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10 CFR 50.55a

102-05141-CDM/SAB/RJR
August 24, 2004

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

References: APS Letter 102-05112-CDM/SAB/RJR, "10 CFR 50.55a Alternative Repair Requests for the PVNGS Pressurizers: Relief Requests 28 and 29," dated June 15, 2004

Dear Sirs:

Subject: Palo Verde Nuclear Generating Station (PVNGS)
Units 1, 2 and 3
Docket No. STN 50-528, 50-529 and 50-530
Response to Request for Additional Information – Relief Requests 28 and 29

In the letter referenced above, Arizona Public Service Company (APS) proposed alternatives to the requirements of American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, 1992 Edition, 1992 Addenda, Section XI, "Rules for Inservice Inspection of Nuclear Power Plant Components."

The enclosure to this letter contains APS' response to the NRC's requests for additional information transmitted to PVNGS via e-mail and facsimile on June 29, 2004 and July 1, 2004. This letter contains no new commitments. Should you have any questions, please contact Thomas N. Weber at (623) 393-5764.

Sincerely,

CDM/SAB/RJR/

Enclosure: Response to the Request for Additional Information - Relief Requests 28 and 29.

Attachments 1. Reformatted Technical Report SIR-04-045, Revision 0
2. ASME Technical Interpretation IN 03-013

A047

cc:

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Enclosure

Response to the Request for Additional Information - Relief Requests 28 and 29

Response to the Request for Additional Information – Relief Requests 28 and 29

Background

This enclosure contains APS' response to the NRC's requests for additional information transmitted to PVNGS via e-mail and facsimile on June 29, 2004 and July 1, 2004.

QUESTIONS ON RELIEF REQUEST 28

NRC Question 1

On page 15, the submittal states (page 4 of Attachment 1) that ultrasonic testing (UT) and surface examinations will be performed according to NB-5000 requirements with the UT acceptance according to NB-5330. Section IV "Proposed Alternative," states that UT will be used in lieu of radiography testing (RT). Provide the specific ASME Code criteria that will be used for nondestructive examinations (NDE) in the proposed alternative.

APS Response

The "Proposed Alternative" acceptance criteria will be according to the 1974 Edition of ASME Code, Section III through the Winter 1975 Addenda, Section NB-5330 for UT and Section NB-5350 for penetrant testing (PT).

NRC Question 2

The submittal states on page 15 that RT is impractical because of accessibility considerations. Provide a discussion of the difficulties (use a sketch if necessary) associated with a RT examination. Discuss the differences in flaw detection between RT and UT.

APS Response

As shown in Figure 2-1, the weld is located in a heater sleeve that has an inside diameter of approximately 1.3-inches. An X-ray film cassette can not be inserted in such a small opening. Also there is no optimal location to place a gamma ray source to give any meaningful image of the weld. The differences in flaw detection between RT and UT are discussed following Figure 2-1.

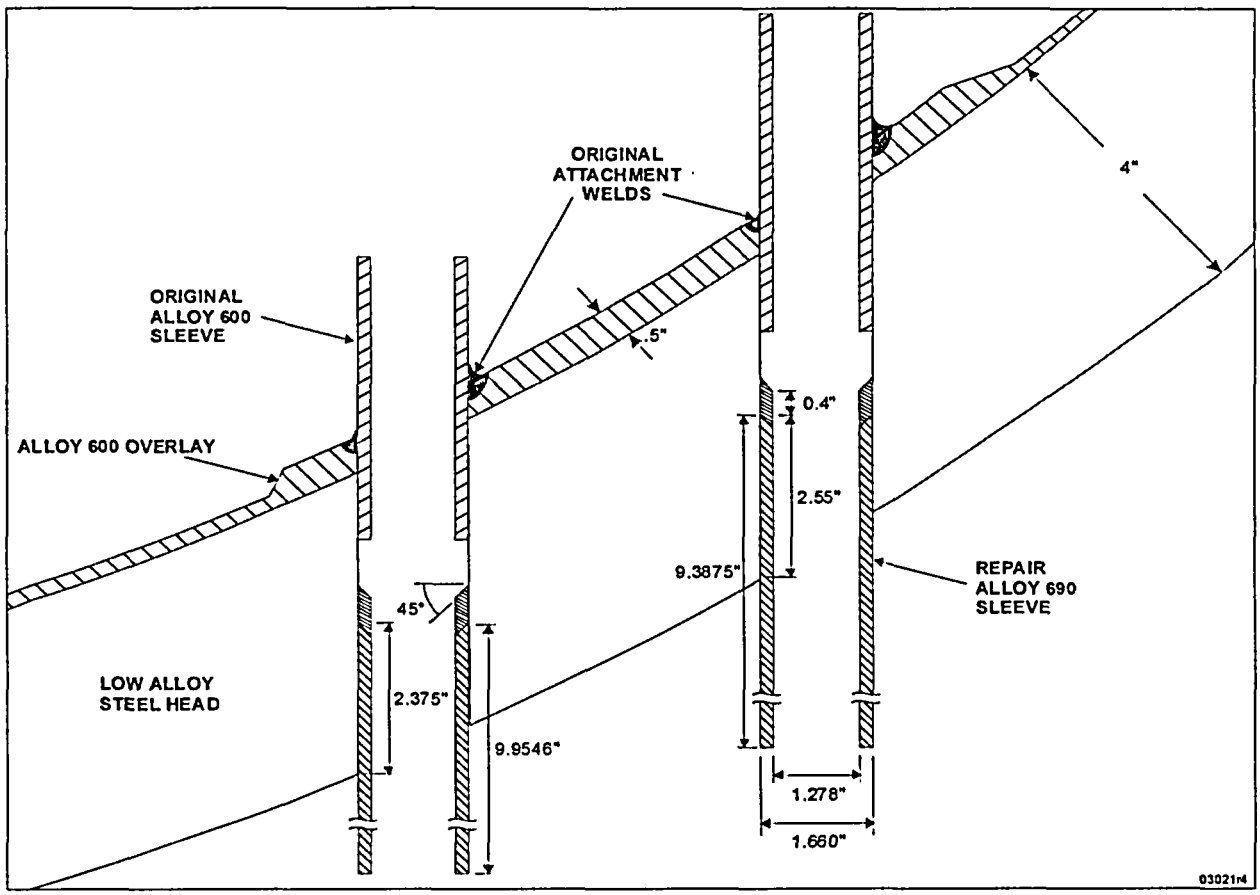

Figure 2-1: Conceptual Drawing of Pressurizer Heater Sleeve Mid-Wall Repair

Radiography testing and UT examination methods are complimentary. Radiography testing is most effective in detecting changes in material density, such as volumetric type flaws (i.e., slag and porosity), and planar type flaws with detectable density differences, such as lack-of-fusion and open cracks that are orientated in a plane parallel to the X-ray beam. Radiography testing is limited in detecting small changes in density such as tight, irregular planar flaws and non-optimally orientated planar flaws with respect to the X-ray beam. Radiography testing is also limited in determining depth characteristics. The flaws that are easiest for RT to detect are three-dimensional.

In contrast, UT examinations are capable of detecting the features in a component that reflects sound waves. The degree of reflection depends on the physical state of matter on the opposite side of the reflective surface and to a lesser extent on specific physical properties of the matter. For instance, sound waves are almost completely reflected at metal-gas interfaces, and partially reflected at metal-to-solid interfaces. Discontinuities that act as metal-gas interfaces, like cracks, laminations, shrinkage cavities, burst, flakes, pores, and bonding faults are easily detected. These are the types of flaws that generally originate during plant operations and from the welding process. Ultrasonic testing is less effective in detecting flaws in a plane parallel to the sound beam because

of target size and in detecting volumetric type flaws such as slag, porosity, and other inhomogenieties because of sound dispersion from irregular surfaces. Ultrasonic testing may also have difficulty in detecting flaws that are present in the shallow layer immediately beneath the surface and in separating flaws from background noises that are caused in certain metal characteristics like large grains in stainless steels.

NRC Question 3

NB-5112 requires that the procedure be proved by actual demonstration. Explain how the effectiveness to detect and size flaws will be demonstrated. If a mock-up is used to demonstrate the effectiveness of the UT, describe the mock-up, and describe the placement and types of flaws in the mock-up. Discuss the applicability of the flaws with respect to the acceptance criteria of NB-5330.

APS Response

As this is a new weld, the flaws of interest are welding defects such as a lack of fusion. As such, a demonstration mockup block will be used that contains as a minimum 10% through-wall notches in both the circumferential and axial directions placed on the ID and OD. These notches will conservatively have a 3 to 1 aspect ratio. In addition, a calibration standard will be constructed of a piece of actual sleeve material, and will contain a range of circumferential/axial notches placed on the OD/ID. The smallest will be approximately 10% through-wall and the largest will be greater than 50% through-wall. In addition, the demonstration block will contain a 1/8 inch flat bottom hole that has been placed at the interface of the weld to the base material. The use of notches and holes is spelled out to demonstrate the capability of the written procedure in all articles of ASME Section V applicable to UT. Specifically, guidance was taken from Article 5, Paragraph T-542 for welds. Additional conservatisms were implemented as allowed in Paragraphs T-542.8.5 and T-110(c) to ensure the highest quality weld.

NRC Question 4

Using sketches show the cross-section volume of the weld and base metal that will be examined with each transducer angle and the depth into the base metal that will be examined. Provide a discussion on the acceptability of the weld volume that cannot be examined with UT (such as the slope of the weld and the pressurizer head, sleeve, and weld root junction).

APS Response

Figure 4-1 shows the coverage. As can be seen from the figure, all areas of the sleeve and root are seen with all angles (axial and circumferential). The weld tip is fully interrogated by the axial transducer looking up and its surface receives a penetrant examination (PT). The pressurizer head volume under the weld is fully interrogated with straight beam and in both directions circumferentially to a depth of 0.25" (which is greater than the depth of the weld). The axial scans have some limitations as shown. This area receives a PT prior to any welding. The coverage obtained will determine if there is any lack of bond or lack of fusion of the weld to the pressurizer in the required structural volume. In addition, the axial and circumferential scans will determine if there are any planar reflectors (inter-bead lack of fusion and/or cracking) caused by welding. In summary, the entire volume of the weld is examined from at least one direction. Most of the volume of the weld is examined from four directions plus a zero degree. The sloped volume of the weld has limited UT coverage. However, to ensure that no cracking extends from the base material underneath, the area to be welded is examined with PT prior to welding and the entire slope is examined with PT after welding. In addition, the adjacent one-half inch is examined with PT after welding. This ensures that no cracking was induced during welding (linear indications) and that no lack of fusion exists that would jeopardize the integrity of the weld.

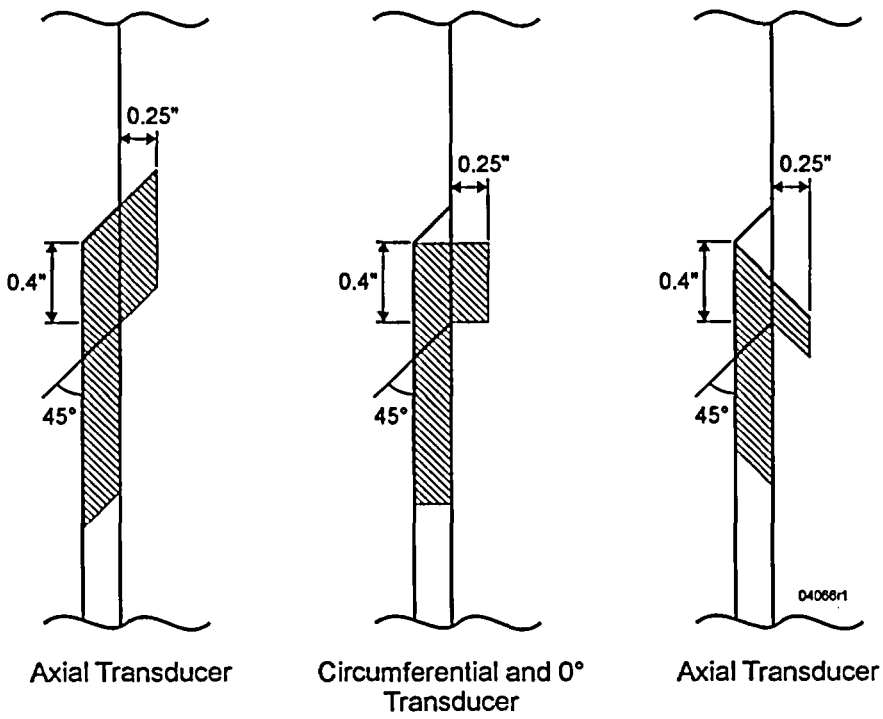

Figure 4-1. UT coverage

NRC Question 5

The repair is a special designed weld that attaches Alloy 690 material to carbon steel. Discuss the NDE methods and examination frequency that will be used for inservice inspection of the repair.

APS Response

The new partial penetration weld attaching the alloy 690 sleeve to the carbon steel vessel will be examined by bare metal visual examination of the pressurizer lower head and alloy 690 sleeve annulus region at every refueling outage. The bare metal visual examination will be performed with the system at normal operating pressure.

NRC Question 6

On page 15, the submittal states that, "Since there is no elevated preheated band, APS will be performing a penetrant examination of the final weld surface and the adjacent heat-affected zone only." NB-5140 requires that external and accessible internal weld surfaces and adjacent base material for at least ½-inch on each side of the weld shall be included in the examination. Provide a sketch showing the weld and base metal on either side of the weld that will be surface examined.

APS Response

APS plans to perform a PT of the pressurizer bore prior to welding, and to perform a PT of the repair weld after it is at ambient temperature for 48 hours. The surface to be examined in each case will extend one-half inch on either side of the repair weld. Therefore at least 1.75 inches of each pressurizer bore will be examined prior to welding, and 0.50 inches on either side of the repair weld will be examined after welding. See Figure 5-1 below.

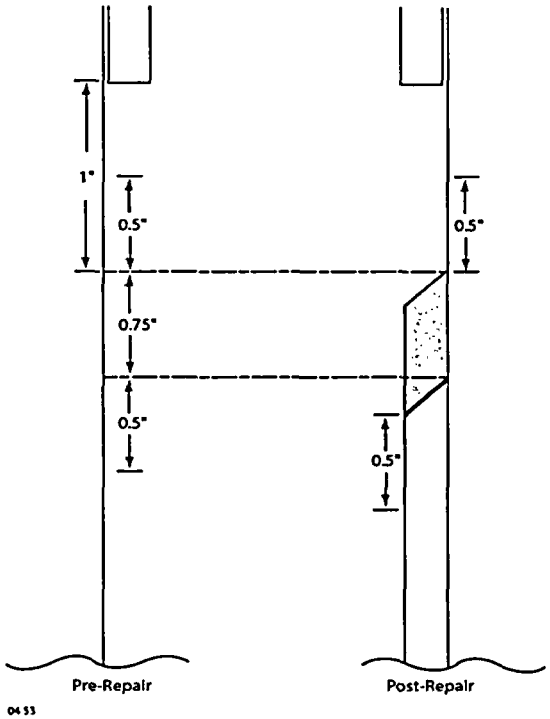

Figure 5-1. PT coverage

NRC Question 7

On page 7, the submittal states that IWA-4533 requires performing NDE examinations 48 hours after reaching ambient temperature. Attachment 1, Section 4.0 on NDE and the proposed alternative are silent on the application of a minimum hold time prior to NDE examinations. Provide a discussion on the minimum hold time at ambient temperature prior to NDE examinations of the repair.

APS Response

The UT and PT of the weld shall be performed after the completed weld has been at ambient temperature for a minimum of 48 hours. No relief has been sought from this requirement.

NRC Question 8

On page 6, the submittal states that,"...because of the large heat sink interpass temperature does not approach anywhere near 350°F." Provide a technical discussion to support this statement.

APS Response

Mockup welding has demonstrated that the maximum interpass temperature, after completion of one bead and prior to starting a subsequent bead, is approximately 195° F.

NRC Question 9

On page 13, the submittal states, "The use of thermocouples and recording instruments is not required by ASME Section XI Code Case N-638 for monitoring welding process temperatures. Code Case N-638 is the basis for APS' proposed alternative." Code Case N-638, Paragraph 4.0(c) states that "Areas from which weld-attached thermocouples have been removed shall be ground and examined using a surface examination method." (the use of thermocouples is implied but not required). Section IV, Proposed Alternative, states that "According to IWA-4500(e)(2), thermocouples and recording instruments shall be used to monitor process temperatures." The proposed alternative (page 6) will not use thermocouples or recording instruments. Attachment 1 to the submittal is silent on the use of thermocouples. Provide a technical discussion to support not using thermocouples or other temperature measuring devices.

APS Response

The ambient temperature will be well above the minimum required temperature of 50° F. The maximum interpass temperature will be approximately 195° F (see the response to Question 8). Containment temperatures are not expected to be less than the required 50° F during the welding operations which would be conducted during the spring or fall. However, to ensure compliance with the minimum temperature requirement, APS will verify the temperature prior to welding. Based on this information, thermocouples will not be utilized.

NRC Question 10

The submittal is being reviewed to specific ASME Code requirements. The proposed alternative identified as Attachment 1 to the submittal contains most [of] the content from Code Case N-638. In the general instructions of Code Case N-638, there is a statement that all other IWA-4000 or 7000, as applicable, are met. The Attachment 1 to the submittal is silent on the use of all other ASME Code requirements. Discuss the applicability of all other ASME Code requirements.

APS Response

The question correctly states that the submittal is being reviewed to specific ASME Code requirements. The statement being quoted is in a Note to the response to the original Code Case question. The Reply states in part that for the materials listed the

repair can be made by automatic or machine GTAW temper bead technique without the specified preheat or post-weld heat treatment and without the NDE requirements of the Construction Code, provided the requirements of 1.0 through 5.0 of the Code Case and all other requirements of IWA-4000 are met. The note to IWA-4000 states IWA-4000 or IWA-7000, as applicable... APS has reviewed the proposed ambient temperature temper bead welding techniques of Attachment 1, "Dissimilar Metal Welding Using Ambient Temperature Machine GTAW Temper Bead Technique," against the GTAW-machine temper bead welding requirements of IWA-4500 and IWA-4530. This review was performed to identify differences between Attachment 1 and IWA-4500 and IWA-4530. Based upon this review, APS proposed the alternatives to the ASME Section XI requirements of IWA-4500 and IWA-4530 discussed in Section IV of the submittal. All other applicable requirements of IWA-4000 shall be met.

NRC Question 11

On page 16, the submittal states that, "APS believes that compliance with the repair rules as stated in Reference 2, and described in Section III...." The application of Reference 2 is not clear. Clarify the aspects from Reference 2 that apply to this paragraph.

APS Response

To clarify the statement at the top of page 16 of the submittal, the reference to Reference 2 has been deleted and the statement is changed to the following.

The proposed alternative discussed in Section IV would provide an acceptable level of quality and safety without exposing the pressurizer head to potential distortion of the sleeves and heater support structure if original Section III requirement of post weld heat treatment is implemented. Additionally, the work required meeting the Section XI Code repair method, automatic or machine GTAW temper bead with 300°F minimum preheat and 300°F post weld hydrogen bake-out would be extremely difficult and the personnel radiation exposures resulting from the set-up, monitoring, and removal of the required equipment is unjustified. It is estimated that a savings of 95-105 Rem per unit could be realized during the pad repair method using ambient temperature temper bead and GTAW in accordance with Relief Request 23 submitted on May 15, 2004 and approved on July 30, 2004. However, an additional 8.5 Rem per unit could be realized by implementing the mid-wall repair described in Relief Request 28 in lieu of the pad repair described in Relief Request 23. Therefore, APS requests that the proposed alternative be authorized pursuant to 10 CFR 50.55a(a)(3)(i).

Response to the Request for Additional Information – Relief Requests 28 and 29

NRC Question 12

In the cover letter to the submittal and various sections in the request for relief, APS references Palo Verde Nuclear Generating Station (PVNGS) Units 1, 2, and 3. On page 16 of the submittal, the request for relief specifies PVNGS Units 1 & 3. Please clarify.

APS Response

Relief Request 28 applies only to heater sleeves in Units 1 and 3 that would be repaired by this proposed alternative. Unit 2 heater sleeves require no further work. Relief Request 29 applies to all three PVNGS pressurizers.

NRC Question 13

The licensee has stated that Code Case N-638 was used as the basis for this relief request; however, Attachment 1 to the relief request does not meet all of the requirements of Code Case N-638. Some of these differences have been identified above. Identify any other differences between Code Case N-638 and Attachment 1 to the submittal. If these differences are not specifically addressed in Section IV, "Proposed Alternative," provide the specific ASME Code paragraph(s) that apply(ies) to the differences and provide justification for the acceptability of these differences.

APS Response

Relief is sought from the preheat and post-weld soak requirements of Section XI. The basis is provided in Section V of the relief request for the alternative requirements which are almost identical to the requirements of Code Case N-638. The following table compares differences that were identified as not specifically addressed in Section IV of the submittal.

Code Case N-638-0	Attachment 1 to Submittal
Impractical to drain the component	Impractical for radiological reasons. Already addressed in Relief Request 28 page 2.
Final weld surface and 5" band around it will be examined by PT and UT after 48 hour delay.	Final weld surface and heat affected zone ½-inch from the weld toe to be examined by PT and UT after 48 hour delay. Mid-wall repair geometry prevents performing UT and PT of the 5" band. Therefore the heat affected zone (1/2" from the weld) and the weld shall be examined by UT and PT.
UT per Appendix I of Section XI. Acceptance Criteria – IWB-3000	UT acceptance criteria per NB-5000. The UT under NB-5000 is identical to the UT under Appendix I for this weld. Both Codes require a UT procedure that complies with ASME Section V.

Response to the Request for Additional Information – Relief Requests 28 and 29

Code Case N-638-0	Attachment 1 to Submittal
PT acceptance per NB-5350	PT acceptance criteria NB-5350
Weld attached thermocouple area to be ground and MT/PT after removal	The use of thermocouples is not required since the ambient temperature in containment is above 50°F and interpass temperature is below 350°F.
NDE personnel qualification per IWA-2300	NDE personnel qualification per NB-5500. However, NDE personnel shall meet IWA-2300 (CP-189) requirements.

Response to the Request for Additional Information – Relief Requests 28 and 29

QUESTIONS ON RELIEF REQUEST 29

NRC Question 1

In the cover letter, the licensee states that Relief Request Nos. 28 and 29 apply to all three units. However, on page 1 of Enclosure 1 to the June 15, 2004, submittal, the licensee states that a half-sleeve pad repair was implemented in Unit 2 in fall 2003. In the executive summary of the Structural Integrity Associates report No. SIR-04-045, it is stated that a mechanical nozzle seal assembly has been utilized as an interim repair. The staff is not clear regarding the following points: (a) whether there are any previous repair[s] made to Unit 1 or Unit 3 heater sleeves, (b) whether previous sleeve repairs performed at Unit 2 will be replaced by the half-sleeve design in Relief Request Nos. 28 and 29, (c) what is the heater sleeve replacement schedule for units 1 and 2, (d) whether relief requests 28 and 29 will apply only to those sleeves that are found to be degraded, or, all heater sleeves will be replaced. Therefore, describe the heater sleeve replacement schedule, the past and/or future sleeve replacement activities, and the scope of the relief request application for each of the three units.

APS Response

(a). There have not been any prior repairs in Unit 1. Three mechanical nozzle seal assemblies (MNSA) are currently installed in Unit 3.

(b). The Unit 2 repairs are complete and Relief Request 28 will not be used. However, Relief Request 29 applies since sleeve remnants remain in the pressurizer.

(c). The Unit 1 sleeves are scheduled for repair in the fall of 2005. There are no additional repairs necessary in Unit 2.

(d). APS will be replacing all the heater sleeves in Units 1 and 3. APS is planning to use Relief Request 28 for these replacements. Relief Request 29 will apply to all heater sleeves in Unit 1 and 3 since sleeve remnants will remain.

NRC Question 2

If the half-sleeve design is to be applied to the repaired sleeves in Unit 2, discuss whether removal of the current sleeve repair pad will increase the local stresses at the pressurizer penetration.

APS Response

The Unit 2 repairs are complete. No additional repairs are necessary. The Unit 2 repairs did use a half-nozzle replacement. However, the attachment weld was made using Relief Request 23 submitted on May 15, 2004 and approved on July 30, 2004.

This method used a weld pad on the outer surface of the pressurizer and the replacement sleeve was welded to this pad.

NRC Question 3

Discuss the plan for inservice inspection of the new half sleeves after installation, including the inspection scope (the number of the sleeves), coverage of individual sleeve, frequency, and technique.

APS Response

The ASME Section XI inservice inspection (ISI) requirements applicable to pressurizer heater sleeves include:

- A VT-2 visual examination for leakage through the partial penetration weld that joins the sleeve to the pressurizer vessel wall under Section XI Examination Category B-E. The Category B-E examination is required to be performed each ten year interval. APS also performs a supplemental VT-2 on all heater sleeves each refueling outage.

- A VT-2 visual examination for leakage through the partial penetration weld under Examination Category B-P. The Category B-P examination is required to be performed after each refueling outage under NOP/NOT conditions.

APS shall perform the above pressure tests per the Section XI requirements

APS has also committed to adopting the three elements of the proposed Westinghouse Owners Group (WOG) inspection program, as discussed in WOG letter WOG-04-057, dated January 30, 2004 and committed to in APS letter 102-05130, dated July 22, 2004.

NRC Question 4

Describe the installation of the half-sleeve step-by-step, including (a) how the new sleeve is attached to the bore of the pressurizer penetration prior to welding (e.g., interference joint, roll joint); (b) how the lower half of the original sleeve is removed from the pressurizer bore; (c) how is the pressurizer penetration bore prepared and inspected prior to installing the new sleeve, (d) what inspection will be performed to determine the acceptance of the sleeve installation, (e) describe the acceptance criteria of the sleeve installation, and (f) discuss whether a hydrostatic or system leakage test will be performed after the sleeve installation and the basis for the selected test.

APS Response

(a) The sleeve is not attached to the bore of the pressurizer prior to welding (i.e. slip fit).

(b) The lower half of the original sleeve is removed in two independent steps. First, the sleeve is cut approximately 1 inch below the bottom surface of the pressurizer using a grinder. Second, the sleeve is severed within the penetration, approximately midwall, using a circular cutting disk.

(c) The pressurizer penetration bore shall be cleaned and a liquid penetrant test shall be performed.

(d) The new sleeve attachment weld shall be examined by ASME Section III UT and PT methods and ASME Section XI pressure tests.

(e) The installation shall meet acceptance criteria of NB-5330 for UT, NB-5350 for PT, and no leakage is allowed during the pressure test.

(f) A system leakage test shall be performed at normal operating pressure after sleeve installation per IWA-4700 and Code Case N-416-1.

NRC Question 5

The licensee did not provide in the submittal a conclusive statement regarding why and how the structural and leakage integrity of the primary system pressure boundary is maintained by the repaired heater sleeve design and associated NRC regulations and ASME Code subarticle(s). The licensee should make such a statement. The licensee referenced 10 CFR 50.55a(a)(3) which provides authorization of relief request; however, that regulation does not provide guidance on pressure boundary integrity.

APS Response

10 CFR 50.55a(a)(3) states only that proposed alternatives to the requirements of paragraphs (c), (d), (e), (f), (g), and (h) can be authorized when compliance would provide an acceptable level of quality and safety, or result in hardship or unusual difficulty without a compensating increase in the level of quality or safety. 10 CFR 50.55a(c)(1) provides the requirements that reactor coolant pressure boundary components must meet. This section states that components which are part of the reactor coolant pressure boundary must meet the requirements for Class 1 components in Section III of the ASME Boiler and Pressure Vessel Code except as provided in paragraphs (c)(2), (c)(3), and (c)(4) of this section.

APS has designed the replacement nozzle and attachment weld in accordance with the requirements of ASME Section III and has not requested relief from any of these requirements. As a result, the structural and leakage integrity of the primary system pressure boundary will be maintained by the repaired heater sleeve design.

The ASME Code also requires APS to use qualified installation (welding) and testing (PT, UT and pressure) procedures. APS, in conjunction with its vendors and associated utilities, is in the process of developing these qualified processes. Relief Request 28 provides alternatives to the requirements of paragraph (g) which includes ASME Section XI, Article IWA-4000, "Repair and Replacement." Through this process, APS is requesting relief from the identified welding and examination requirements.

NRC Question 6

The new pressure boundary repair weld that connects the new half-sleeve and the low alloy pressurizer base metal contains a material triple point. The triple point is at the root of the repair weld where the half-sleeve will be welded to the pressurizer base metal. Experience has shown that during solidification of the weld filler material, a lack of fusion may occur which is otherwise described as a welding solidification anomaly. A flaw should be assumed at this triple point and its stability and flaw growth should be evaluated. It seems that the licensee's analysis did not consider this flaw. Explain.

ASP Response

APS vendors (WSI and SI) have conducted an extensive welding development and metallurgical examination program to address the potential triple point/welding solidification anomaly. This program includes the production of approximately fifteen weldments to date, which simulate the weld geometry and triple point by welding Alloy 690 sleeves into large blocks of low alloy steel material that have been bored to simulate the pressurizer bottom head. The initial seven welding samples were slightly over-sized (2.1" inside diameter sleeves) to accommodate a larger welding head that was immediately available for testing. The last eight welding samples were field size (1.3" inside diameter sleeves), and used the field welding head specifically developed for this repair. Welding parameters were continuously evolved and optimized during this program, and each sample was sectioned and metallurgically examined at high magnification after welding. Although initial attempts resulted in small triple point cracks due to welding solidification problems (Figure 6-1), a production welding process was subsequently developed that consistently produces welds that contain no welding triple point defects or solidification anomalies (Figure 6-2, which is typical of over seven weldments produced using the prototype geometry and production welding head). Thus, the primary response to this question is that, by virtue of the optimized welding parameters obtained in the welding development effort, mid-wall repair welds in the field will not contain any triple point solidification anomalies.

Nonetheless, since the actual installation welds on the pressurizer cannot be sectioned for metallurgical examination, a fracture mechanics evaluation has been conducted to establish inspection criteria and acceptance standards for the field welds. The evaluation was conducted for two crack paths emanating from the triple point, as illustrated in Figure 6-3.

1. The evaluation first utilized ASME Code, Section XI Allowable Flaw Standards for Austenitic Piping and Dissimilar Metal Welds (Subparagraphs IWB-3514.3 and IWB-3514.4). These were used to establish limits on NDE detectibility for the mid-wall repair weld. If no indications are detected that exceed these limits, the welds are considered acceptable in accordance with ASME Code, Section XI, IWB-3112, and no successive examinations, in accordance with ASME Code, Section XI, IWB-2420, are required. The standards for preservice inspection, which are more conservative than those for inservice inspection, are used. Both IWB-3514.3 and IWB-3514.4 refer to Table IWB-3514-2 (attached here as Figure 6-4 for reference). For a preservice inspection, the allowable a/t = 9.4% for a 360° flaw in a component with wall thickness = 0.312" or less. For a potential flaw along Path 1 (t = 0.177"), therefore $a_{allowable}$ = 0.0166". For Path 2 (t=0.577"), the allowable a/t by interpolation of Table IWB-3514-2 is 9.05%. Therefore, for a potential flaw along Path 2, $a_{allowable}$ = 0.0522".

2. To confirm the safety margins inherent in these preservice inspection standards, fracture mechanics evaluations were also performed of potential triple point indications using the flaw evaluation methods of Section XI, IWB-3640, including fatigue crack growth evaluations for the remainder of the 60 year extended life of the plant, to demonstrate that the allowable flaw sizes permitted by the standards would not grow to an unacceptable size in service. The allowable end-of-evaluation period flaw sizes were determined in accordance with Table IWB-3641-1 (attached here as Figure 6-5 for reference). Stresses for the flaw evaluation were obtained from prior finite element analyses performed of the Palo Verde pressurizer mid-wall repair. These result in $(P_m + P_b) / S_m$ values less than 0.6 for both paths in Figure 6-3, resulting in an allowable flaw size as a fraction of thickness (a/t) for a 360° flaw of 0.63. Applying this fraction to radially oriented flaws emanating from the triple point (Path 1), the allowable end-of-evaluation period flaw size is 0.112". Applying it to laminar type flaws propagating in the same plane as the annular gap between the heater sleeve and the pressurizer bottom head (Path 2), results in an allowable flaw size of 0.36".

Fracture mechanics fatigue crack growth calculations were then performed for both crack paths. Since the assumed triple point flaws are not exposed to the reactor water environment, PWSCC is not a factor, and the Section XI fatigue crack growth law for austenitic material in air environments was used (ASME Code, Section XI, Appendix C, Figure C-3210-1). An operating temperature of 650°F was assumed in the crack growth law. The analyses were performed for various initial flaw sizes, using the computer program **pc-CRACK**.

For added conservatism, a high residual stress level of 50 ksi uniform through the thickness was assumed perpendicular to both flaw paths. This results in a high sustained stress level, about which cycling between the various operational stress levels was superimposed. The effect of residual stress in fatigue crack growth is to produce a high R-ratio (K_{min}/K_{max}) which increases the crack growth rate for given cycling amplitude.

Analysis results are illustrated in Figures 6-6 and 6-7 for assumed Path 1 and Path 2 cracks, respectively. In both figures, the lower and upper horizontal dashed lines represent the ASME Code, Section XI Standards (IWB-3514.4) and End-of-Evaluation Period (IWB-3640) allowable flaw sizes, respectively. Two crack growth curves are shown in both figures. The lower crack growth curves represent starting flaw sizes approximately twice the depth of the ASME Code standards. These show essentially no growth in sixty years. The upper crack growth curves represent the approximate starting crack growth size that would grow to the end-of-evaluation period allowable crack size in sixty years. It is seen from these figures that there are large margins between the Section XI standards and the flaw sizes that can be justified by fracture mechanics evaluations. Also shown, as cross-hatched regions in the two figures, are the target detectibility ranges for the two assumed flaw paths. The inspection detectibility targets are set consistent with the Section XI standards, to avoid successive inspection requirements. The triple point flaw evaluation results are summarized in Table 6-1.

Table 6-1. Summary of Evaluation Results

Location	Allowable Flaw Size per Section XI Standards	Allowable Flaw Size per Fracture Mechanics Evaluation	
		Initial Flaw Size*	End-of-Evaluation Period
Path 1	0.017"	0.089"	0.112"
Path 2	0.052"	0.263"	0.360"

*Approximate flaw size that would grow to end-of-evaluation period allowable in sixty years.

NRC Question 7

In the Table of Contents, various sections of the report are listed; however, in the report, sections are not numerated or identified. Include the sections in the report.

APS Response

Please see the attachment to this enclosure for a reformatted Technical Report. The technical content has not been revised.

NRC Question 8

Pages 5 and 6. ASME Section III Stress Analysis.

a. Clarify whether a bending load is applied to the heater sleeve. If not, discuss the basis. If a bending load is applied, discuss how and where on the sleeve is the bending load applied and the magnitude of the bending load.

b. Discuss whether the stress analysis considered the effect of the heater inside the sleeve.

c. Describe how the heater is attached to the sleeve.

d. The stress intensity of the new sleeve is shown in Tables 3-5 and 3-6. However, discuss the stress intensity of the new attachment weld.

e. ASME Section III specifies seismic and/or dynamic loading in stress analysis of components. Discuss whether seismic and dynamic loads were included in the load combination, and

f. Demonstrate that the new half-sleeve will not be ejected from the pressurizer bore under the accident conditions.

APS Response

a. For the ASME Code, Section III evaluations, design basis loading conditions were considered. These are documented in the construction General and Project Specifications, and Analytical Reports. As stated in the portion of the Analytical Reports related to the heater sleeves: "Although the heater assemblies are subjected to seismic loads, the resulting stresses are insignificant since the design of the heater assembly does not load the welds in this event." This same logic holds for the evaluation of the mid-wall repairs. It should also be noted that the mid-wall repair weld is significantly stronger than the existing J-groove weld.

b. The heater element is welded to the heater sleeve outside the pressurizer bottom head, and there is a relatively small radial gap between the heater element and the sleeve. Since the radial gap is small, and the heater element is welded to the heater sleeve outside the pressurizer bottom head, the contained water in the radial gap is relatively stagnant. As such, the inside surface of the heater sleeve was not subjected to thermal transient loadings.

c. The heater is welded (fillet weld) to the sleeve.

d. Figure 3-3 (page 3-20 of the attachment to this enclosure) shows the two paths used to extract the stresses shown in Tables 3-5 and 3-6 (page 3-15 of the attachment to this enclosure). These paths represent the locations of maximum stress intensity in the replacement sleeve and mid-wall weld. As seen in the figure, both paths are through the weld, which is the controlling location.

e. As stated in the response to Question 8(a), design basis loading conditions per the original construction documentation were considered, and consisted of pressure and thermal transient conditions.

f. All design basis conditions have been considered in the ASME Code evaluation of the mid-wall repair. These include all normal and upset conditions, as well as any postulated accident conditions. Since ASME Code criteria have been satisfied, including appropriate factors-of-safety, ejection is not a concern.

NRC Question 9

Page 6, The licensee used 200 degree F/hour for heatup and cooldown operation. Discuss the basis of this rate and provide the reference from which the 200 degree F/hr was obtained.

APS Response

The heatup/cooldown transient is a design basis condition, and is extracted from the construction General Specification.

NRC Question 10

Page 7. Under option 1 of the fatigue calculation and in Table 3-12, cooldown+Heatup+$P_{operate}$ is shown to have 30 cycles. Confirm whether a value of 30 cycles is correct because this value seems to be low in the 60 years (considering 20 years of license extension) of plant operation.

APS Response

For the fatigue analyses, the original design basis transients were used. In addition, the original design basis number of transients for a 40-year life was increased by 50% to account for an additional 20-year life extension. Table 3-3 (page 3-12 of the attachment to this enclosure) summarizes the number of events considered for each controlling design basis transient.

In performing the fatigue analyses, ranges of stress are of interest. The heatup transient results in the largest compressive stress while the reactor trip transient results in the largest tensile stress. Therefore, 720 cycles (the number of total cycles for the reactor trip transient) were evaluated for this combination, which results in the largest range of stress intensity when considering all other transient conditions. Since 720 of the 750 heatup transients have been combined with the reactor trip transient, that leaves 30 heatup transients which still need to be considered. These 30 heatup transients were then combined with 30 cooldown transients to determine the next largest range of stress intensity.

NRC Question 11

Page 8. The report states that flaws were postulated in the remnant portion of the original sleeve, the original attachment (J-groove) welds, and the overlay pressurizer base metal. However, on page 14, the report states that the initial flaw size was taken at the overlay/low alloy steel interface. The staff is not clear regarding the flaw configuration and flaw location modeled in the finite element analysis.

a. Discuss whether a single, continuous flaw is modeled in the original sleeve wall, original attachment weld, and overlay base metal, or, three individual, discrete flaws are modeled in each of the three materials. Provide diagram(s) to show where the flaw is located with respect to the above three components.

b. Provide the initial flaw length and depth. On page 13, a flaw depth of 0.6 inch and 1.2 inches are discussed; however, the staff is not clear whether the 1.2-inch is used in the analysis. Discuss whether 1.2 inch flaw was modeled in the analysis and discuss the basis of selecting these flaw sizes.

c. Describe where the initial flaw is located in the material(s), which direction the flaw propagates, and where it is finally arrested.

d. On page 14, the final flaw size is calculated to be 1.16 inch for the initial flaw size of 0.6 inch. Discuss whether a flaw size of 1.16 inch is within the acceptance criteria.

e. Discuss what would be the final flaw size for the initial flaw size of 1.2 inch.

f. Describe the flaw configuration assumed in the analysis (e.g., semi-elliptical, axial, circumferential)

APS Response

a. The postulated flaw configuration considered is shown in Figure 3-4 (page 3-21 of the attachment to this enclosure). This is considered a very conservative depiction of any actual flaw geometry. The rational for the depicted flaw configuration is based upon PWSCC initiation and growth through the entire sleeve remnant, original J-groove weld, and overlay material (i.e., all locations are assumed coincidently

cracked for the fracture mechanics evaluation). In addition, it is conservatively postulated that the same flaw configuration is on both the uphill side and downhill side of the heater sleeve centerline.

The PWSCC growth is assumed to arrest at the intersection of the overlay material and the low allow steel pressurizer bottom head base material. Further growth into the base material is postulated to be through a fatigue crack growth mechanism.

b. The thickness of the overlay material is 0.5 inches. Because the heater sleeves are non-radial, the 0.5" dimension results in a 0.6" overlay thickness in a direction parallel to the heater sleeve axis, i.e., the length from Crack Tip 101 to the interface with the base material in Figure 3-4. As seen in Figure 3-4, the resulting flaw in the overlay material is diamond shaped with legs of about equal length. The 1.2" dimension is an arbitrary number chosen for the elastic-plastic fracture mechanics evaluation.

c. The above discussion describes the initial flaw assumptions. The largest applied stress intensity factor in the base material is at the interface with the bore hole. Therefore, it is postulated that the flaw grows along the bore hole. As to arrest, analyses have been performed to show that the postulated flaw does not grow to unacceptable depths during the sixty-year evaluation period. Analyses have not been performed to determine at what depth the flaw will arrest.

d. Although fracture mechanics acceptance criteria have been maintained using linear elastic fracture mechanics techniques for the initial postulated flaw configuration, fatigue crack growth for the remaining life of the plant results in unacceptable results. Consequently, elastic-plastic fracture mechanics techniques have been utilized. The elastic-plastic fracture mechanics analyses have shown that a flaw that is 1.2" deep is acceptable. The fatigue crack growth analyses have shown that after sixty years of operation, the postulated flaw only grew to a depth of 1.16". Therefore, acceptance criteria have been maintained.

e. As stated in the response to Question 11(c), final flaw size calculations have not been performed.

f. The assumed flaw configuration is as stated above, and shown in Figure 3-4 (page 3-21 of the attachment to this enclosure).

NRC Question 12

Page 9. The report states that an ASME Code, Section XI, interpretation has been issued regarding the safety factor of $\sqrt{2}$. to be considered in calculating the allowable stress intensity factor at the end of the cooldown transient. (a) Provide the reference of this interpretation. (b) The NRC does not routinely recognize ASME Interpretations. Therefore, the licensee needs to use the safety factor of $\sqrt{10}$. as specified in ASME Code Section IX IWB-3612(a) to calculate the allowable stress intensity factor. Discuss whether the results and conclusion of the flaw evaluation would be changed based on the change of the allowable stress intensity factor. Alternatively, the licensee needs to provide justification regarding the acceptability of a safety factor of $\sqrt{2}$. in calculating the allowable stress intensity factor.

APS Response

a. The ASME Code interpretation is File Number IN 03-013, dated September 8, 2003 (see Attachment 2).

b. As seen in Table 3-9, the calculated applied stress intensity factor at the end of the cooldown transient is 22.9 $ksi\sqrt{in}$. As stated in Table 3-9, the allowable stress intensity factor, based upon a factor-of-safety of $\sqrt{2}$, is 47 $ksi\sqrt{in}$. If the factor-of-safety is $\sqrt{10}$, then the allowable stress intensity factor is 21 $ksi\sqrt{in}$, and the acceptance criteria are not maintained.

   IWB-3613 is titled "Acceptance Criteria for Flanges and Shell Regions near Structural Discontinuities." Even though the paragraph states in part that areas <u>such as</u> vessel-flange and top head-flange intersections, these are only examples of shell regions near structural discontinuities. The shell region near a heater sleeve is also a structural discontinuity, and the criteria of IWB-3613 should apply to this structural discontinuity. This would allow the use of a factor-of safety of $\sqrt{2}$.

NRC Question 13

Page 9. [Page 3-5 of reformatted report] The report states that the maximum stress intensity factor at the overlay-low alloy steel interface is calculated. This indicates that the flaw is located in the low alloy base metal. (a) Discuss whether a flaw is postulated in the original sleeve wall or in the original weld. (b) Discuss whether the flaws in the original attachment weld or in the original sleeve wall were considered in the stress intensity factor calculations. (c) Discuss whether material properties of original sleeve or attachment welds were considered in calculating stress intensity factor.

APS Response

(a) This is addressed previously in the response to NRC Question 11a.

(b) This is addressed previously in the response to NRC Question 11a.

(c) The stress analyses performed, and as described previously, considered properties for all materials evaluated. These were obtained from the ASME Code. For weld materials, base material properties were used.

NRC Question 14

Pages 8 and 9. It seems that the residual stresses of the original attachment weld are not included in calculating the stress intensity factor. Explain why the residual stresses are not included in the flaw evaluation.

APS Response

The effect of weld residual stresses has been evaluated for another plant's pressurizer of similar geometry. The approach taken was as follows:

1. A three-dimensional finite element model of a heater sleeve with axisymmetric geometry was developed.

2. The model was subjected to the process used during original construction. Elastic-plastic techniques were utilized.

   - Weld overlay material was applied to the base material, and then postweld heat treated.

   - The model then incorporated the bore hole and machining of the J-groove.

   - The J-groove weld and cover fillet were then applied to the model.

   - The model was subjected to a hydrostatic test pressure, where the pressure was increased to account for the increased pressure stresses in the heater sleeve located furthest away from the pressurizer centerline.

3. The resulting stresses were applied to a fracture mechanics finite element model, and the resulting applied stress intensity factors at the interface between the overlay material and pressurizer bottom head base material were insignificant.

NRC Question 15

Page 13. The report states that the fatigue crack growth evaluation used the number of cycles for 40 years from Table 3-3. The report states further that Table 3-12 contains number of cycles for a postulated 60 year life. Clarify whether the transient cycles for 40 years or 60 years were used in the crack growth calculations.

APS Response

Sixty years of fatigue crack growth were considered in the evaluation. The wording in the attached report is somewhat misleading. The number of cycles was assumed to be evenly distributed over a plant life of 40 years, i.e., for every two years of fatigue crack growth, 25 heatup/cooldown events were considered, 24 reactor trips were considered, and 10 plant leak tests were considered. Since the number of cycles for 60 years of life is directly related to the number of cycles for 40 years, the results for a block of two years are identical.

NRC Question 16

Page 14. 4th paragraph. The report states that the flaw at the end-of-evaluation period is less than the allowable flaw size calculation in Section 3.3.2. Section 3.3.2 is not identified in the report. The staff assumes that Section 3.3.2 is related to calculation of applied J-T which is on page 12. (a) Provide the allowable flaw size for the end-of-evaluation period. (b) Clarify whether 40 or 60 year is the end-of-evaluation period.

APS Response

(a) The calculated flaw size at the end of 60 years is 1.16", which is less than the 1.2" allowable flaw size determined in the elastic-plastic fracture mechanics evaluations.

(b) This is addressed previously in the response to NRC Question 15 above.

NRC Question 17

Page 20. Table 3-9 shows the allowable stress intensity factors which presumably were converted from a K_{IC} value. It seems that a K_{IC} value of 200 in-ksi/in^2 was used, but not mentioned in the report. Confirm this K_{IC} value.

APS Response

Referring to Table 3-9 of the attachment, K1a is used versus K1c for normal/upset conditions and K1c for emergency/faulted conditions. Both equal a value of 200 $ksi\sqrt{in}$ in the "hot" conditions.

NRC Question 18

Page 31. There are two graphs on this page but with only one caption, i.e., Figure 3-9. The staff assumes that the bottom graph is Figure 3-10. The only difference between the two graphs is that the bottom graph is the enlargement of the top graph. Confirm this observation.

APS Response

See Figures 3-9 and 3-10 in the attached report.

NRC Question 19

Page 33. In the Conclusion section, the specific subarticle of ASME Code Section III that the half-sleeve design satisfies should be cited.

APS Response

The ASME Code, Section III evaluation was performed to the criteria contained in Subarticle NB-3200.

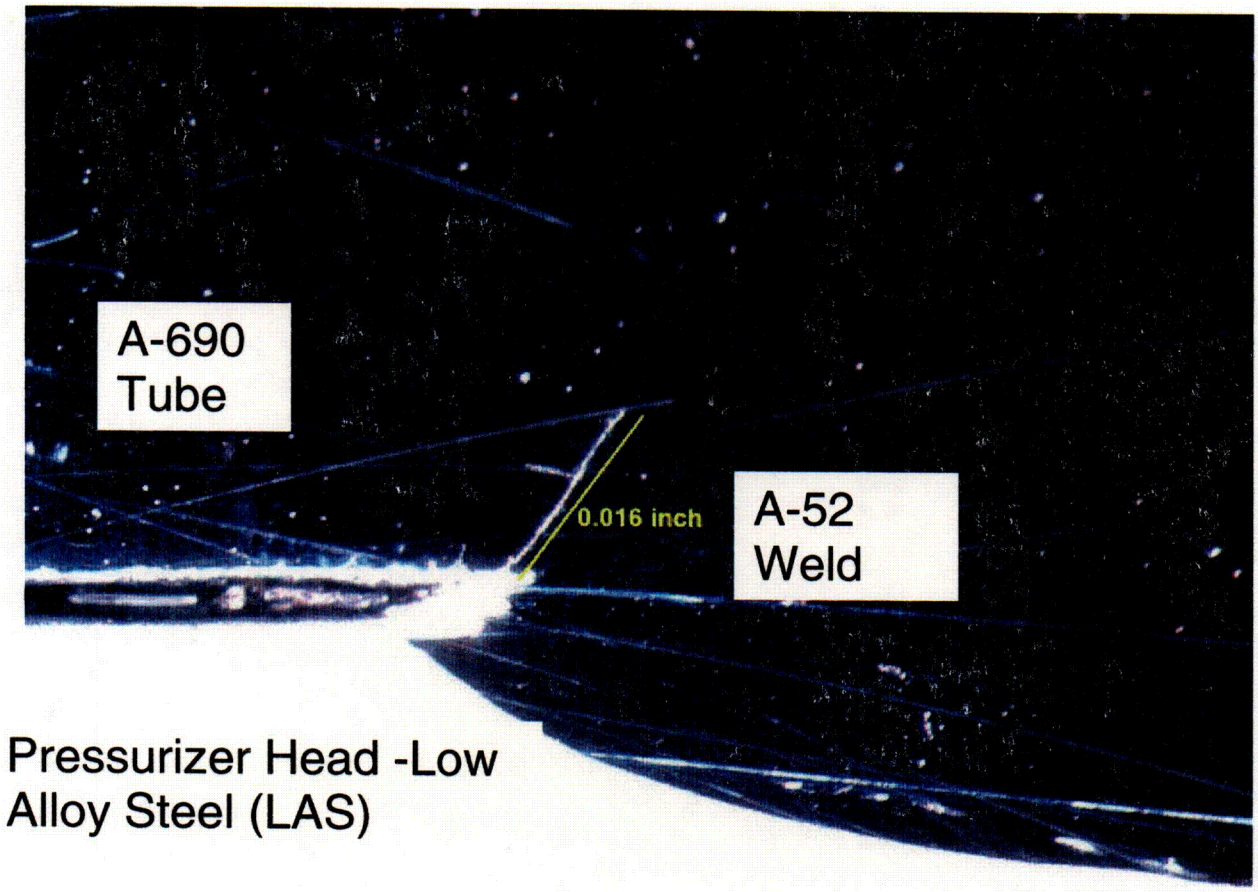

Figure 6-1.
Photo-micrograph (50x) of weld sample produced early in weld development program that exhibited cracking at the weld root.

C01

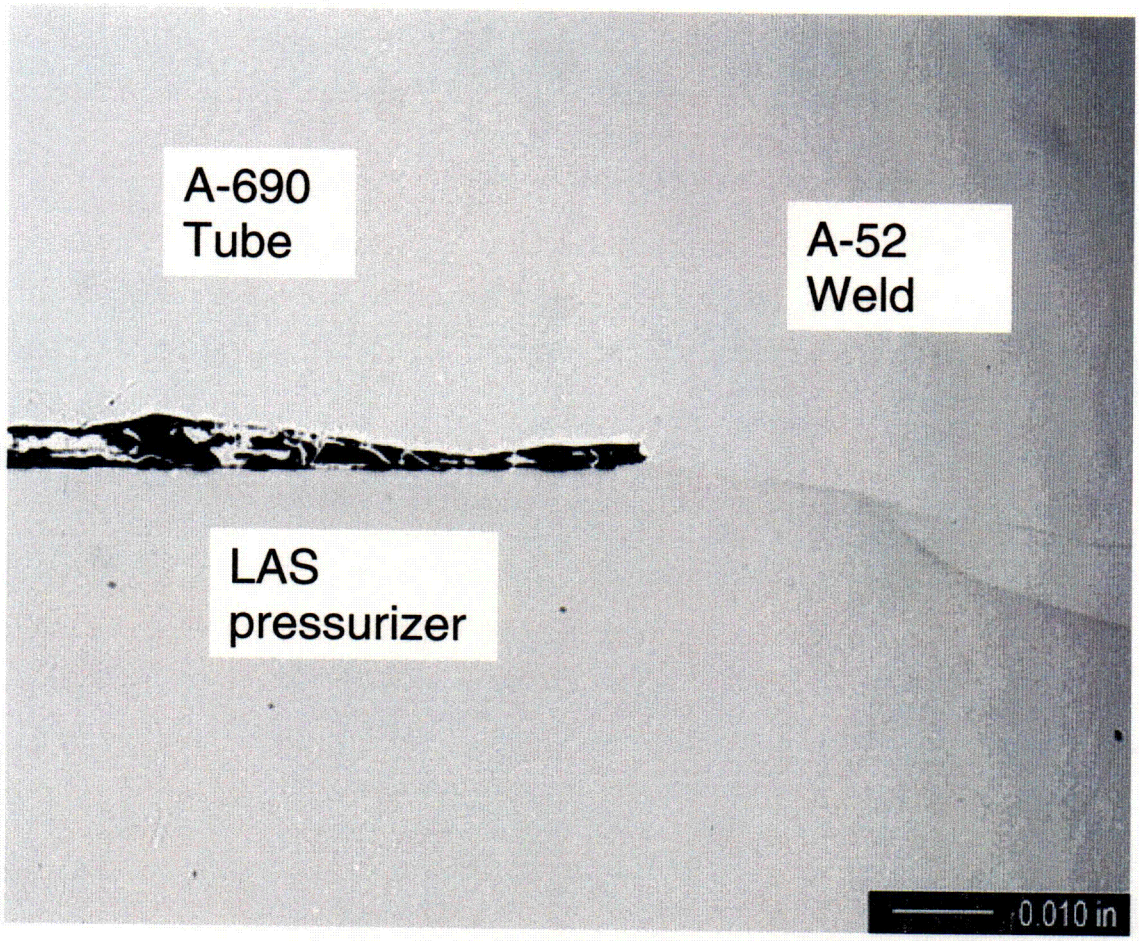

Figure 6-2.
Photo-micrograph (50x) of weld sample representative of production welding process. Typical of over eight samples produced with the final welding parameters that resulted in no triple point cracking.

C02

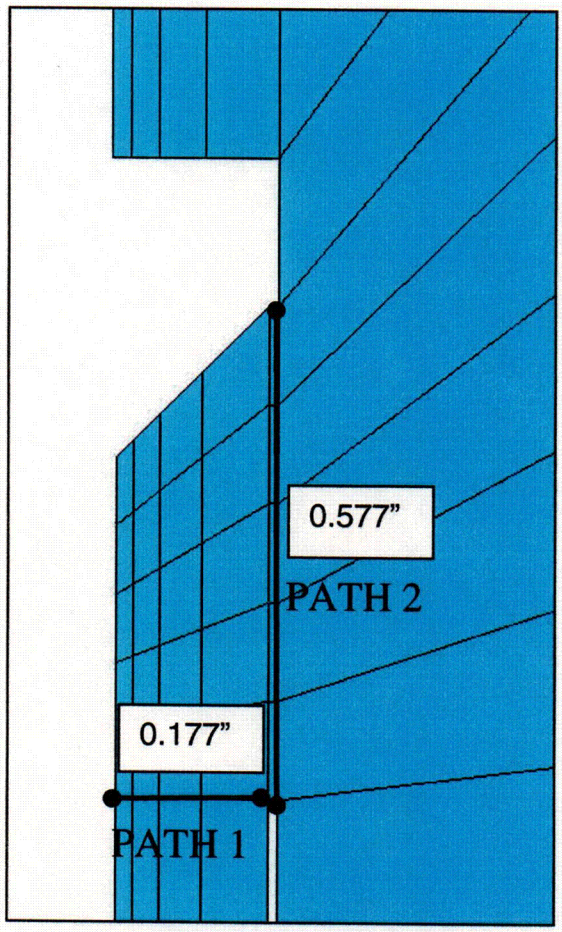

Figure 6-3.

Illustration of assumed flaw paths for potential triple-point indications.

C03

TABLE IWB-3514-2
ALLOWABLE PLANAR FLAWS
Material: Austenitic steels that meet the requirements for the specified minimum yield strength of 35 ksi (291 000 kPa) or less at 100°F (38°C)

Aspect Ratio,[1] a/ℓ	Volumetric Examination Method, Nominal Wall Thickness,[1,2] t, in.								Surface Examination Method	
	0.312 (8)		1.0 (25)		2.0 (51)		3.0 (76)			
	Surface Flaw, a/t, %	Subsurface Flaw,[3,4] a/t, %	Surface Flaw, a/t, %	Subsurface Flaw,[3,4] a/t, %	Surface Flaw, a/t, %	Subsurface Flaw,[3,4] a/t, %	Surface Flaw, a/t, %	Subsurface Flaw,[3,4] a/t, %	Nom. Wall Thickness,[1,2] t, in. (mm)	Flaw Length, ℓ, in. (mm)
Preservice Examination										
0.00	9.4	9.4Y	8.5	8.5Y	8.0	8.0Y	7.6	7.6Y	0.312 (8) or less	1/8 (3.2)
0.05	9.6	9.6Y	8.6	8.6Y	8.2	8.2Y	7.7	7.7Y		
0.10	9.8	9.8Y	8.8	8.8Y	8.3	8.3Y	7.8	7.8Y	1.0 (25)	3/16 (4.8)
0.15	9.9	9.9Y	8.9	8.9Y	8.4	8.4Y	7.9	7.9Y		
0.20	10.0	10.0Y	9.1	9.1Y	8.6	8.6Y	8.1	8.1Y	2.0 (51)	1/4 (6)
0.25	10.0	10.0Y	9.2	9.2Y	8.7	8.7Y	8.2	8.2Y		
0.30	10.0	10.0Y	9.4	9.4Y	8.9	8.9Y	8.3	8.3Y	3.0 (76) and over	1/4 (6)
0.35	10.0	10.0Y	9.5	9.5Y	9.0	9.0Y	8.5	8.5Y		
0.40	10.0	10.0Y	9.7	9.7Y	9.1	9.1Y	8.6	8.6Y		
0.45	10.0	10.0Y	9.8	9.8Y	9.3	9.3Y	8.7	8.7Y		
0.50	10.0	10.0Y	10.0	10.0Y	9.4	9.4Y	8.9	8.9Y		
Inservice Examination										
0.00	11.7	11.7Y	10.6	10.6Y	10.0	10.0Y	9.5	9.5Y	0.312 (8) or less	0.2 (5)
0.05	12.0	12.0Y	10.7	10.7Y	10.2	10.2Y	9.6	9.6Y		
0.10	12.2	12.2Y	11.0	11.0Y	10.4	10.4Y	9.7	9.7Y	1.0 (25)	0.25 (6)
0.15	12.4	12.4Y	11.1	11.1Y	10.5	10.5Y	9.9	9.9Y		
0.20	12.5	12.5Y	11.4	11.4Y	10.7	10.7Y	10.1	10.1Y	2.0 (51)	0.45 (11)
0.25	12.5	12.5Y	11.5	11.5Y	10.9	10.9Y	10.2	10.2Y		
0.30	12.5	12.5Y	11.7	11.7Y	11.1	11.1Y	10.4	10.4Y	3.0 (76) and over	0.65 (16)
0.35	12.5	12.5Y	11.9	11.9Y	11.2	11.2Y	10.6	10.6Y		
0.40	12.5	12.5Y	12.1	12.1Y	11.4	11.4Y	10.7	10.7Y		
0.45	12.5	12.5Y	12.2	12.2Y	11.6	11.6Y	10.9	10.9Y		
0.50	12.5	12.5Y	12.5	12.5Y	11.7	11.7Y	11.1	11.1Y		

NOTES:
(1) For intermediate flaw aspect ratios a/ℓ and thickness t, linear interpolation is permissible. Refer to IWA-3200(b) and (c).
(2) t is nominal wall thickness or actual wall thickness as determined by UT examination.
(3) The total depth of a subsurface flaw in $2a$.
(4) $Y = (S/t)/(a/t) = S/a$. If $S < 0.4t$, the flaw is classified as a surface flaw. If $Y > 1.0$, use $Y = 1.0$.

Figure 6-4.

ASME Code, Section XI acceptance standards for flaws in austenitic piping (preservice and inservice). Also applicable to high nickel allow portion of dissimilar metal welds.

TABLE IWB-3641-1
ALLOWABLE END-OF-EVALUATION PERIOD FLAW
DEPTH[1] TO THICKNESS RATIO
FOR CIRCUMFERENTIAL FLAWS — NORMAL OPERATING (INCLUDING UPSET AND TEST) CONDITIONS

$\frac{P_m + P_b}{S_m}$ [Note (2)]	Ratio of Flaw Length, ℓ_f, to Pipe Circumference [Note (3)]					
	0.0	0.1	0.2	0.3	0.4	0.5 or Greater
1.5	(4)	(4)	(4)	(4)	(4)	(4)
1.4	0.75	0.40	0.21	0.15	(4)	(4)
1.3	0.75	0.75	0.39	0.27	0.22	0.19
1.2	0.75	0.75	0.56	0.40	0.32	0.27
1.1	0.75	0.75	0.73	0.51	0.42	0.34
1.0	0.75	0.75	0.75	0.63	0.51	0.41
0.9	0.75	0.75	0.75	0.73	0.59	0.47
0.8	0.75	0.75	0.75	0.75	0.68	0.53
0.7	0.75	0.75	0.75	0.75	0.75	0.58
≤ 0.6	0.75	0.75	0.75	0.75	0.75	0.63

NOTES:
(1) Flaw depth = a_n for a surface flaw
$2a_n$ for a subsurface flaw
t = nominal thickness
Linear interpolation is permissible.
(2) P_m = primary longitudinal membrane stress ($P_m \leq 0.5\ S_m$)
P_b = primary bending stress
S_m = allowable design stress intensity (in accordance with Section III)
(3) Circumference based on nominal pipe diameter.
(4) IWB-3514.3 shall be used.

Figure 6-5.

Maximum allowable end-of-evaluation period flaw size for austenitic piping (including wrought stainless steel and Ni-Cr-Fe alloy pipe material and associated weldments) for use in fracture mechanics evaluation of flaws observed in inservice inspections.

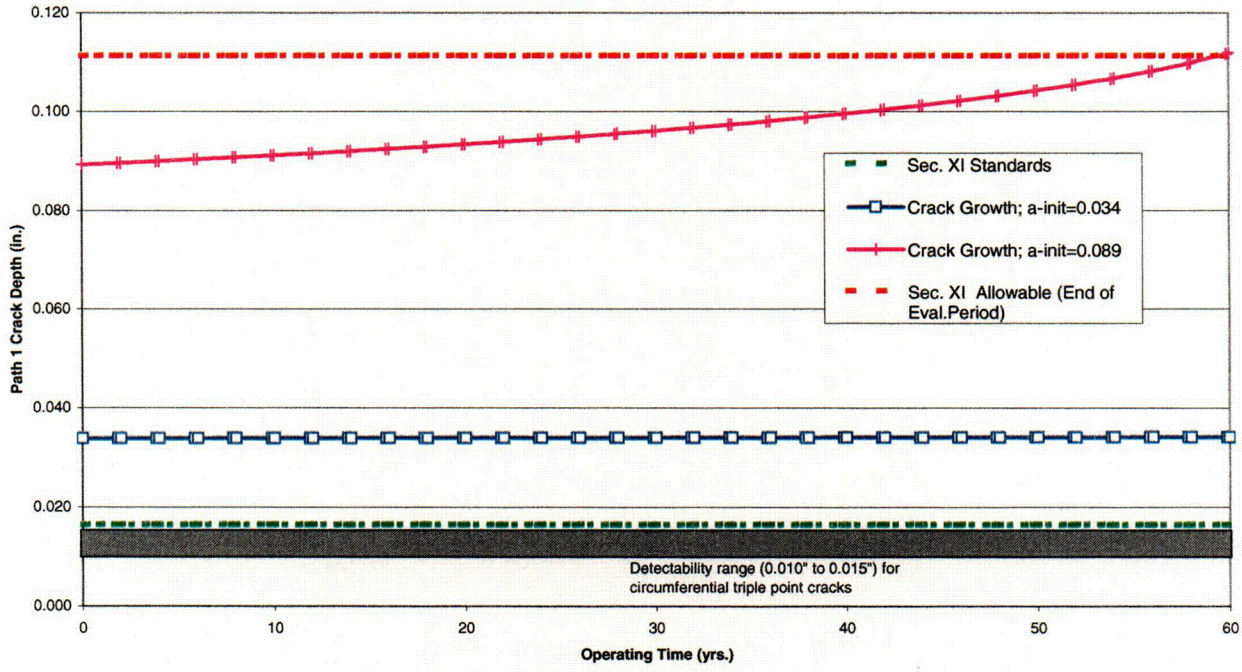

Figure 6-6.

Evaluation results for assumed Path 1 crack.

C04

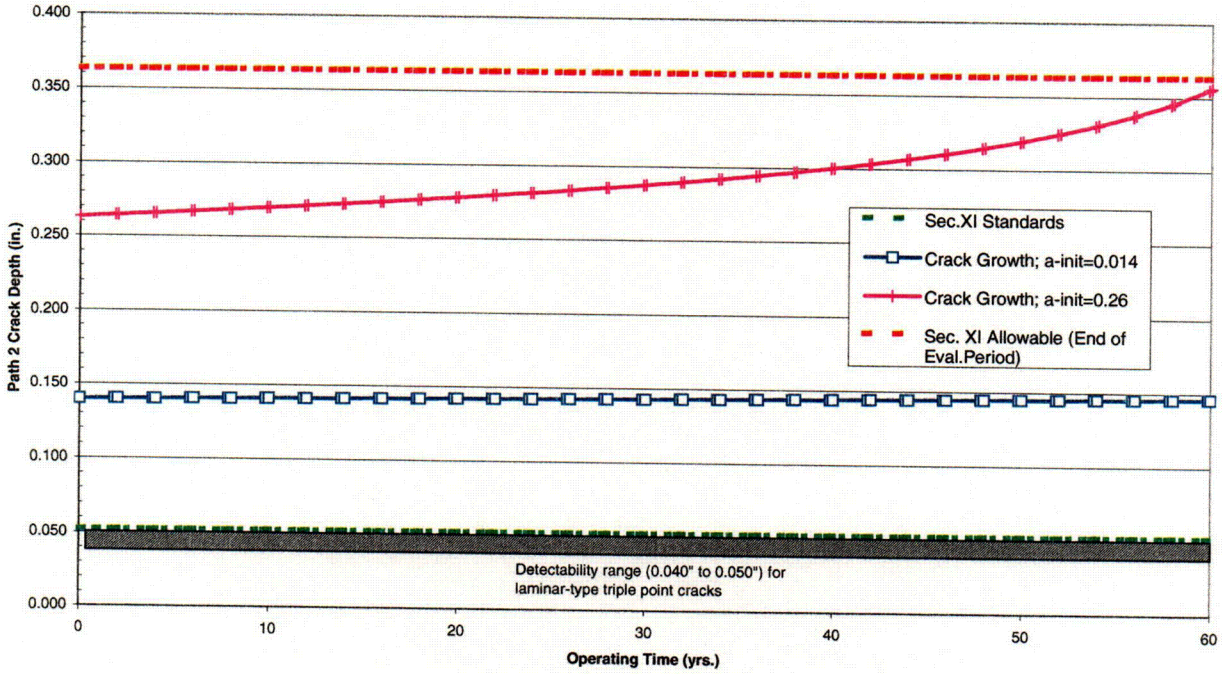

Figure 6-7.

Evaluation results for assumed Path 2 crack.

C05