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PG&E Letter DCL-14-028

U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, DC 20555-0001

10 CFR 50.55a

Docket No. 50-323, OL-DPR-82
Diablo Canyon Unit 2
Inservice Inspection Program Relief Request SWOL-REP-1 U2 for Approval of an Alternative to the ASME Code, Section XI, for Preemptive Full Structural Weld Overlays

References:

1. PG&E Letter DCL-07-038, "ASME Section XI Inservice Inspection Program Relief Request REP-1 U2," dated March 28, 2007 (ML070990060)
2. PG&E Letter DCL-07-099, "ASME Section XI Inservice Inspection Program Relief Request REP-1 U2, Revision 1, and Response to Request for Additional Information," dated October 22, 2007 (ML073040029)
3. PG&E Letter DCL-07-105, "ASME Section XI Inservice Inspection Program Relief Request REP-1 U2, Revision 1; Response to Request for Additional Information," dated November 29, 2007 (ML073460045)
4. NRC Letter, "Diablo Canyon Power Plant, Unit No. 2 – Approval of Relief Request REP-1 U2, Revision 1, for the Application of Weld Overlay on Dissimilar Metal Welds of Pressurizer Nozzles (TAC No. MD4974)," dated February 6, 2008 (ML080110001)
5. PG&E Letter DCL-13-021, "ASME Section XI Inservice Inspection Program Relief Request REP-1 U2, Revision 2," dated March 5, 2013 (ML13078A294)
6. PG&E Letter DCL-13-024, "Supplement to ASME Section XI Inservice Inspection Program Relief Request REP-1 U2, Revision 2," dated March 7, 2013 (ML13067A343)
7. NRC Letter, "Diablo Canyon Power Plant, Unit No. 2 – Request for Approval of an Alternative to the ASME Code, Section XI, for Preemptive Full Structural Weld Overlays (TAC No. MF0880)," dated August 28, 2013 (ML13232A308)

A047
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8. NRC Letter, "Summary of October 2, 2013, Pre-submittal Meeting with Pacific Gas and Electric Company to Discuss a Request to use an Alternative to Disposition Detected Laminar Indications on Pressurizer Safety Nozzles (TAC No. MF2675)," dated November 7, 2013 (ML13282A382)

Dear Commissioners and Staff:

In 2008, the NRC approved the Relief Request REP-1 U2, Revision 1 for the application of structural weld overlays (SWOL) on the Diablo Canyon Power Plant (DCPP) Unit 2 pressurizer nozzles dissimilar metal welds (DMW) (References 1 through 4). In 2013, the NRC authorized the Relief Request REP-1 U2, Revision 2 to allow the laminar indications detected in the overlaid DMWs that exceeded the original installation acceptance criteria of 3 inch linear length, to remain in service for one fuel cycle (References 5 through 7).

Pursuant to 10 CFR 50.55a(a)(3)(ii), Pacific Gas and Electric Company (PG&E) hereby requests NRC approval of Inservice Inspection (ISI) Program Relief Request SWOL-REP-1 U2 for an alternative to the ASME Code, Section XI, for preemptive full SWOLs.

This request for relief contains alternative requirements to ASME Section XI Repair/Replacement rules as applied to the DCPP Unit 2 pressurizer SWOLs. The bases for the request for relief are provided in the Enclosure. The key elements of the analyses associated with this relief request were presented to the NRC staff at the pre-submittal meeting (Reference 8).

Attachments 2 through 7 to the Enclosure contain AREVA Calculations associated with stress and flaw growth analyses which demonstrate the structural integrity of the DCPP Unit 2 pressurizer SWOLs for the 38-year design life of the weld overlays (current license plus 20 years), which are proprietary to AREVA. Attachment 8 includes AREVA's Affidavit for the calculations mentioned above. The affidavit is signed by AREVA, the owner of the information. The affidavit sets forth the basis on which the AREVA proprietary information contained in Attachments 2 through 7 may be withheld from public disclosure by the Commission, and it addresses with specificity the considerations listed in paragraph (b)(4) of 10 CFR 2.390 of the Commission's regulations. PG&E requests that the AREVA proprietary information be withheld from public disclosure in accordance with 10 CFR 2.390. Correspondence with respect to the AREVA Affidavit or the AREVA proprietary information provided in Attachments 2 through 7 should reference the AREVA Affidavit and be addressed to Gayle F. Elliott, Product Licensing Manager, AREVA NP, 3315 Old Forest Road, Lynchburg, VA 24501.

Attachments 9 through 14 to the Enclosure contain AREVA calculations that are non-proprietary versions of Attachments 2 through 7. Attachment 15 to the Enclosure contains conclusions of a third party review of AREVA calculations.

PG&E makes a new regulatory commitment to submit a supplemental analysis that will evaluate the reported flaw sizes with additional margin to account for possible flaw sizing variations that are associated with the repeatability of manual ultrasonic examination results, in future ISI inspections. That supplemental analysis will be submitted no later than June 16, 2014.

PG&E also makes a revised regulatory commitment in this submittal (as defined by NEI 99-04) to be implemented following NRC authorization of this Relief Request. The commitments are summarized in Attachment 16 to the Enclosure.

PG&E performed a root cause evaluation (RCE) to investigate the reasons that the fabrication related flaws were not detected during the installation acceptance examinations or during the first ISI examinations. A summary of the RCE and the list of corrective actions are presented in Attachment 1 to the Enclosure.

PG&E requests authorization of this relief request no later than July 31, 2014, in support of planning for the DCPP Unit 2 eighteenth refueling outage.

If you have any questions, or require additional information, please contact Tom Baldwin at (805) 545-4720.

Sincerely,

Barry S. Allen

Barry S. Allen
Site Vice President

RNTT/4231/50033145-78
Enclosure
cc: Diablo Distribution
cc/enc: Peter J. Bamford, NRC Project Manager
Marc L. Dapas, NRC Region IV Administrator
Thomas R. Hipschman, NRC Senior Resident Inspector
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Proposed Alternative
In Accordance with 10 CFR 50.55a(a)(3)(ii)

SWOL-REP-1 U2 Use of Alternate Repair Criteria

--Hardship or Unusual Difficulty
Without Compensating Increase in Level of Quality or Safety--

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Attachment 15: Conclusions of a Third Party Review of AREVA Calculations

Attachment 16: List of Commitments

Proposed Alternative
In Accordance with 10 CFR 50.55a(a)(3)(ii)

SWOL-REP-1 U2 Use of Alternate Repair Criteria

--Hardship or Unusual Difficulty
Without Compensating Increase in Level of Quality or Safety--

1. <u>ASME Code Component Affected</u>

The Code components associated with this request are three Class 1 dissimilar metal welds (DMWs) fabricated with Alloy 82/182 weld metal and overlaid with full structural weld overlays (SWOLs) that are listed in Section 1.2. The three subject SWOLs on Safety Nozzles A, B, and spray nozzle were applied in accordance with REP-1 U2, Revision 1 of this relief request during the Diablo Canyon Power Plant (DCPP) Unit 2 fourteenth refueling outage (2R14) in 2008.

1.1 Category and System Details:

Code Class: ASME Class 1
System: Reactor coolant system
Examination Categories: B-F (Risk-informed Category R-A)

1.2 Component Descriptions:

The proposed alternative applies to SWOLs installed on two safe end-to-safety nozzle DMWs and one safe end-to-spray nozzle DMW. The SWOLs extend outward across the adjacent stainless steel pipe-to-safe end welds. The applicable weld identifications are as follows:

a) Weld No. WIB-369SE Safe End-to-8010A Safety Nozzle Weld and adjacent Pipe-to-Safe End Weld No. WIB-369
Line Identifier 2-S6-729-6 (Safety Nozzle A)
b) Weld No. WIB-423SE Safe End-to-8010B Safety Nozzle Weld and adjacent Pipe-to-Safe End Weld No. WIB-423
Line Identifier 2-S6-728-6 (Safety Nozzle B)
c) Weld No. WIB-345SE Safe End-to-Spray Nozzle Weld and adjacent Pipe-to-Safe End Weld No. WIB-345
Line Identifier 2-S6-15-4SPL (Spray Nozzle)

1.3 Component Materials:

a) Nozzles are Low Alloy Steel SA-508 CL2 (P-No. 3 Group No. 3)
b) Safe End-to-Nozzle Welds and Buttering are Alloy 82/182 (F-No. 43)
c) Safe Ends are Wrought Stainless Steel SA-182 GR F316L (P-No. 8)
d) Attached Pipe is Wrought Seamless Stainless Steel SA-376 Type 316 (P-No. 8) and Welds are Stainless Steel (A-No. 8)
e) Pre-SWOL barrier layers were applied as follows: ER309L for the stainless steel base and weld metal, and ERNiCr-3 (Alloy 82) used locally at the interface between the Alloy 182 DMW and the stainless steel.
f) SWOL consisting of ERNiCrFe-7A (Alloy 52M) weld metal. The welding was performed to the requirements of REP-1 U2, Revision 1 using a remote machine gas tungsten arc welding (GTAW) process and the ambient temperature temper bead method.

The materials listed above apply to all pressurizer nozzles. A typical SWOL configuration is depicted in Figure 1.

2. Applicable Code Edition and Addenda

DCPP Unit 2 is currently in the third 10-year inservice inspection (ISI) interval. The ASME Boiler and Pressure Vessel Code (Code) of record is Section XI, 2001 Edition, including Addenda through 2003 (Reference 8.1) for the current 10-year ISI interval and the Repair/Replacement Program. ASME Code Section XI, 2001 Edition, no Addenda, Appendix VIII, Supplement 11, (Reference 8.2) as implemented by the Performance Demonstration Initiative (PDI) Program, is used for ultrasonic examination (UT) qualification for SWOLs. ASME Code Section XI, Appendix Q, 2004 Edition with 2005 Addenda (Reference 8.5) is used for SWOL ISI requirements for the remainder of the third inspection interval, nominally scheduled to end June 30, 2016.

3. Applicable Code Requirement

The applicable Code requirement for which relief is requested is ASME Code Section XI, 2001 Edition, including Addenda through 2003, IWA-4611 (Reference 8.1);

IWA-4611.1(a) states, in part, the following:

"Defects shall be removed in accordance with IWA-4422.1. A defect is considered removed when it has been reduced to an acceptable size."

4. Reason for Request

ISI examinations of the DCPP Unit 2 pressurizer SWOLs in the Unit 2 seventeenth refueling outage (2R17) identified lack of bond/interbead non-fusion fabrication flaws in three of the subject SWOLs that exceed the 3 inch linear length acceptance criteria established in the NRC approved SWOL installation relief request REP-1 U2, Revision 1 (References 8.6 to 8.9). As such, modification to the acceptance criteria in REP-1 U2, Revision 1 was needed for continued operation without repair. After performing structural evaluations of the fabrication flaws, REP-1 U2, was revised to include the 2R17 as-found flaw sizes and re-submitted for NRC approval in March of 2013 (References 8.10 to 8.11). On March 8, 2013, the NRC verbally authorized the use of Relief Request REP-1 U2, Revision 2, for one fuel cycle following 2R17. This authorization was formalized by NRC letter dated August 28, 2013 (ADAMS Accession No. ML13232A308), which also contains the Safety Evaluation Report (SER) for DCPP Unit 2 Relief Request REP-1 U2, Revision 2 alternative acceptance criteria for flaws in pressurizer nozzle welds (Reference 8.12).

PG&E requests NRC approval of SWOL-REP-1 U2 for continued operation to the end of current license plus 20 years, with the as-found flaw sizes reported in 2R17.

4.1 Background of Request

The SWOLs were installed during 2R14 in 2008 on the Unit 2 pressurizer nozzles. Industry operating experience indicated that the weld material used to connect the nozzles to the associated piping was susceptible to primary water stress corrosion cracking (PWSCC). As such, routine UT of the welds was required to confirm the absence of cracking. However, prior to SWOL installation, due to the geometric profile of the nozzles, full coverage of the Code specified inspection volume was not possible. Consequently, a SWOL was applied, which shifted the stress in the nozzle welds from tensile to compressive, eliminating the susceptibility to cracking. In addition, the SWOL provided a surface contour that supported future UT of the SWOLs and part of the underlying base material.

Immediately following the installation of the six DCPP Unit 2 pressurizer SWOLs (on Safety Nozzles A, B, C, spray nozzle, power operated relief valve nozzle, and surge nozzle), the original equipment manufacturer (OEM) (i.e., the SWOL installation vendor) performed acceptance and pre-service inspection (PSI) examinations using the manual, conventional UT process in accordance with the PDI generic procedure, PDI-UT-8 Revision F, under the cover of the OEM implementing procedure.

The manual conventional PDI generic procedure employs discrete beams including 0, 40, 45, 60, and 70° refracted longitudinal (RL) and a high angle beam referred to as OD Creeper (ODCR) for the acceptance examination of the SWOL volume and the PSI examination of the outer 25 percent of the original base material. No indications were reported in any of the nozzles with the exception of Safety Nozzle A SWOL where two indications, each approximately 1 inch in length, were detected near the SWOL to base-material interface and over the low-alloy steel nozzle forging. The indications were recorded with both 0 and 45° search units, classified as "lack of bond" and evaluated as acceptable per the criterion established in PG&E overlay installation relief request REP-1 U2, Revision 1.

In October 2009, during the Unit 2 fifteenth refueling outage (2R15), all six SWOLs received the first ISI examination by OEM examiners. The same PDI generic procedure (i.e., PDI-UT-8) was used, but the examination angles were limited to 40, 45 and 60° RL angle beams as indicated by the procedure for ISI examinations (i.e., PDI-UT-8). The results were identical to the acceptance examinations with the two indications in the Safety Nozzle A reported as unchanged. Based on these results, the six pressurizer SWOLs inspection extent and frequency converted to the normal ISI schedule with 25 percent of the welds selected for examination over the ten-year ISI interval per the requirements of REP-1 U2, Revision 1.

In 2R17, one pressurizer safety nozzle SWOL was routinely scheduled for ISI examination. During the inspection, three adjacent and co-linear lack of bond/interbead non-fusion flaws were detected that when combined in length per the rules of IWA-3300(b), Figure IWA -3360 -1, exceeded the 3 inch length limit for laminar indications established in REP-1 U2, Revision 1. Examination scope was expanded to a second safety nozzle SWOL where a longer lack of bond/interbead non-fusion flaw that also exceeded the installation acceptance criteria of 3-inch linear length was identified. Subsequent to this finding, scope was expanded to include all pressurizer SWOLs. Similar flaws exceeding the criteria of 3-inch linear length were detected in the spray nozzle SWOL and smaller indications

meeting the established acceptance criteria were detected in the third safety nozzle SWOL. No recordable indications were reported in the power operated relief valve and surge line nozzle SWOLs.

Table 1 provides a comprehensive list of recordable indications that were detected during 2R17 ISI examination. Circumferential and axial locations of indications in Safety Nozzles A, B, C and spray nozzle are shown in Figures 2 through 9, which supplement the information presented in Table 1. The lengths of identified flaws in Safety Nozzle C are less than the 3-inch linear length acceptance criteria. Safety Nozzle C is included only for completeness.

REP-1 U2, Revision 2 addressed the newly detected fabrication-related flaws identified in the SWOLs during 2R17. The request included a structural evaluation that concluded that the identified flaws did not pose a challenge to the structural integrity of the SWOLs. REP-1 U2, Revision 2 also reported the apparent cause for the subject flaws not being detected in the acceptance and subsequent ISI UTs. After 2R17, PG&E conducted an extensive root cause evaluation (RCE) for the missed detections.

<u>Missed Fabrication Flaws Root Cause Evaluation</u>

The RCE found that the SWOL fabrication flaws were not detected in 2008 acceptance examinations and the 2009 ISI examination due to a combination of factors. Investigations in 2R17 by PG&E and Electric Power Research Institute (EPRI) found that the subject fabrication flaws are detectable with the conventional UT procedure, PDI-UT-8, Revision F which was used for the acceptance and the subsequent initial ISI examinations.

A summary of the RCE report including PG&E/EPRI evaluations of the conventional and phased array (PA) UT techniques applied to the SWOLs and the results of the Human Error Investigation Tool used to evaluate the human performance aspects is included in Attachment 1 to the Enclosure. A summary of the RCE conclusions follows:

- The same exam rigor applied in qualification testing was not applied in the field. This finding is supported by the short 0° scan times recorded for the 2008 acceptance examinations that indicate field scan speeds were at or near procedure maximums. In contrast, RCE investigations determined that the scan speeds employed during qualification testing for the 0° search unit are typically significantly less than the maximum allowed by procedure. The root cause states

that the conventional UT exam procedure PDI-UT-8, Revision F did not constrain the 0° scan speeds adequately.

- The 2013 reinvestigation efforts by EPRI and PG&E found that slower scan speeds were required to produce indications with easily recognizable signal to noise ratios and to trace the extent of the indications with the 0° transducer. With the higher scan speed used for the 0° acceptance examinations, failure to detect the subject fabrication flaws is not unexpected and provides an explanation for the performance delta between qualification testing and field implementation.

- The RCE primary contributing cause is inattentive error by examiners. This assessment applies to both 0° and angle beam examinations and is based on the 2R17 reinspection of Safety Nozzle A. During both the acceptance and first ISI examinations, two small indications were recorded with both 0 and 45° search units. The reinvestigation with the original exam equipment and procedure found that indications were detectable and could be traced to extents comparable to the PA UT results.

The conventional UT procedure PDI-UT-8 has proven multiple times in qualification testing the ability to detect flaws as specified by the ASME XI, Appendix VIII, Supplement 11 rules. Additionally, there are many instances where the subject procedure has identified rejectable laminar type flaws in the field. The RCE concludes: "Based on EPRI review of manual conventional UT and manual PA SWOL qualification test results from 2010 through 2013, regardless of the advantages of PA for field application, no statistical advantage for either method exists regarding missed detections of fusion type (LOB) flaws in qualification testing. This evidence supports the conclusion that, if the rigor applied in the qualification setting is transferred to the field, reasonable performance of the conventional UT process should be expected."

Corrective Actions to Prevent Recurrence

The RCE primary corrective action precludes use of the conventional UT procedure which was used for the acceptance examinations during 2R14 and the subsequent 2R15 initial ISI examinations.

To ensure reliability of the subsequent pressurizer SWOL examinations, PG&E will use the same PA UT procedure that detected the missed indications, EPRI-WOL-PA-1 Revision 2, "Procedure for Manual Phased

Array Ultrasonic Examination of Weld Overlaid Similar and Dissimilar Metal Welds," or a later revision.

Additionally, new PG&E procedures are in effect that control and monitor implementation of non-destructive examination (NDE) activities with special considerations for DCPP and industry operating experience (OE) related to missed UT detections. The procedures contain the latest industry guidance developed by the NDE Improvement Focus Group (NIFG). PG&E's implementation of the guidance exceeds NEI-03-8 requirements and includes:

- Development of pre-job planning package with information such as component configuration, materials of construction, location, exam history, etc.
- NDE/UT specific pre and post job briefing requirements that address issues related to industry OE on missed indications.
- Requirement for documented formal oversight that verifies preparation, briefing, implementation (including scan speed) and documentation activities meet procedure requirements.

<u>Unit 2 Seventeenth Refueling Outage Phased Array Examinations</u>

<u>Phased Array Technique Advantages</u>
The manual PA procedure used for the 2R17 examinations, EPRI-WOL-PA-1, like the manual conventional UT procedure, PDI-UT-8, has been proven effective in qualification testing in accordance with Appendix VIII, Supplement 11 rules and also has detected and rejected laminar reflectors in the field. The PA examination process that identified the previously undetected flaws in 2R17 has distinct advantages that enhance the examiner's ability to detect and size flaws. The following is a list of some of the PA technique's beneficial attributes:

- The part is simultaneously interrogated with a full range of angles from 0° through approximately 85° for optimum response from flaws of various orientations and from irregular surface contours
- Procedure method for establishing examination gain setting results in high sensitivity at low angles that produces large reflections from lack of bond/interbead non-fusion indications
- Improved user interface and indication response characteristics including:
  - Display of all exam angles simultaneously
  - Greatly enhanced signal persistence from narrow width, lack of bond/interbead non-fusion indications as the various angles

interrogate the reflector while scanning

- Sector scan presentation provides examiner with spatial relationship of indications
- Color amplitude encoding of signal amplitude enhances contrast of signal responses
- Simultaneous display of the sector scan and conventional type A-scan provides supplemental characterization information

As stated in EPRI Report IR -20130541 R1, "Review of Ultrasonic Examinations Performed at Diablo Canyon Nuclear Power Plant during In-Service Examination of Pre-Emptive Weld Overlays":

> "This review concluded that both techniques were capable of detecting these flaws, but that the newly deployed PA techniques were much more sensitive (>6dB) and provided a more robust capability to identify and characterize these flaws due to the use of multiple beam angles. The new techniques required less operator precision during scanning and provided enhanced displays, which aided in detection and evaluation."

<u>2R17 Examination Implementation Rigor</u>

Root cause investigations from recent industry OE regarding missed flaw detections implicate exam implementation rigor as a major influence in the performance of UTs. Similar to the DCPP RCE findings, scan speed and examiner performance have been highlighted as contributing factors for missed flaw detections. Industry initiatives intended to correct these issues have been recently developed and implemented. The 2R17 exams that identified the previously undetected fabrication flaws incorporated the latest industry guidance developed to address these issues.

Specifically, in light of this recent OE the industry responded by forming the NIFG to address improvements to examinations of DMWs. Although not specifically required for performance of overlay examinations, PG&E elected to implement applicable elements of the corrective actions from NIFG for the scheduled PA examinations of the DCPP overlay in 2R17.

PG&E recognizes the importance of proper implementation rigor for NDE examinations, especially for non-standard applications. As such, the planning, preparation activities and execution of the 2R17 PA examinations received added attention and oversight. The following actions were implemented to assure an effective examination:

Examination preparations

- Examiners had recent PA exam training and practice at EPRI
- Overlay fabrication and examination records including results, surface contours, thickness profiles were reviewed
- Calibration and exam parameters were developed and tested pre-outage
- A formal oversight plan was developed based on recent industry missed indications OE
- An extensive pre-job brief was performed that included elements specific to recent OE on missed indications
- Monitored hands on practice on representative EPRI "Rhino Horn" overlay sample prior to exam in 2R17

Field Implementation

- Exams were performed by PG&E level III personnel
- Formal oversight of examinations by PG&E level III experienced in PA
- Full physical access to SWOLs and no scanning limitations
- Recorded exam durations indicate careful approach to scanning
- A previously unrecorded flaw was detected early in the 2013 ISI exam, raising examiners awareness for the possibility of additional previously unrecorded indications
- Re-validation of flaw indications was performed to confirm sizes and positions
- Sample time encoded data was forwarded to EPRI and OEM experts for independent review of indication characterization

PG&E's attention to detail in the implementation of the 2013 examinations combined with the robustness of the PA technique provided high confidence that any fabrication flaws that may have a long term impact over the remaining service life of the subject pressurizer SWOLs would have been detected and correctly sized.

The EPRI reinvestigation of the results of the 2013 PA examinations concluded that flaw extents are comparable between the two techniques when the conventional technique is applied appropriately. This result indicates the recent industry developed corrective actions for missed flaw detections are correctly focused towards the goal of improving the reliability of UTs.

5. Proposed Alternative and Basis for Use

This relief request proposes the use of alternate repair criteria requirements. The proposed alternative is to allow the lack of bond/interbead non-fusion indications identified and sized in 2R17 to remain in-service without repair. PG&E proposes that the alternate criteria, determined by the technical analysis as described herein for the pressurizer Safety Nozzles A, and B, and the spray nozzle, be applied in lieu of the repair requirements of ASME Section XI, IWA-4611.1(a).

A brief summary of the previous evaluation of indications that was submitted to the NRC in 2013 is presented in Section 5.1 (Reference 8.10). Pertinent items that were discussed with the NRC during the pre-submittal meeting in October 2013, are presented in Section 5.2 (Reference 8.13). A summary of the current evaluation of indications is presented in Section 5.3. Successive inspections that are planned during the next three ISI periods and related inspections are presented in Section 5.4 and Section 5.5, respectively. The potential hardship associated with repair activity of the SWOLs is presented in Section 5.6, followed by the conclusion in Section 5.7.

5.1 Summary of Previous Evaluation of Indications Exceeding the Criteria of REP-1 U2, Revision 1

The evaluations of indications exceeding the criteria of 3-inch linear length of REP-1 U2, Revision 1, performed during 2R17 are documented in Reference 8.10. The following is a brief summary of the approach used in the evaluations of the indications.

Planar Flaw Evaluations

In 2013, an analysis was performed to address the circumferential planar indication (Indications 1 and 1A are evaluated as planar due to the reported difference in depth of the coexisting lack of bond flaws) in Safety Nozzle A (AREVA Calculation 32-9199805-000, "Diablo Canyon Power Plant Unit 2 Pzr Safety and Spray Nozzles Planar Flaw Analysis") (see Enclosure 3 in Reference 8.10). This evaluation considered detailed path line transient and residual stresses from existing path lines used in the original design of the weld overlay that was completed in 2007. As such, the path line stresses in close proximity to the indications were selected with justification. In addition, both circumferential and axial planar flaws were postulated in the occluded zones of 2R17 PA inspections in Safety Nozzles B and C, as well as in the Spray Nozzle. The planar flaw growth evaluations were performed, considering the design transients for the 38-

year design life of the weld overlays (current license plus 20 years). All the planar flaws were demonstrated to meet the flaw acceptance standards of ASME Section XI, IWB-3514 and the acceptance criteria of ASME Section XI, IWB-3640.

Laminar Flaw Evaluations

The as-found laminar indications in the safety nozzles , and the spray nozzle that exceeded the original installation acceptance criteria of 3-inch linear length (Reference 8.9) were evaluated in AREVA Calculation No. 32-9199937-000, "DCPP Unit 2 –Evaluation of Laminar Indications on Pressurizer Nozzles" (see Enclosure 4 in Reference 8.10). This analysis demonstrated that all laminar indications exceeding the 3 inch linear length criteria of REP-1 U2, Revision 1, meet the surface area acceptance criteria of ASME Section XI, Table IWB-3514-3. The nozzle geometry and SWOL length of each of these affected nozzles were also evaluated, excluding the laminar indications, and were determined to be of sufficient length to transfer the faulted condition loads through shear back to the base metal conservatively considering a 100 percent through-wall crack in the PWSCC susceptible material. This was based on a conservative criterion for maximum allowable shear stress from ASME Section III, NB-3227.2. However, this evaluation did not account for potential fatigue crack growth for laminar indications (due to the design transients for the 38-year design life of the weld overlays) since there is no such explicit requirement when evaluating laminar indications per Section XI of the ASME Code.

Summary

On March 8, 2013, the NRC verbally authorized the use of Relief Request REP-1 U2, Revision 2, for one fuel cycle following 2R17. This authorization was formalized by NRC letter dated August 28, 2013), which also contains the SER for DCPP Unit 2 Relief Request REP-1 U2, Revision 2 alternative acceptance criteria for flaws in pressurizer nozzle welds (Reference 8.12).

In Reference 8.12 the NRC staff expressed concern regarding the impact of the laminar indications on the structural integrity of the overlaid welds, if they are permitted to remain in service. In Section 3.2.4 of the SER, the NRC Staff concludes that although the licensee's flaw evaluation has demonstrated the structural integrity of the overlaid DMWs with the laminar indications, the flaw evaluation in accordance with the ASME Code, Section XI, IWB-3600 is based on the analysis of a single flaw, not a group of flaws in a component. The NRC Staff noted that one possible

solution is to use a finite element model that would include all the laminar indications to analyze the impact of combined laminar indications on the overlaid DMWs.

5.2 Safety Evaluation Report Clarification and October 2, 2013, Pre-Submittal Meeting with the NRC

At the October 2, 2013, pre-submittal meeting (summarized in Reference 8.13) the key elements of the flaw analysis modeling and analytical approach were presented to the NRC Staff. PG&E's technical approach to addressing the NRC Staff's concerns from Section 3.2.4 of the SER was presented. Key elements of the technical approach are: for a given nozzle, combine multiple flaws into larger bounding flaws in accordance with ASME proximity rules; extract stresses from two-dimensional axisymmetric finite element models; use classical crack models for stress intensity factors; and calculate the fatigue crack growth for remaining life (i.e., 38-years). There were no objections from the NRC Staff regarding the use of PG&E's technical approach to address NRC Staff's concerns in the SER. The NRC Staff did suggest to PG&E to describe and/or define acceptance criteria for indications and/or crack growth from repeatability of inspections, in the relief request.

5.3 Evaluations of All Detected Laminar and Planar Indications in the Structural Weld Overlays (SWOL) of the Pressurizer Nozzles Using Alternative Criteria

All recordable indications from Safety Nozzle A, B, C, and Spray Nozzle are reported in Table 1. The lengths of identified flaws in Safety Nozzle C are less than the 3-inch linear length acceptance criteria. Safety Nozzle C is included only for completeness. For each of these nozzles, all recordable indications are illustrated as a radial rollout of the nozzle with the overlay, and with a corresponding axial view of the nozzle with the overlay as Figures 2 through 9, respectively. Spot indications (i.e., indications without significant length or width dimensions) are included in Table 1 and in Figures 2 through 9 for completeness. As a result, all the recordable indications except for the spot indications are considered, as reportable indications and summarized in Table 2. Table 2 also provides a comparison of the recordable indications against the original installation acceptance criteria of 3" linear length for the laminar indications. Detailed analysis of these recordable indications, for a given nozzle, were subsequently performed. The results from this rigorous analysis are summarized in Table 3.

All the laminar indications in safety nozzles, including a through-wall dimension of an indication in Safety Nozzle A that is conservatively treated as a planar indication, are evaluated in AREVA Proprietary Calculation No. 32 -9215965-001 "Diablo Canyon Unit 2 Pressurizer Safety/Relief Nozzles Laminar/Planar Flaw Analysis" (see Attachment 2). All the laminar indications in the spray nozzle are evaluated in AREVA Proprietary Calculation No. 32-9213780-001, "Diablo Canyon Unit 2 Pressurizer Spray Nozzle Laminar Flaw Analysis" (see Attachment 3). A detailed fatigue crack growth analysis is performed considering the design transients, to demonstrate acceptability of the final flaw size of the planar and the laminar indications over the 38-year design life of the weld overlay (current license plus 20 years). The planar flaw evaluation is performed in accordance with the rules of ASME Section XI, IWB-3612 and IWB-3640. The predicted final flaw sizes of the laminar indications are evaluated in accordance with the rules of ASME Section XI, Table IWB-3514-3 and ASME Section III, article NB-3227.2.

The analysis approach used in the evaluation of the laminar indications is to combine multiple flaws, per the ASME Section XI proximity rule, and further extend them to include a complete 360° circumferential length. By this means, detailed localized path line stresses (located at flaw indications as shown in Figures 2 through 9 and oriented to capture the required stresses) can be extracted from the uncracked two-dimensional axisymmetric finite element models. For the safety nozzles, the operating transient path line stresses at each of the applicable planar and laminar indication locations are extracted from AREVA Proprietary Calculation No. 32-9049114-003, "Diablo Canyon Unit 2 Pressurizer Safety/Relief Nozzle Weld Overlay Structural Analysis" (see Attachment 4). Similarly, the residual stresses for the safety nozzles are extracted from AREVA Proprietary Calculation No. 32-9049062-004, "Diablo Canyon Unit 2 Pressurizer Safety/Relief Nozzle Weld Overlay Residual Stress Analysis" (see Attachment 5). For the spray nozzle, the operating transient path line stresses at each of the applicable laminar indication locations are extracted from AREVA Proprietary Calculation No. 32-9049112-003, "Diablo Canyon Unit 2 - Pressurizer Spray Nozzle Weld Overlay Structural Analysis" (see Attachment 6). Similarly, for the spray nozzle, the residual stresses are extracted from AREVA Proprietary Calculation No 32-9049061-005, "Diablo Canyon Unit 2 Pressurizer Spray Nozzle Weld Overlay Residual Stress Analysis" (see Attachment 7).

For the laminar indications that are located at the interface between the nozzle and the SWOL material, two sets of path line stresses are considered for each indication. The first set of path line stresses

considered an SWOL material and the second set of path line stresses considered a nozzle material.

The applied stress intensity factors for the laminar indications are evaluated considering the classical center-cracked panel model solution. The crack is assumed to grow along the width of the laminar indications (i.e. longitudinally along the axis of the pipe). The component stresses that contribute to crack growth in this direction are the radial and shear stresses. As a result, these types of component stresses are extracted for the transient operating conditions as well as the residual stresses to evaluate the end of life flaw sizes for these laminar indications. A mixed mode fracture mechanics analysis is performed to address the radial and shear stresses using the center-cracked panel model solutions. The applied stress intensity factor for the planar flaw is evaluated assuming a full 360° circumferential flaw. Hence, axial component stresses are extracted for the transient operating conditions as well as residual stresses to evaluate the end of life flaw size for the planar indication.

Safety Nozzle A

Laminar Flaw Growth Evaluations

The flaw growth evaluations were performed considering the design transients for the 38-year design life of the weld overlays (current license plus 20 years). The laminar indications 1 and 1A, with an initial width of 0.4 inches with an assumed 360° circumferential extent to conservatively estimate the axial growth is predicted to grow to a final flaw size of only 0.40017 inches at the end of the 38-year SWOL design life. . These indications have an initial circumferential length of 16.3 inches and a final circumferential length of 16.306785 inches. They were compared against the acceptance standards of ASME Section XI, IWB-3514-3. The surface area of these indications is 4.9 in^2 versus an allowable of 7.5 in^2 and found to be acceptable. The Safety Nozzle A geometry and SWOL length excluding these indications have been evaluated and determined to be sufficient to transfer the load through shear back to the base metal, conservatively considering a 100 percent through wall crack in the PWSCC susceptible material (an effective length of 0.91 inches versus a required length of 0.77 inches). A conservative criterion for maximum allowable shear stress from ASME III, NB-3227.2 was utilized. These indications are acceptable as-is due to the ample amount of structural integrity margin in the remaining weld overlay.

Planar Flaw Growth Evaluations

Indications 1 and 1A, while being primarily laminar in nature, were conservatively assumed to have a 0.080 inches through-wall dimension (planar indication). The flaw growth of this planar indication, over 38 years, was determined to be negligible (0.080002 inches final flaw depth). The final flaw size was evaluated against the allowable flaw depth in accordance with the rules of ASME Section XI, IWB-3612 and IWB-3640, considering normal, upset and faulted loading conditions and found to be acceptable with significant margin. AREVA Calculation No. 32-9215965-001 provides a quantitative and conservative assessment of this margin (see Attachment 2).

Safety Nozzle B: Laminar Flaw Growth Evaluations

The flaw growth evaluations were performed considering the design transients for the 38-year design life of the weld overlays (current license plus 20 years). The combined laminar indications 1, 2 and 3, with an initial width of 0.25 inches and an assumed 360° circumferential extent are predicted to have negligible growth after 38 years. These indications have a combined initial circumferential length of 4.7 inches and a surface area of 0.9 in^2, considering flaw growth over 38 years, versus an allowable of 7.5 in^2 per ASME Section XI, IWB-3514-3 and found to be acceptable. The Safety Nozzle B geometry and SWOL length excluding these indications have been evaluated and determined to be sufficient to transfer the load through shear back to the base metal, conservatively considering a 100 percent through wall crack in the PWSCC susceptible material (an effective length of 1.06 inches versus a required length of 0.77 inches). A conservative criterion for maximum allowable shear stress from ASME III, NB-3227.2 was utilized. These indications are acceptable as-is due to the ample amount of structural integrity margin in the remaining weld overlay. AREVA Calculation No. 32-9215965-001 provides a quantitative and conservative assessment of this margin (see Attachment 2).

Safety Nozzle C : Laminar Flaw Growth Evaluations

The axial position of laminar indication 3 is approximately the same as that of indication 1a of Safety Nozzle A. Indication 3 has a width of 0.25 inches and a circumferential length of only 0.75 inches and is conservatively considered to be bounded by the results of the laminar flaw evaluation of indications 1 and 1A of safety nozzle A.

Laminar indication 4 with an initial width of 0.25 inches and an assumed 360° circumferential extent is predicted to have negligible growth after 38 years. This indication has an initial circumferential length of 2 inches and a surface area of 0.4 in^2, considering flaw growth over 38 years, versus an allowable of 7.5 in^2 per ASME Section XI, IWB-3514-3 and found to be acceptable. The Safety Nozzle C geometry and SWOL length excluding these indications have been evaluated and determined to be sufficient to transfer the load through shear back to the base metal, conservatively considering a 100 percent through wall crack in the PWSCC susceptible material (an effective length of 4.41 inches versus a required length of 1.073 inches). A conservative criterion for maximum allowable shear stress from ASME III, NB-3227.2 was utilized. These indications are acceptable as-is due to the ample amount of structural integrity margin in the remaining weld overlay. AREVA Calculation No. 32-9215965-001 provides a quantitative and conservative assessment of this margin (see Attachment 2).

Spray Nozzle : Laminar Flaw Growth Evaluations

The flaw growth evaluations were performed considering the design transients for the 38 year design life of the weld overlays (current license plus 20 years). The laminar indications 1 and 4, with a maximum initial width of 0.42 inches with an assumed 360° circumferential extent to conservatively estimate the axial growth is predicted to grow to a final flaw size of only 0.4222 inches at the end of the 38 year SWOL design life.

For evaluation of the surface area, the laminar indications 1 and 4 are grouped into two groups based on the proximity rules of Section XI of the ASME code. The first group is 16.3 inches long (initial length) with an initial width of 0.42 inches, and the second group is 2.1 inches long (initial length) with an initial width of 0.25 inches. For the second group, an initial width of 0.42 inches was conservatively used to assess the final width and the area. The surface area of the first group and the second group were compared against the acceptance standards of ASME Section XI, IWB-3514-3. The surface area of the first group is 5.2 in^2, considering flaw growth over 38 years, versus an allowable of 7.5 in^2 and found to be acceptable. The surface area of the second group is 0.67 in^2, considering flaw growth over 38 years, versus an allowable of 7.5 in^2 and found to be acceptable. The spray nozzle geometry and SWOL length excluding these indications have been evaluated and determined to be sufficient to transfer the load through shear back to the base metal, conservatively considering a 100 percent through wall crack in the PWSCC susceptible material (an effective length of 1.26 inches versus a required length of 0.48 inches). A conservative criterion for maximum allowable shear

stress from ASME III, NB-3227.2 was utilized. These indications are acceptable as-is due to sufficient amount of structural integrity margin in the remaining weld overlay.

The laminar indications 2 and 3, with a maximum initial width of 0.312 inches with an assumed 360° circumferential extent to conservatively estimate the axial growth, is predicted to grow to a final flaw size of only 0.3263 inches at the end of the 38-year SWOL design life. These indications have a circumferential length of 0.8 inches. They were compared against the acceptance standards of ASME Section XI, IWB-3514-3. The surface area of these indications is 0.2 in^2, considering flaw growth over 38 years, versus an allowable of 7.5 in^2 and found to be acceptable. The spray nozzle geometry and SWOL length excluding these indications have been evaluated and determined to be sufficient to transfer the load through shear back to the base metal, conservatively considering a 100 percent through wall crack in the PWSCC susceptible material (an effective length of 3.93 inches versus a required length of 0.76 inches). A conservative criterion for maximum allowable shear stress from ASME III, NB-3227.2 was utilized. These indications are acceptable as-is due to ample amount of structural integrity margin in the remaining weld overlay. AREVA Calculation No. 32-9213780-001 provides a quantitative and conservative assessment of this margin (see Attachment 3).

5.4 Successive Inspections

SI examination of Safety Nozzle A, B, and C, and the Spray Nozzle SWOLs will be performed during the next three ISI periods in accordance with Section XI, IWB-2420 using the manual phased array examination procedure EPRI-WOL-PA-1 Revision 2, "Procedure for Manual Phased Array Ultrasonic Examination of Weld Overlaid Similar and Dissimilar Metal Welds" or later revision, to confirm that the identified reflectors have not exceeded the acceptance criteria being established in the supplemental analysis. The reexaminations will include those indications that are located outside the defined inservice inspection volume.

5.5 Related Inspections

The Pressurizer Nozzles are subject to VT-2 examination during pressure test associated with startup every refueling outage.

5.6 Potential Hardship

To restore the weld overlays to compliance with the 3-inch linear dimension requirement specified in REP-1 U2, Revision 1, the flaws in the overlays will have to be excavated and repaired. The repairs of the overlays present a hardship for the following reasons:

- Repairs to the weld overlay would be required on Safety Nozzle A, Safety Nozzle B, and spray nozzle. These nozzles are located at the top of the pressurizer, which is approximately 25 feet from the containment floor with intervening hazards. Repair of the overlays will expose personnel to potential fall hazards. Exacerbating the fall hazard, is the tight and awkward environment in which the work is required to be performed, requiring workers to maneuver around pipes and openings in grating.

- Completion of the repair would incur increased dose. Although the average effective dose rate is not excessive in the area (approximately 4.5 mR per hour), the amount of work and number of people required to prepare, perform, monitor, inspect and demobilize from the repair is such that the total dose accumulated is high. Based on schedule and personnel estimates, the total dose required to perform the repair work is at least 2.6 Rem. This would result in this single activity being approximately 10 percent of the total dose expected for an entire refueling outage.

- The installation of the original weld overlays required rework of pipe hangers and realignment of piping. Although the repair work is not as extensive as the original overlay work, it does have the potential to require rework of some pipe hangars and cutting and re-welding to realign the discharge piping for the two safety relief valve SWOLs that would require repairs. This would further increase personnel exposure to fall hazards and radiation.

5.7 Conclusion

NRC approved requests have been used to produce acceptable weld overlays (References 8.6 to 8.9) when applied to Alloy 82/182 DMWs at other facilities (see Section 6). NRC approved criteria (Reference 8.9) was developed to cover operating experience that is associated with similar SWOL applications at the time the SWOLs were applied. Indications identified with the PA ultrasonic technique have been evaluated based on NRC approved criteria (Reference 8.9), NRC Staff's

concerns presented in Section 3.2.4 of the SER (Reference 8.12), NRC Staff's suggestions at pre-submittal meeting (Reference 8.13), and the requirements that are discussed in Sections 5.1 to 5.3 of this request. The structural analysis and the fracture mechanics flaw growth analyses that have been performed by AREVA demonstrate that the existing structural integrity of the weld overlay provides an acceptable level of quality and safety with significant margin, and that the repair of the identified flaws on Safety Relief Valve Nozzles A, B and the pressurizer spray line nozzle does not provide a compensating increase in safety to offset the hardships discussed above.

Therefore, this request proposes the use of the alternative to repair criteria requirements. PG&E considers that the technical analysis discussed in Sections 5.1 to 5.3, and continued application of the previously NRC-approved PDI Program ultrasonic examination qualification alternative to ASME Section XI, 2001 Edition, no Addenda, Appendix VIII, Supplement 11, and successive ISI examinations in the next three ISI periods, provide an acceptable level of quality and safety, and that the hardship of implementing repair activities on the existing SWOLs does not provide a compensating increase in safety.

6. <u>Precedents</u>

Relief requests have been submitted by other utilities to address the PWSCC susceptibility of Alloy 82/182 weld issues that are contained in this request. The following relief requests have been approved by the NRC:

6.1 AmerGen Energy Company, Three Mile Island Nuclear Station, Unit 1, on July 21, 2004, in NRC letter, "Three Mile Island Nuclear Station, Unit 1 (TMI-1) Request for Relief from Flaw Removal, Heat Treatment, and Nondestructive Examination Requirements for the Third 10-year Inservice Inspection (ISI) Interval, (TAC No. MC1201)," (ADAMS Accession No. ML041670510).

6.2 Constellation Energy's Calvert Cliffs Nuclear Power Plant, Unit 2, on July 20, 2005, in NRC letter, "Calvert Cliffs Nuclear Power Plant, Unit Nos. 2 – Relief Request for Use Weld Overlay and Associated Alternative Inspection Techniques (TAC Nos. MC6219 and MC6220)," (ADAMS Accession No. ML051930316).

6.3 Millstone Unit 3, on January 20, 2006, in NRC letter, "Millstone Power Station, Unit No. 3 – Issuance of Relief from Code

Requirements (TAC No. MC8609)," (ADAMS Accession No. ML053260012).

6.4 Indiana Michigan Power Company, Donald C. Cook Unit 1, on February 10, 2006, in NRC letter, "Donald C. Cook Nuclear Plant, Unit 1 (DCCNP-1) – Alternatives Regarding Repair of Safe-End-To-Elbow Weld 1-RC-9-01F (TAC No. MC8807)," (ADAMS Accession No. ML060240355).

6.5 Indiana Michigan Power Company, Donald C. Cook Unit 2, on March 1, 2007, in NRC letter, "Donald C. Cook Nuclear Plant, Unit 2 (DCCNP-2) – Alternative Regarding Use of Preemptive Weld Overlays on Certain Dissimilar Metal Welds (TAC No. MC9305)," (ADAMS Accession No. ML070460121).

7. Duration of Proposed Alternative

The alternative examination acceptance criterion of this request will be applied to the subject SWOLs for the expected life of the overlays, which is 20 years beyond the current license expiration date of August 26, 2025.

The alternate examination qualification requirements will be applied until the end of the SWOL subsequent examination schedule.

8. References

8.1 ASME Code, Section XI, 2001 Edition, including Addenda through 2003

8.2 ASME Code, Section XI, 2001 Edition, no Addenda, Appendix VIII, Supplement 11

8.3 EPRI MRP-169 "Technical Basis for Preemptive Weld Overlays for Alloy 82/182 Butt Welds in PWRs," October 2005

8.4 EPRI Report 1013558, "Temperbead Welding Applications, 48 Hour Hold Requirements for Ambient Temperature Temperbead Welding," Technical Update, December 2006

8.5 ASME Code Section XI, Appendix Q, 2004 Edition with 2005 Addenda

8.6 PG&E Letter DCL-07-038, "ASME Section XI Inservice Inspection Program Relief Request REP-1 U2," dated March 28, 2007 (ML070990060)

8.7 PG&E Letter DCL-07-099, "ASME Section XI Inservice Inspection Program Relief Request REP-1 U2, Revision 1, and Response to Request for Additional Information," dated October 22, 2007 (ML073040029)

8.8 PG&E Letter DCL-07-105, "ASME Section XI Inservice Inspection Program Relief Request REP-1 U2, Revision 1; Response to Request for Additional Information," dated November 29, 2007 (ML073460045)

8.9 NRC Letter, "Diablo Canyon Power Plant, Unit No. 2 – Approval of Relief Request REP-1 U2, Revision 1, for the Application of Weld Overlay on Dissimilar Metal Welds of Pressurizer Nozzles (TAC No. MD4974)," dated February 6, 2008 (ML080110001)

8.10 PG&E Letter DCL-13-021, Diablo Canyon Unit 2 "ASME Section XI Inservice Inspection Program Relief Request REP-1 U2, Revision 2" dated March 5, 2013 (ML13078A294)

8.11 PG&E Letter DCL-13-024, Diablo Canyon Unit 2 "Supplement to ASME Section XI Inservice Inspection Program Relief Request REP-1 U2, Revision 2" dated March 7, 2013 (ML13067A343)

8.12 NRC Letter, "Diablo Canyon Power Plant, Unit No. 2 – Request for Approval of an Alternative to the ASME Code, Section XI, for Preemptive Full Structural Weld Overlays (TAC No. MF0880)," dated August 28, 2013 (ML13232A308).

8.13 NRC Letter, "Summary of October 2, 2013, Pre-submittal Meeting with Pacific Gas and Electric Company to Discuss a Request to use an Alternative to Disposition Detected Laminar Indications on Pressurizer Safety Nozzles (TAC No. MF2675)," dated November 7, 2013 (ML13282A382)

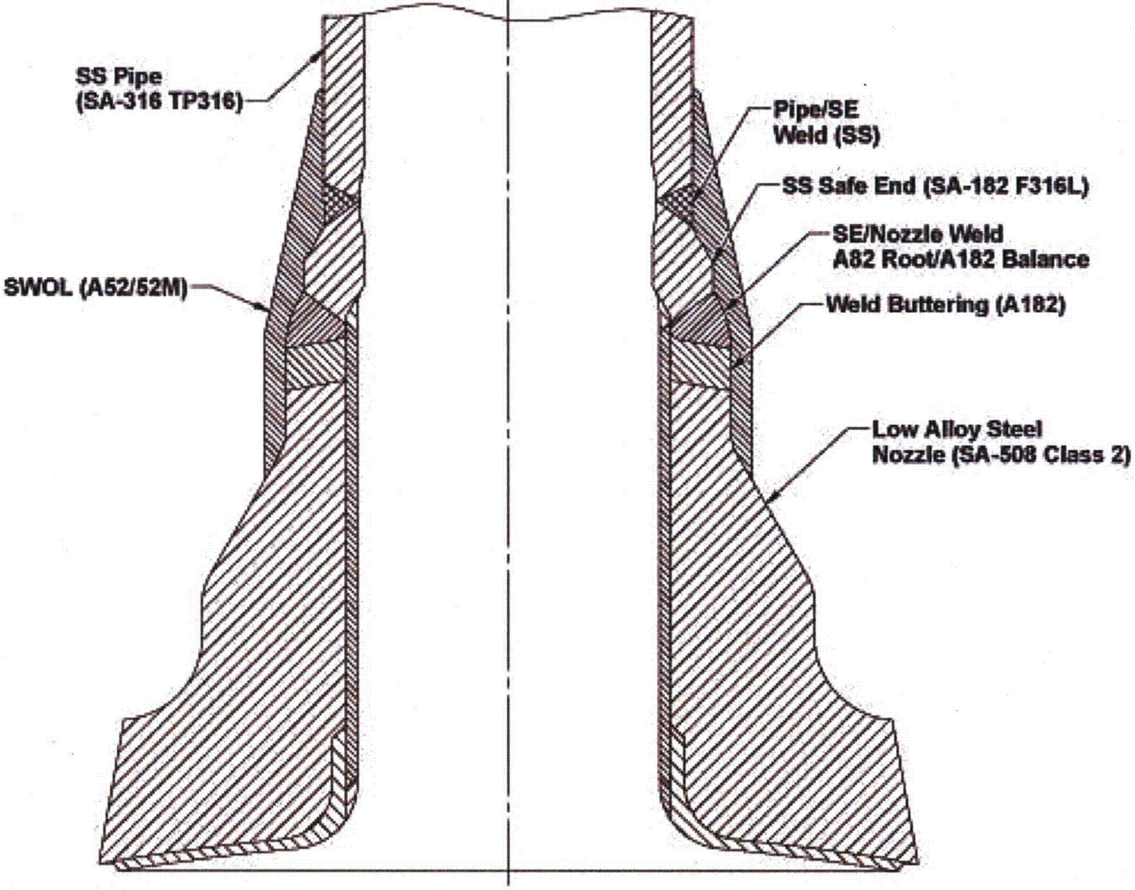
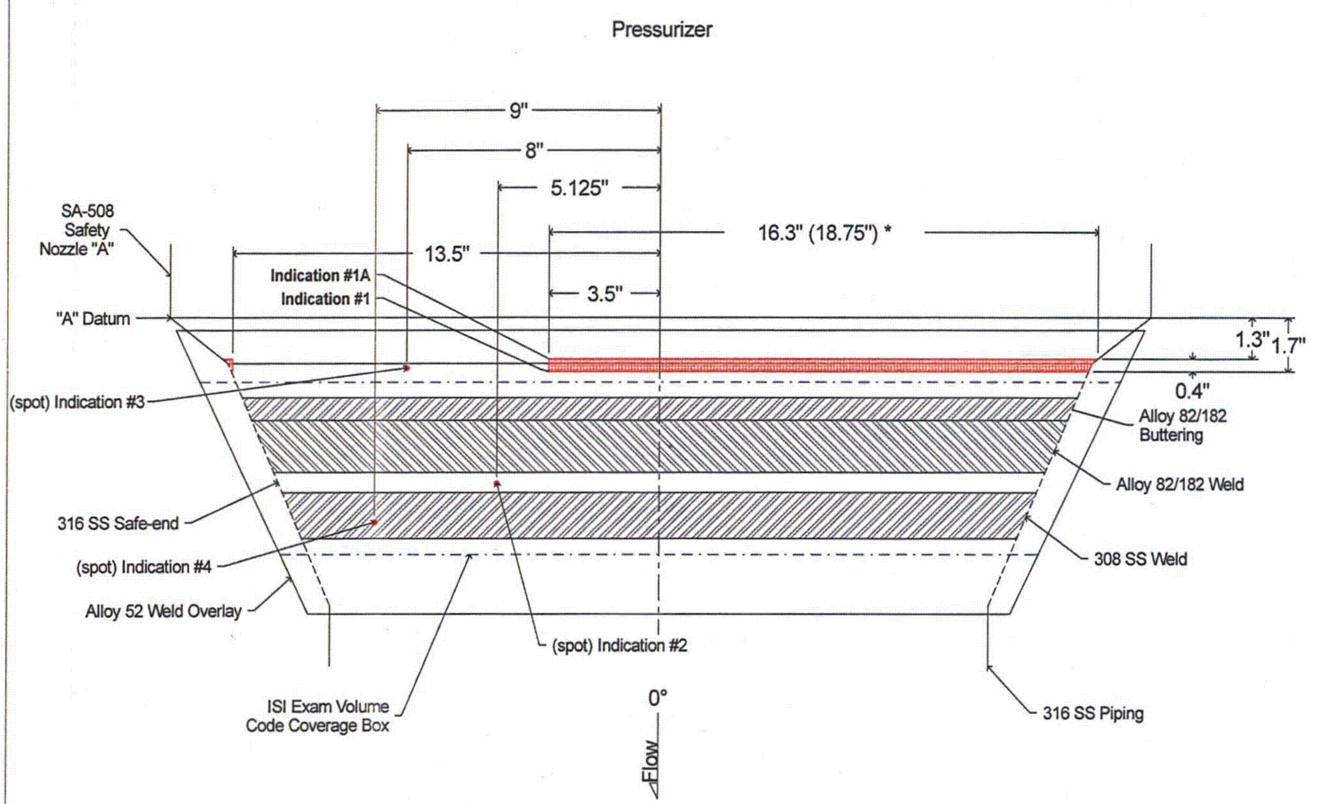
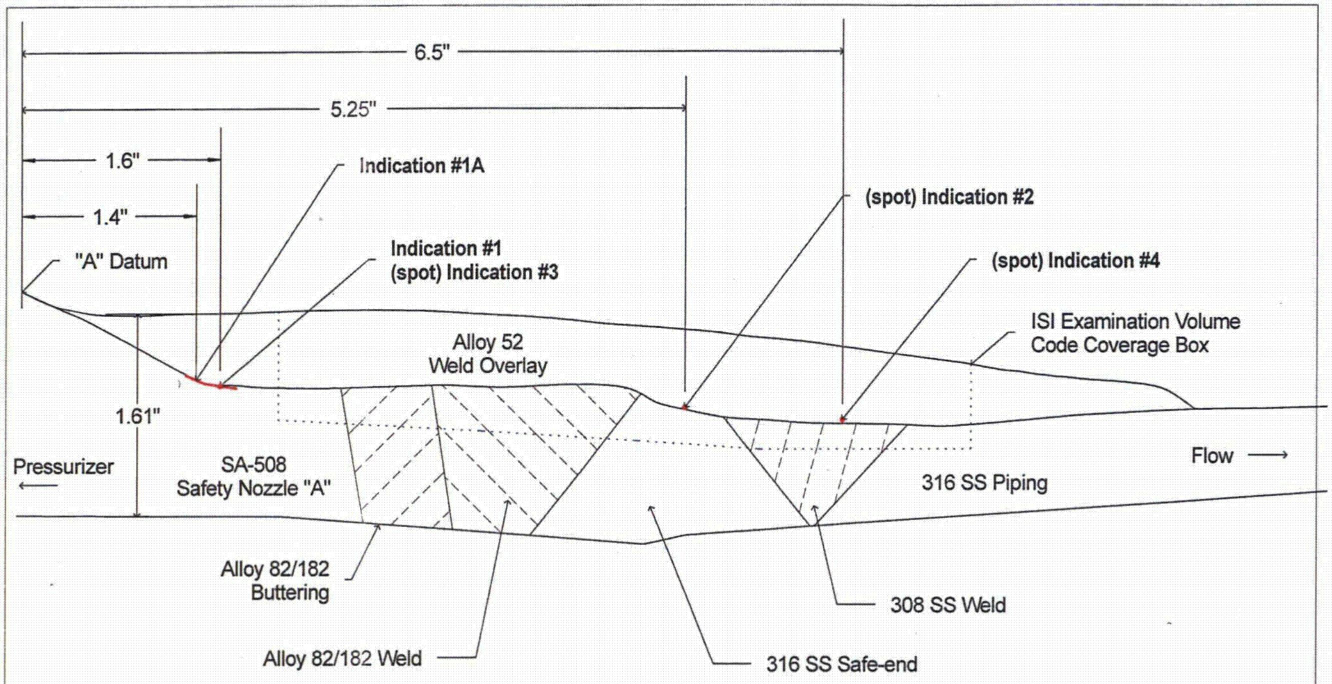


Figure 1 - Typical SWOL Configuration



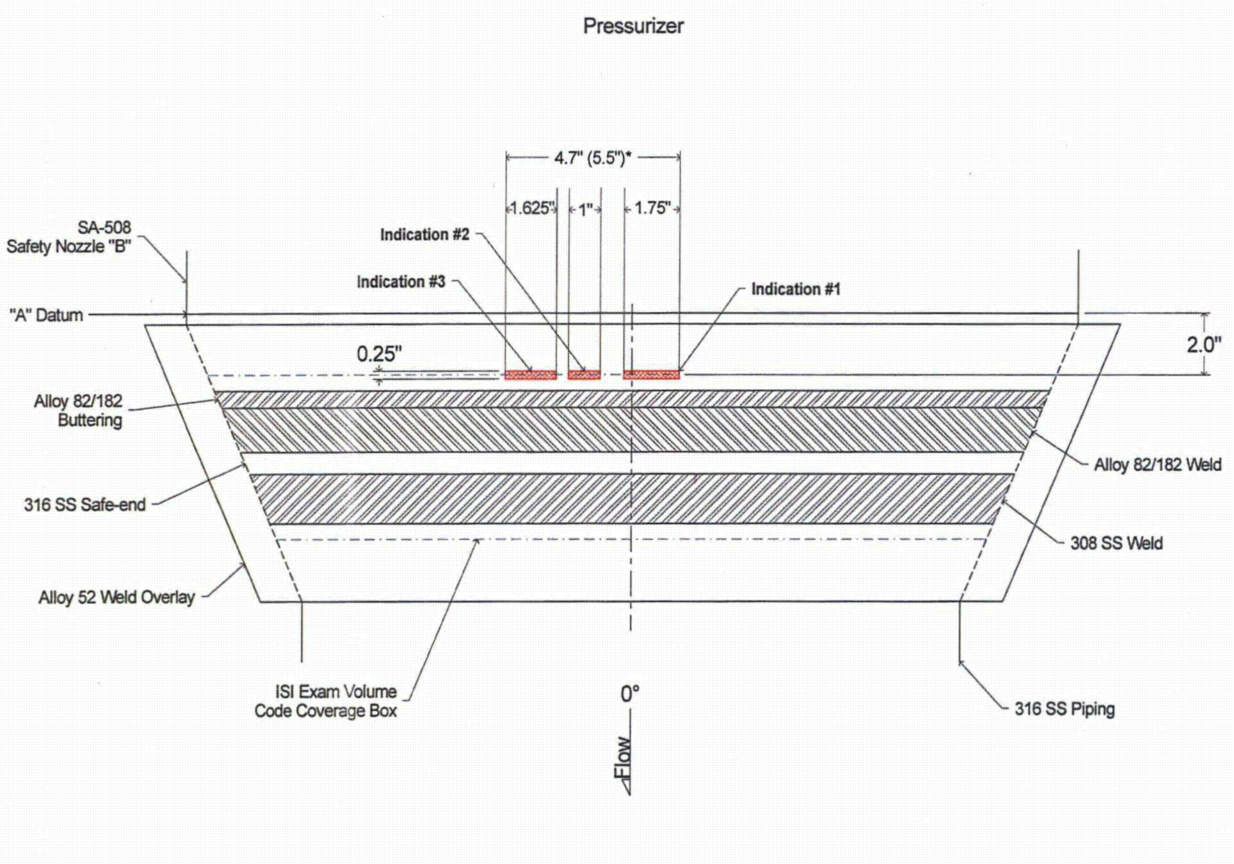
* 18.75" is measured on OD surface, 16.3" is corrected indication length due to diameter in area of indication / diameter of overlay OD surface

Safety Nozzle A - Circumferential Location of Indications
Figure 2



Safety Nozzle A - Axial Location of Indications
Figure 3

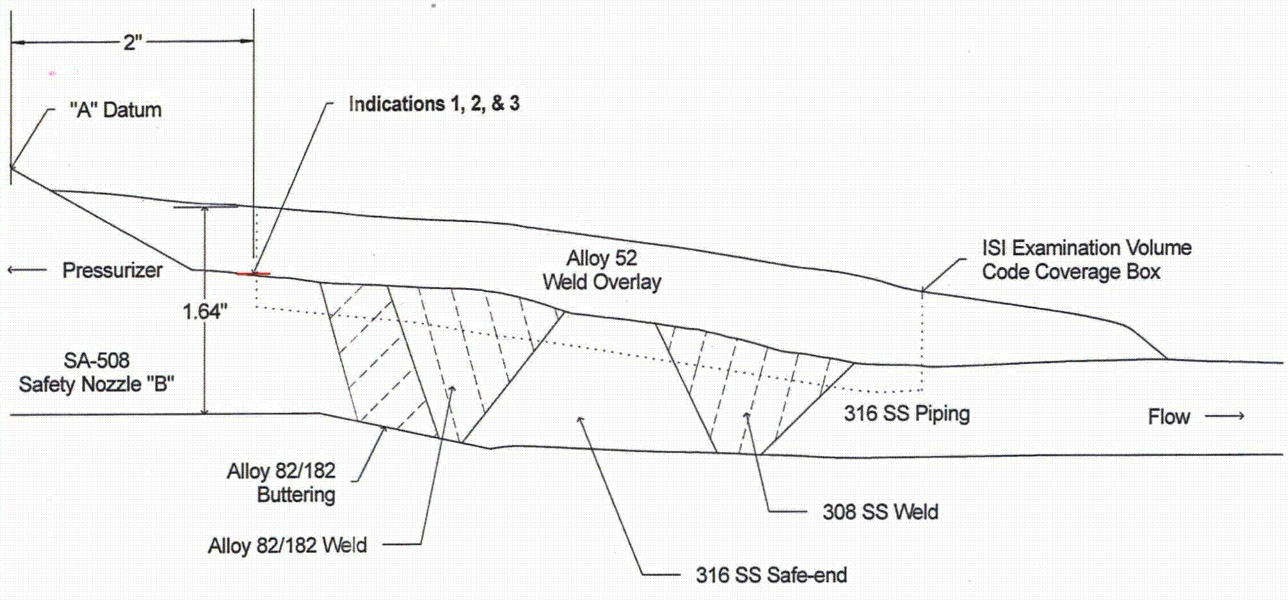
Attachments 2 through 7 to the Enclosure contain Proprietary Information –
Withhold Under 10 CFR 2.390



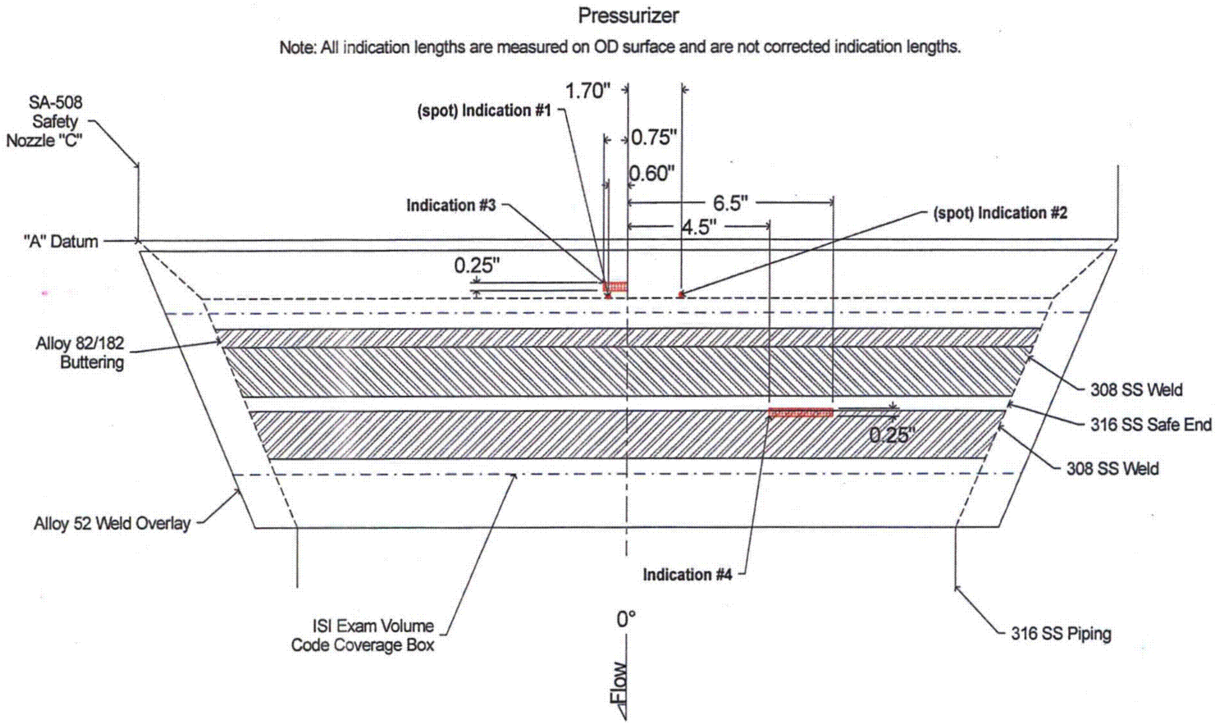
* 5.5" is measured on OD surface,
4.7" is corrected indication length due to diameter in area of indication / diameter of overlay OD surface

Safety Nozzle B - Circumferential Location of Indications
Figure 4

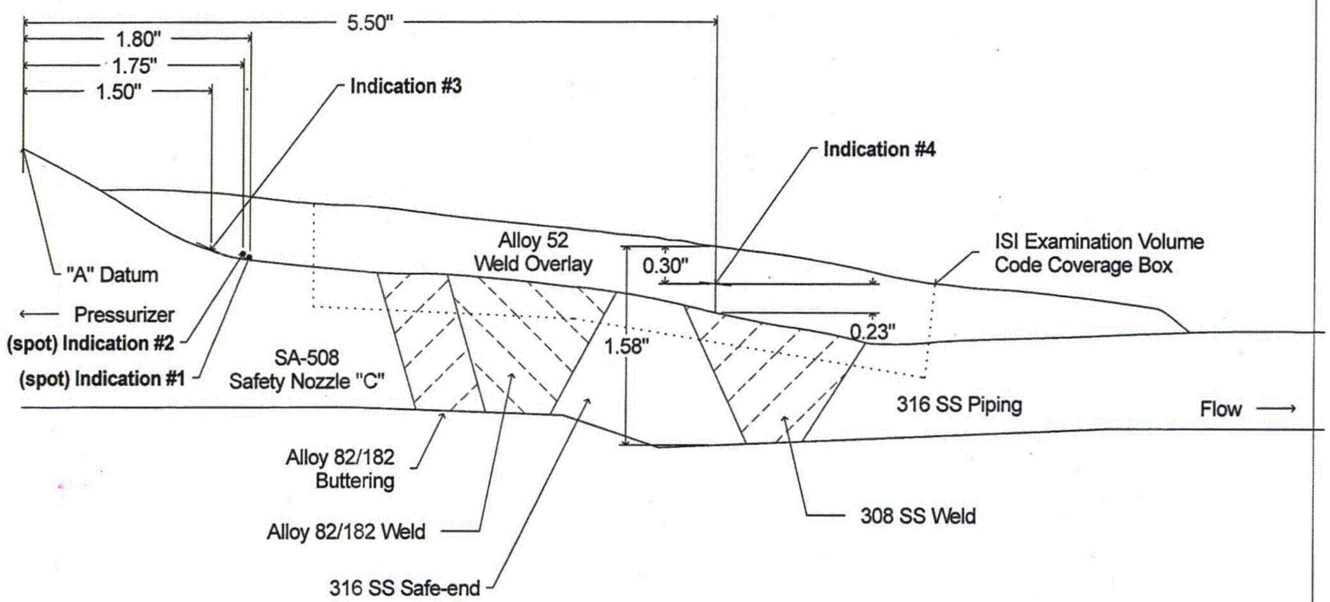
Attachments 2 through 7 to the Enclosure contain Proprietary Information
When separated from Attachments 2 through 7, this document is decontrolled.



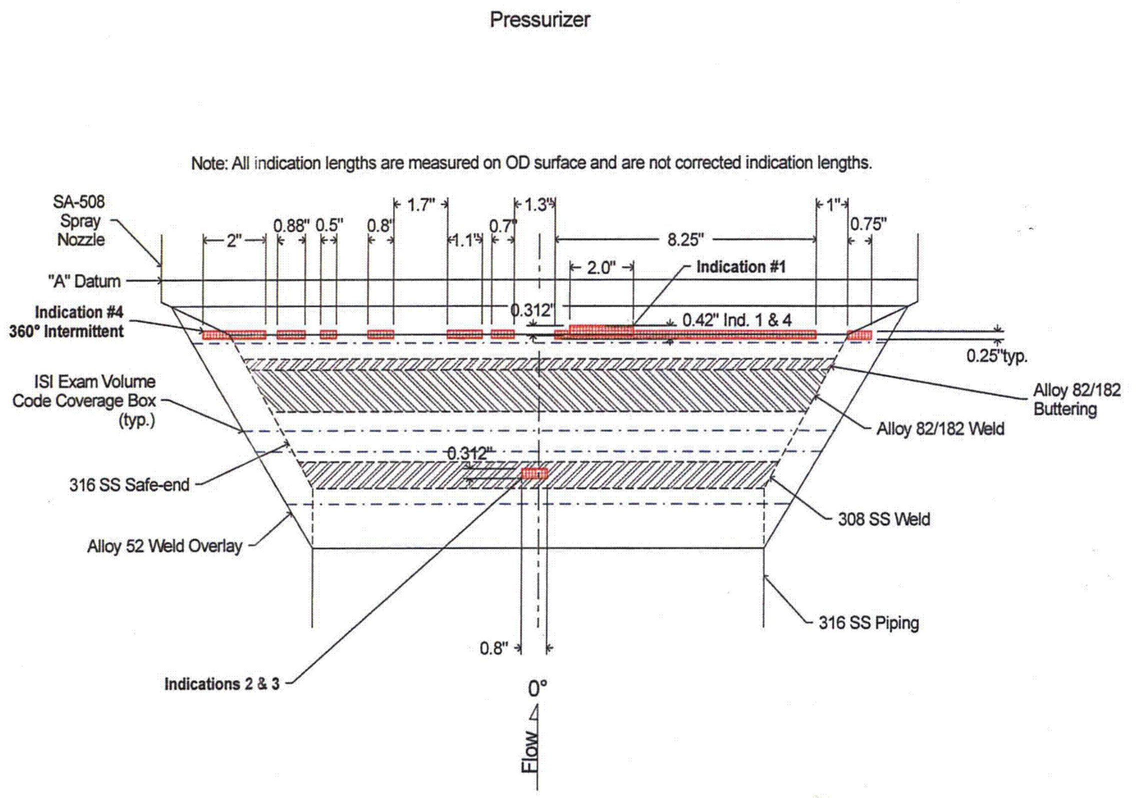
Safety Nozzle B - Axial Location of Indications
Figure 5



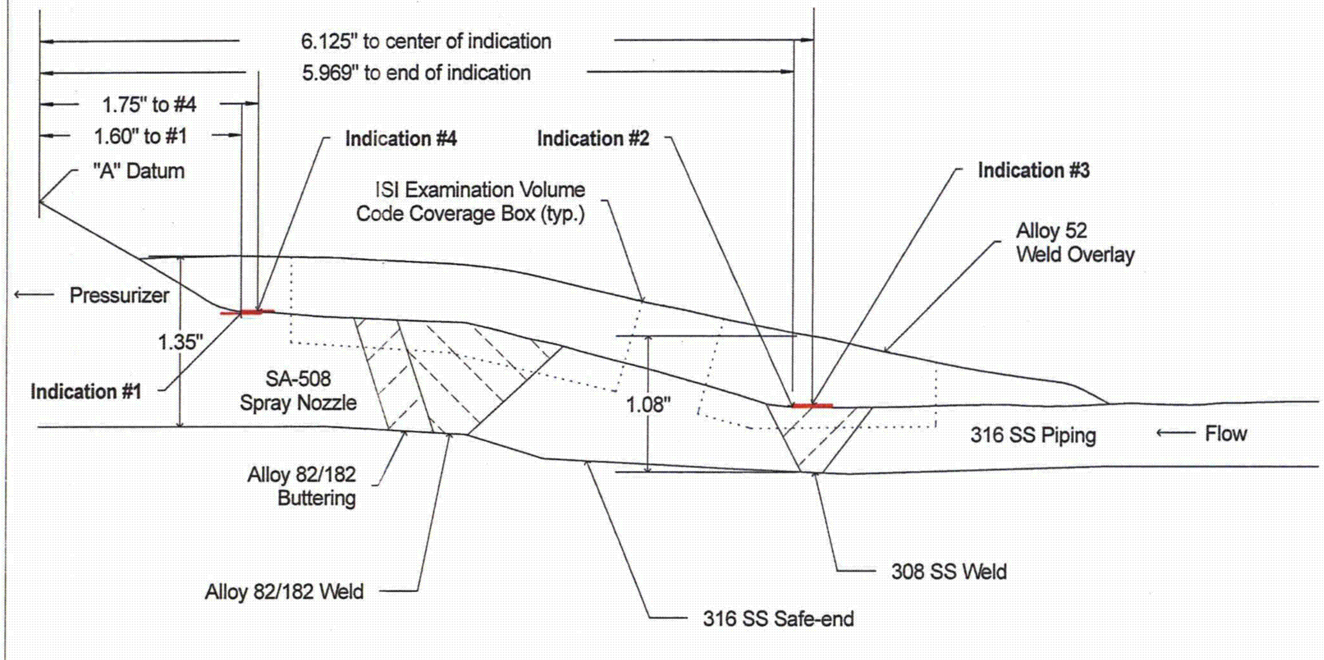
Safety Nozzle C - Circumferential Location of Indications
Figure 6



Safety Nozzle C - Axial Location of Indications
Figure 7



Spray Nozzle - Circumferential Location of Indications
Figure 8



Spray Nozzle - Axial Location of Indications
Figure 9

Table 1: Comprehensive list of Reported Indications

Nozzle [Note 1]	Indication #	Orientation	Class [Note 2]	Length (in.)	Width (in.)	Depth[8] (in.)	Comments
Safety Nozzle A	1	Circ	LOB/IBLOF	16.3	0.4	0.60	Note 3
	1a	Circ	LOB/IBLOF	16.3	0.4	0.52	Note 3
	2	None	LOB/IBLOF	Spot	Spot	0.62	Spot
	3	None	LOB/IBLOF	Spot	Spot	0.58	Spot
	4	None	LOB/IBLOF	Spot	Spot	0.58	Spot
Safety Nozzle B	1	Circ	LOB/IBLOF	4.7	0.25	0.58	Notes 3, 4
	2	Circ	LOB/IBLOF	4.7	0.25	0.65	Notes 3, 4
	3	Circ	LOB/IBLOF	4.7	0.25	0.65	Notes 3, 4
Safety Nozzle C	1	None	LOB	Spot	Spot	0.48	Spot
	2	None	LOB	Spot	Spot	0.46	Spot
	3	Circ	LOB/IBLOF	0.75	0.25	0.48	
	4	Circ	LOB/IBLOF	2	0.25	0.30	
Spray Nozzle	1	Circ	LOB/IBLOF	2.0	0.42	0.46	Note 5
	2	Circ	LOB/IBLOF	0.8	0.25	0.545	Note 6
	3	Circ	LOB/IBLOF	0.8	0.312	0.56	Note 6
	4	Circ	LOB/IBLOF	20.1	0.25	0.43	Note 7

Notes:

1. No indications were detected in PORV Nozzle and Surge Nozzle.
2. Lack of Bond /Interbead lack of fusion.
3. Length corrected for diameter (corrected indication length)
4. Length is combined for indications 1, 2, and 3
5. Actual indication width is 0.312", reported indication is 0.42" (overlays indication #4 width in this area is included)
6. Indications 2 and 3 are in the same location, detected from opposite directions at slightly different depth.
7. As shown in Figure 8, numerous indications (intermittent over a length of 20.1") are combined and designated as indications 1 and 4. See rollout for pictorial representation of occurrence, in Figure 8.
8. Indication depth location is relative to the top of the weld overlay.

Table 2: 2R17 Reportable Laminar Indications Versus Acceptance Criteria[1]

Nozzle	Indication (s) #	Length, L (in.)	Width, W (in.)	Area (0.75*L*W) (sq.in.)	Table IWB-3514-3 Criteria (Area<=7.5 sq.in.) [Note 5])	Length < 3.0 in. or length < 10% of circumference	Less than 10% reduction in coverage volume
Safety Nozzle A	1 and 1a [Note 4]	16.3	0.40	4.89	Acceptable	Unacceptable	Acceptable 100% coverage
Safety Nozzle B	1, 2, 3	4.7	0.25	0.8813	Acceptable	Unacceptable	Acceptable 98.94% coverage
Safety Nozzle C	4	2	0.25	0.375	Acceptable	Acceptable	Acceptable 99.63% coverage
Spray Nozzle	1, 4 (1st group) [Note 2]	16.3	0.42	5.14	Acceptable	Unacceptable	Acceptable 99.93% coverage
Spray Nozzle	1, 4 (2nd group) [Note 2]	2.1	0.25	0.67 [Note 2]	Acceptable	Acceptable [Note 3]	Acceptable 99.93% coverage
Spray Nozzle	2, 3	0.8	0.312	0.20	Acceptable	Acceptable	Acceptable 99.93% coverage

Notes:

1. ASME Section XI Flaw Evaluation and TAC NO. MD4974 Acceptance Criteria (Reference 8.9)
2. As shown in Figure 8, numerous indications are combined and designated as indications 1 and 4. These numerous indications (shown in Figure 8) are grouped into two groups based on the proximity rules of Section XI of the ASME code (The first group start/stop measurements are: 0.50-8.75", 9.75- 10.5", 10.75 - 12.75", 13.125 - 14", 14.5- 15", 16 - 16.8". The second group start/stop measurements are: 18.5- 19.6", 19.9 - 20.6"). The first group is 16.3 inch long x 0.42 inch width, and the second group is 2.1 inch long x 0.25 inch width. For the second group, initial width of 0.42 inch was conservatively used for the area estimation.
3. First group and second group are combined for laminar flaw growth analysis (see Attachment 3).
4. Stacked laminar indications 1 and 1A in the Safety Nozzle "A" are on the edge of the acceptance volume and have been conservatively evaluated as a planar indication with a height of 0.080".
5. For a given nozzle, all laminar indications combined have a total surface area <10% of the weld surface area.

Table 3: Summary of Results of Laminar Flaw Growth Analysis (end of design life, 38 years)

Nozzle	Laminar Indication # [Note 1]	Initial Width, $W_{initial}$ (in)	Final Width, W_{final} (in)	Initial Length, $l_{initial}$ (in)	Final Length l_{final} (in)	Area, A (=0.75*(W_{final}*l_{final}) (sq.in.)	Table IWB-3514-3 Criteria (A<=7.5 sq.in.)	NB-3227.2 Shear stress check $l_{req} < l_{eff}$? (in) [Note 4]	Structural Integrity
Safety Nozzle A	Indications 1 and 1A [Note 2]	0.4	0.40016647	16.3	16.306785	4.8941	Acceptable	0.77 < 0.91 Yes, Acceptable	Accept As-Is (attachment 2)
Safety Nozzle B	Indications 1, 2, and 3	0.25	0.25000685	4.7	4.700129	0.8813	Acceptable	0.77 < 1.06 Yes, Acceptable	Accept As-Is (attachment 2)
Safety Nozzle C	Indication 4	0.25	0.25000165	2.0	2.000013	0.375	Acceptable	1.07 < 4.41 Yes, Acceptable	Accept As-Is (attachment 2)
Spray Nozzle	Indications 1 and 4 (1st group) [Note 3]	0.42	0.422204	16.3	16.38554	5.19	Acceptable	0.48 < 1.26 Yes, Acceptable	Accept As-Is (attachment 3)
Spray Nozzle	Indications 1 and 4 (2nd group) [Note 3]	0.42	0.422204	2.1	2.11102	0.67	Acceptable	0.48 < 1.26 Yes, Acceptable	Accept As-Is (attachment 3)
Spray Nozzle	Indications 2 and 3	0.312	0.326246	0.8	0.815615	0.2	Acceptable	0.76 < 3.93 Yes, Acceptable	Accept As-Is (attachment 3)

Notes:

1. Indication numbers correspond to those on exam data sheets. The Indications were analyzed individually or combined per ASME Section XI, proximity rule.
2. Stacked laminar indications 1 and 1A in the Safety Nozzle "A" are on the edge of the acceptance volume and have been conservatively evaluated as a planar indication with a height of 0.080" to Table IWB-3514-2 as ACCEPTABLE.
3. As shown in Figure 8, numerous indications are combined and designated as indications 1 and 4. These numerous indications (shown in Figure 8) are grouped into two groups based on the proximity rules of Section XI of the ASME code. The first group is 16.3 inch long x 0.42 inch width, and the second group is 2.1 inch long x 0.25 inch width. For the second group, initial width of 0.42 inch was conservatively used for the final width and area evaluation.
4. ASME Section III, Article NB-3227.2 used to verify that the weld overlay length excluding the indications is sufficient to transfer the load through shear back to the base metal considering a 100% through wall crack in the PWSCC susceptible material.

Summary of Root Cause Evaluation Report
U2 Pressurizer Structural Weld Overlays
Missed Fabrication Flaws

In 2013, during the Diablo Canyon Power Plant (DCPP) Unit 2 seventeenth refueling outage (2R17), inservice inspection (ISI) examinations identified previously unknown fabrication flaws in four of six pressurizer structural weld overlays (SWOLs) that were installed by the vendor during fourteenth refueling outage (2R14). Following 2R17, a Root Cause Team (RCT) was formed to identify the causes that resulted in the flaws to be missed in both 2R14 and fifteenth refueling outage (2R15) inspections. A summary of the root cause investigation including the use of a human error investigation tool and the corrective actions are presented in this section.

Problem Statement:

The ultrasonic acceptance examinations of the Unit 2 pressurizer SWOLs performed immediately after the installation, and the ISI exams during the subsequent refueling outage failed to identify fabrication flaws in the SWOLs. Consequently, Unit 2 operated for three cycles with unidentified flaws that did not meet the requirements of the overlay installation relief request REP-1 U2, Revision 1.

The SWOLs were installed in 2R14 on the Unit 2 pressurizer nozzles. Industry operating experience indicated that the weld material used to connect the nozzles to the associated piping was susceptible to primary water stress corrosion cracking (PWSCC). As such, routine examination of the welds was required to confirm the absence of cracking. However, due to the geometric profile of the nozzles, inspection using ultrasonic testing (UT) was not possible. Consequently, a SWOL was applied, which shifted the stress in the nozzle welds from tensile to compressive, eliminating the susceptibility to cracking. In addition, the SWOL provided a surface that supported future inspection of the SWOL and part of the underlying base material.

Following installation of the SWOLs in 2R14, the vendor that performed the installation also performed UT examination of the SWOLs. The examination was performed using several discrete, ultrasonic angle beams. The technique, which is referred to in this report as conventional UT, was qualified for the application, and the examiners were qualified for its use.

In 2R15, a required follow-up inspection was performed of the SWOLs to identify service induced flaws. The inspection was performed using the conventional UT

technique by the same vendor that installed the SWOLs and performed the acceptance examination. Since the purpose of the inspection was to identify service induced flaws, some specific angle beams used in the acceptance examination (e.g., the 0° angle beam) were not used for the inspection. This inspection did not identify any flaws not previously identified in the acceptance examination.

During 2R17, one pressurizer SWOL (Safety Nozzle "B") was scheduled to be inspected. During the inspection, previously unknown flaws were identified using a phased array (PA) UT technique. The PA technique differs from the conventional UT technique in that it uses a spectrum of ultrasonic signals with angles between 0 and 85°. Not only does the PA technique assure that at least part of the signal is normal to a flaw, but its instrumentation also provides a better image of the flaw. This can result in flaws being more readily detectable in some cases. It was determined that the flaw in Safety Nozzle "B" was likely a fabrication flaw and would have exceeded the acceptance criteria of the relief request REP-1 U2, Revision 1. Ultimately, the inspection was expanded to all six pressurizer SWOLs. The inspection identified previously unknown fabrication flaws in 4 of 6 pressurizer SWOLs installed by the vendor during 2R14. Some of the newly identified flaws exceeded the maximum acceptance criteria specified in the relief request REP-1 U2, Revision 1. Although the flaws had been in service for two cycles, discussions with the NRC indicated that since they were indicative of fabrication flaws, the acceptance criteria of relief request REP-1 U2, Revision 1 applied. Prior to completing 2R17, both the SWOL original equipment manufacturer (OEM) and EPRI personnel examined selected indications to provide data and feedback regarding the capability to identify the flaws. Both the OEM and EPRI personnel indicated that the flaws could be identified using conventional UT.

Following 2R17, a RCT was formed to identify the causes that resulted in the flaws to be missed in both 2R14 and 2R15 inspections. Because of the potential impacts of the investigation on other plants that have already installed SWOLs and on the conventional UT process, EPRI, the OEM for DCPP, and an industry peer were included as part of the RCT investigative team.

RCT Actions and Conclusions

The RCT developed a Comparative TimeLine© of the events and generated an events and causal factors (E&CF) chart to map the unwanted conditions/events and to identify any broken barriers. Furthermore, the RCT used the stream analysis to validate the results of the E&CF Chart methodology. Based on the investigation methodologies, the RCT determined that the root cause (RC) and contributing cause (CC) of the problem, as stated above, were:

RC (Root Cause)
A mismatch exists between the conventional UT weld overlay inspection procedure PDI-UT-82 and the Performance Demonstration Initiative (PDI) qualification process.

Although the qualification process successfully demonstrated the ability to detect flaws, the procedure instructions do not adequately constrain the 0° scan speed to assure that small cross-section, low-angle flaws are consistently detected in the field.

CC (Contributing Cause)
Inattentive error was made by vendor examiners.

1) Data indicate that 45° angle beam was able to detect indications in the weld overlays, yet the indications were not recorded.

2) Examiners failed to adequately investigate indication responses to determine the actual length of the flaw.

3) Examiners failed to recognize 0° ergonomic factors necessitated reduced scan speed to maintain optimum search unit coupling.
The RCT determined that the following corrective action to prevent recurrence (CAPR) and corrective actions (CORRs) would be required to prevent a similar event, or to minimize its probability of recurrence.

CAPR (Corrective Action to Prevent Recurrence)
Revise AD5.ID2, "Inservice Inspection Program," to specify that PDI UT-8, "PDI Generic Procedure for the Ultrasonic Examination of Weld Overlaid Similar and Dissimilar Welds," Revision F, as well as earlier or subsequent revisions, will not be used to perform inspections of weld overlays at DCPP until the recommendations in CORR1 have all been addressed.

CORR1 (Corrective Action - RC)
DCPP will provide the following recommendations to PDI for revision of:

1) The conventional UT SWOL procedure (PDI-UT-8) training/qualification process:

a. Assure that scan speed, length sizing, and any other essential variables used during qualification testing are conservatively reflected in the examination procedure.

b. Expand the sample set to include Westinghouse Nuclear Steam Supply System pressurizer-nozzle configuration.

c. Include more realistic oriented fabrication-related flaws.

2) The procedure (PDI-UT-8):

a. Add guidance on when to reduce scan speed.

b. Evaluate the need to increase sensitivity for 0° examinations.

c. Include instructions related to detection of low-angle flaws.

CORR2 (Corrective Action - CC)
DCPP will recommend to EPRI to publish a communique to all Conventional UT overlay qualified examiners to review the causes and contributors of the DCPP event.

Human Performance and Organizational Factors

The RCT used the Human Error Investigation Tool (HEIT) to determine the level of personnel and/or organizational culpability in the event under investigation via this root cause evaluation.

The answers to the HEIT specific questions are as follows (refer to the Figure 1 below for an overview of the questions and the path resulting from the corresponding answers):

Were the actions as intended?

Yes - The performance of the UT examination was as intended, included the scanning speed and indication cultivation techniques used. The scanning speed was performed in accordance with the procedure guidelines of a max scan speed of 2 inches per second.

Were the consequences as intended?

No - Based on interviews with vendor inspection personnel, they neither intended nor expected to miss identification of any flaws in the weld overlay.

Are there established workable standards?

Were the work procedures and other work documents useable, accurate, controlled and up-to-date?

Yes/No – The work procedure in question is PDI-UT-8. The procedure is an industry standard procedure for UT inspection of weld overlays. The procedure contains guidance on maximum scan speed and requires that scan speed be reduced for poor weld-surface conditions. The definition of poor weld-surface conditions is left up to the inspector. The procedure has been proven to be able to detect the DCPP flaws when lower scan speeds are used.

Since the procedure has been proven to be able to detect flaws even at the high scan speeds using some of the specified search units during qualification testing, and PG&E inspection personnel could readily detect flaws using some of the specified angles (specifically 45°), the question is answered yes.

Since the scan speed is left to the judgment of the inspector, the question is answered no.

Were the inputs the person received appropriate, correct, and timely (e.g., Written or verbal instructions, clarifications, etc.)?

Yes – The procedure used was the industry proven procedure, and was accurate. Interviews indicate that pre-job briefs were conducted; however, the level of technical detail on how to perform the scan would not be typically included in the pre-job brief. It would be analogous to including the method for turning a wrench in a pre-job brief.

Were multiple or competing priorities present and were they clarified (either prior to, or during, performance of the task)?

No – Based on interviews with the vendor inspectors, multiple or competing priorities were not present. In addition, all vendor personnel indicated that they did not remember time pressure from either their own organization or PG&E.

Based on the above, both the yes and no paths will be evaluated because of the differing answers to the first question, depending on what part of the issue was being addressed (scan speed for 0° search unit – procedure deficiency; indication identification with 45° search unit – procedure adequate)

Aware of the standard?

Yes – This is indicated by the fact that all the individuals successfully completed a performance demonstration in the lab, proving that they could detect indications using a 45° angle beam.

Intend to violate standard?

No – During the interviews with the individuals, they indicated that they were complying with the procedural requirements. This would indicate that they intended to follow the standard.

Inattentive error

Based on the fact that the inspections were conducted 3 to 5 years ago, inspectors could not recall any specific behaviors that might have contributed to the inattentive error. Note that the conclusion of inattentive error was reached from both box 5 and box 8.

Pass the substitution test?

Yes/No – This question is answered both yes and no because application of the substitution test was not conclusive. By the fact that three inspectors missed flaws in the weld overlay would indicate that the substitution test is passed. However, two additional inspectors not involved in the overlay project also scanned selected overlays during 2R17and were able to identify the flaws, indicating the substation test is not passed. The resulting paths from both answers were evaluated.

Deficiencies in training and/or experience?

No - The individuals that performed the overlay work were qualified in accordance with the PDI process. Interviews indicated that they had not performed many weld overlay inspections; however, they had performed many UT inspections.

Organizationally induced error

The cause for the high scan speed appears to be organizationally induced in that the PDI procedure left reductions in scan speed up to the judgment of the inspector. The procedure provided direction to reduce scan speed for irregular weld-surface conditions, but it leaves the definition of irregular surface conditions up to the judgment of the inspector (note that the interviews indicated that the inspectors did not think the surface condition was irregular). Also, an industry expert cited that scan speed should be reduced when an underlying complex geometry exists; however, this requirement is not described in the PDI procedure.

Figure -1 Human Error Investigation Tool (HEIT) Flowchart