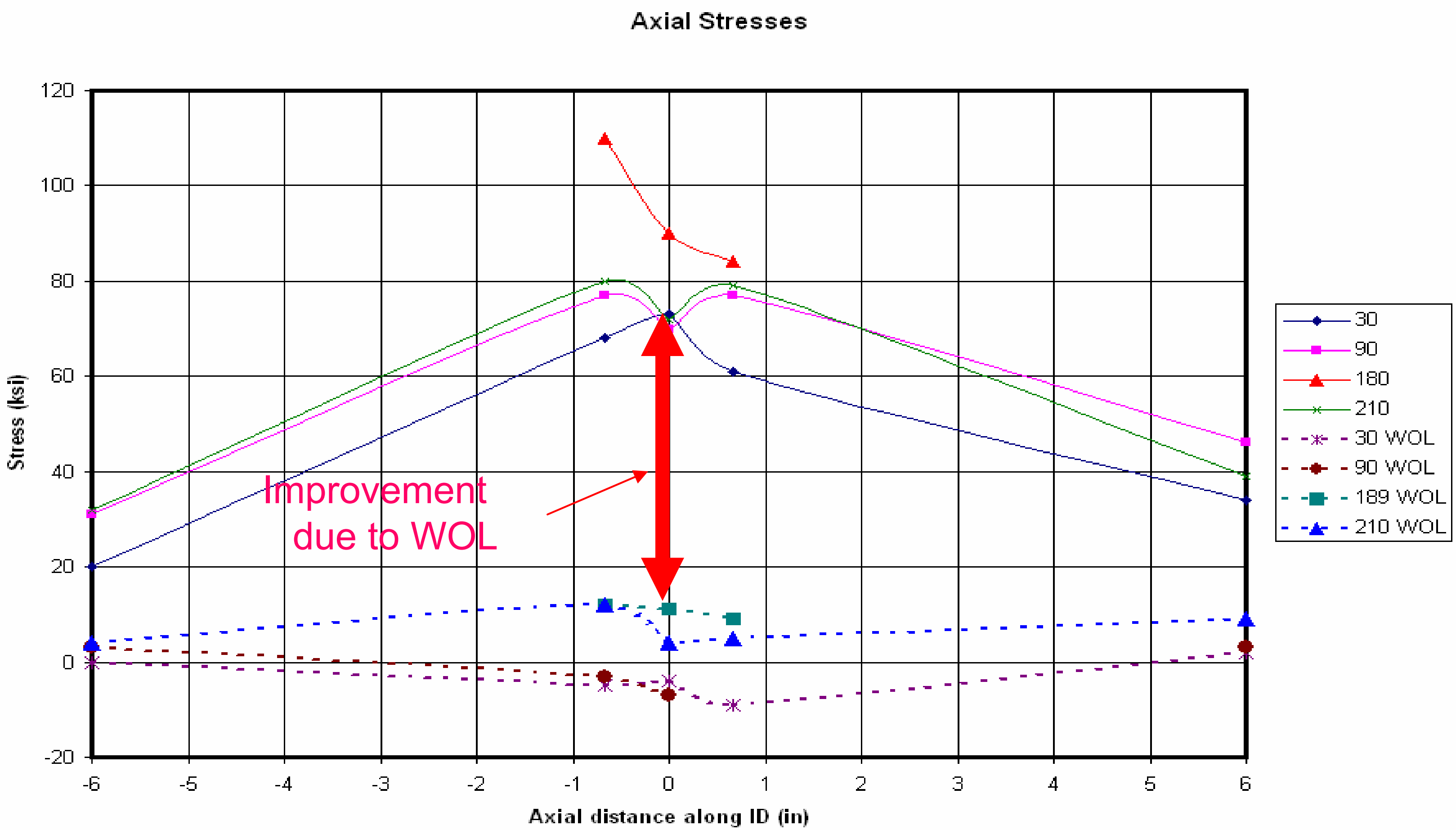
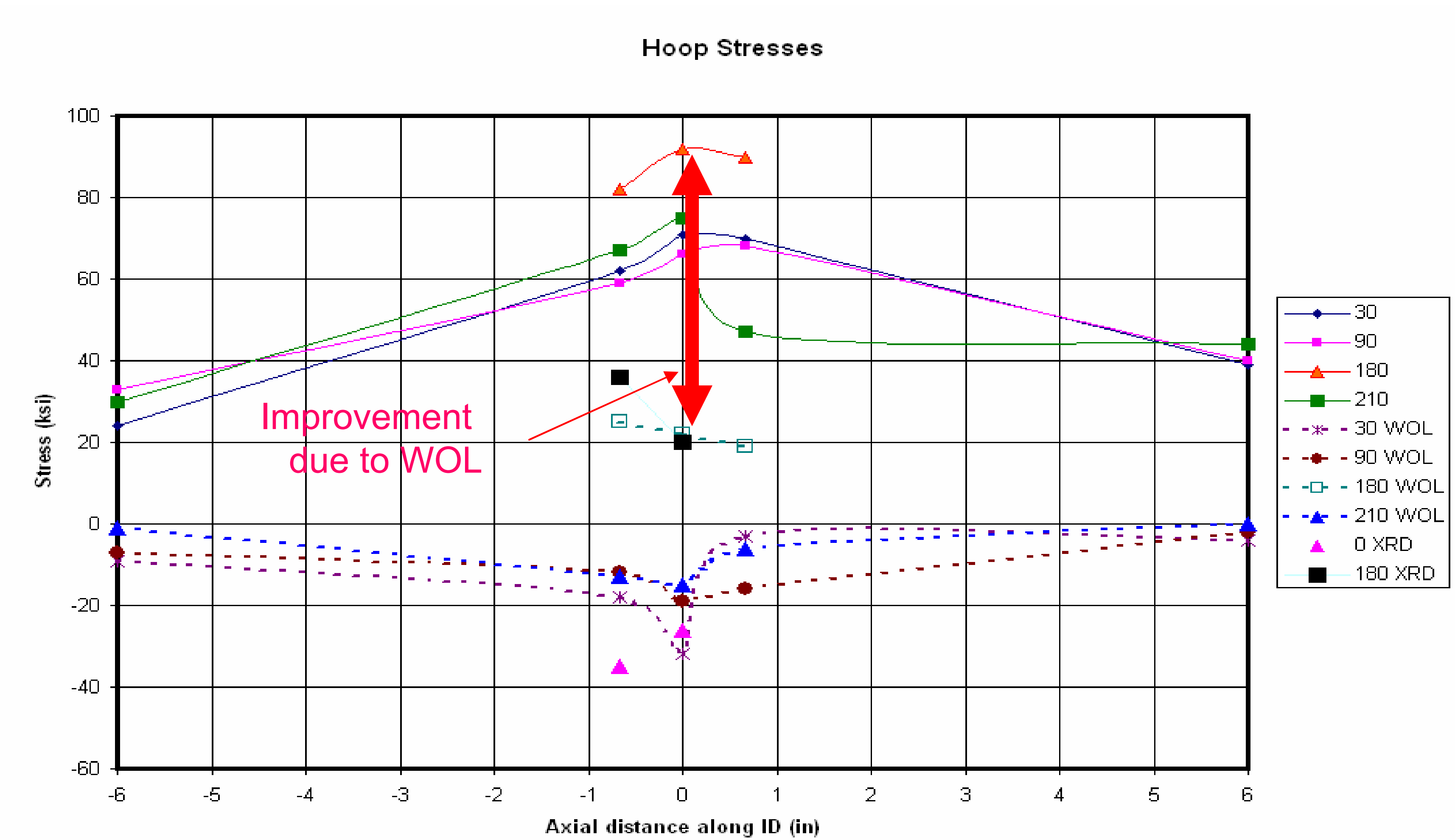
# Measured Axial Stresses (Pre- and Post-Overlay)



# Axial Residual stress (ksi) change due to WOL

| | 30º | 90º | 150º | 180º | 210º | 270º | 330º |
|---|---|---|---|---|---|---|---|
| A | -20 | -28 | -26 | N/A | -28 | -19 | -26 |
| B | -73 | -80 | -74 | -98 | -68 | -77 | -62 |
| C | -77 | -77 | -69 | -79 | -68 | -64 | -74 |
| D | -70 | N/A | -61 | -75 | -74 | -104 | -89 |
| E | -32 | -43 | -47 | N/A | -30 | 19 | -37 |

# Measured Hoop Stresses (Pre- and Post-Overlay)





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# Hoop Residual stress change (ksi) due to WOL

| | 30º | 90º | 150º | 180º | 210º | 270º | 330º |
|---|---|---|---|---|---|---|---|
| A | -33 | -40 | -27 | N/A | -36 | -34 | -41 |
| B | -80 | -71 | -73 | -57 | -82 | -63 | -68 |
| C | -103 | -85 | -85 | -70 | -87 | -102 | -81 |
| D | -73 | -84 | -71 | -71 | -65 | -37 | -73 |
| E | -43 | -42 | -35 | N/A | -49 | 11 | -46 |





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# Discussions

- Results demonstrate the effectiveness of WOL in reducing large diameter DMW residual stresses
- Perform more stress FEA modeling to evaluate effects of:
  - SS butt weld
  - ID repair / counterbore fill-in
  - Model Boundary Conditions (HTC, etc)
- Study correlation between WOL size and residual stress.
- Evaluate thru-wall stress distributions for crack growth
- 3-D modeling as necessary