March 2, 2005

Mr. Harold B. Ray
Executive Vice President
Southern California Edison Company
San Onofre Nuclear Generating Station
P.O. Box 128
San Clemente, CA 92674-0128

SUBJECT: SAN ONOFRE NUCLEAR GENERATING STATION, UNITS 2 AND 3 - EVALUATION OF RELIEF FOR REPAIR OF PRESSURIZER SLEEVES DURING THE THIRD 10-YEAR INSERVICE INSPECTION (ISI) INTERVAL (TAC NOS. MC4789 AND MC4790)

Dear Mr. Ray:

By letter dated October 15, 2004, as supplemented by letters dated October 25 and December 2, 2004, you requested that the NRC review and approve relief requests ISI-3-11, Revision 1 and ISI-3-12 for repairs of pressurizer nozzle penetrations at San Onofre Nuclear Generating Station (SONGS), Units 2 and 3. Pursuant to 50.55a(a)(3)(i) of Title 10 of the *Code of Federal Regulations* (10 CFR), you proposed your relief requests as acceptable alternatives to requirements of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (Code), Section XI. The NRC staff has evaluated your requests for relief, and reports its findings in the enclosed NRC Safety Evaluation.

The NRC staff concludes that the licensee's relief request ISI-3-11, Revision 1, from the requirements of Article IWA-4600 of the ASME Code, Section XI provides an acceptable level of quality and safety, and is authorized pursuant to 10 CFR 50.55a(a)(3)(i) for the third 10-year ISI interval at SONGS, Units 2 and 3. The NRC staff also concludes that the licensee's proposed relief request ISI-3-12 shows that compliance with the ASME Code requirements regarding flaw characterization and successive examinations of remnant pressurizer sleeves and welds impractical, and is therefore authorized, pursuant to 10 CFR 50.55a(g)(6)(i), for the third 10-year ISI interval at SONGS, Units 2 and 3. During a teleconference call with Mr. Jack Rainsberry of your staff on December 16, 2004, the NRC also granted verbal authorization for these two reliefs.

Sincerely,

/RA/

Robert A. Gramm, Chief, Section 2
Project Directorate IV
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Docket Nos. 50-361 and 50-362

Enclosure: Safety Evaluation

cc w/encl: See next page

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SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

THIRD 10-YEAR INSERVICE INSPECTION INTERVAL

REQUESTS FOR RELIEF ISI-3-11, REVISION 1 AND ISI-3-12

SOUTHERN CALIFORNIA EDISON

SAN ONOFRE NUCLEAR GENERATING STATION, UNITS 2 AND 3

DOCKET NOS. 50-361 AND 50-362

1.0 INTRODUCTION

By letter dated October 15, 2004, as supplemented by letters dated October 25, 2004, and December 2, 2004, pursuant to 50.55a(a)(3)(i) of Title 10 of the *Code of Federal Regulations* (10 CFR), Southern California Edison (SCE or the licensee) submitted two requests for relief to be implemented during the third 10-year inservice inspection (ISI) interval at San Onofre Nuclear Generating Station (SONGS), Units 2 and 3.

In relief request ISI-3-11, Revision 1, the licensee seeks relief from the requirements of Article IWA-4600 of Section XI of American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (Code), 1995 Edition, 1996 Addenda, to perform weld repairs on pressurizer nozzle penetrations. The licensee proposes to perform this repair utilizing a half-nozzle repair method with a remotely operated weld tool, along with the machine Gas Tungsten Arc Welding (GTAW) process and an ambient temperature temper bead method of 50E F minimum preheat temperature and no post weld heat treatment, as described in the NRC-approved ASME Code Case N-638. The Code Case provides relief to allow the use of machine GTAW with ambient temperature preheat and no post weld heat treatment (PWHT) when draining the vessel is impractical. SCE has stated its intention to apply Code Case N-638 with two exceptions: (1) although draining the vessel at SONGS, Units 2 and 3 is not impractical (i.e., it can be drained), the licensee still seeks to use the ambient temperature temper bead method with 50E F minimum preheat temperature and no PWHT, consistent with the philosophy of SONGS's as low as reasonably allowable (ALARA) program, and (2) the licensee proposes an alternative to the requirements of ASME Section XI, IWA 4610(a), pertaining to preheat and interpass temperature monitoring. In addition to Code Case N-638, the licensee also requests to forgo hydrostatic testing requirements and perform a system leak test instead using the provisions in ASME XI, IWA-4540(a)(2), 1998 Edition through the 2000 Addenda. The licensee also proposes to use a contact pyrometer to monitor process temperatures instead of thermocouples and recording instruments.

In ISI-3-12, the licensee requests relief from the requirements of paragraph IWA-3300 of the ASME Code Section XI, to determine the size of the flaws left in the J-groove weld of the nozzle and instead proposed to use the worst-case assumptions to conservatively estimate the size and orientation of flaw. The licensee also requests relief from the requirements of IWB-2420 which requires successive inspections of areas of components, containing flaws, that have been accepted for continued service.

2.0 REGULATORY EVALUATION

The ISI requirements of the ASME Code Class 1, 2, and 3 components in nuclear plants is to be performed in accordance with the ASME Code Section XI and applicable edition and addenda as required by 10 CFR 50.55a(g), except where specific relief has been granted by the Commission pursuant to 10 CFR 50.55a(g)(6)(i). Paragraph 10 CFR 50.55a(a)(3) states, "Proposed alternatives to the requirements of paragraphs (c), (d), (e), (f), (g), and (h) of this section or portions thereof may be used when authorized by the Director of the Office of Nuclear Reactor Regulation. The applicant shall demonstrate that: (i) The proposed alternatives would provide an acceptable level of quality and safety, or (ii) Compliance with the specified requirements of this section would result in hardship or unusual difficulty without a compensating increase in the level of quality and safety."

Paragraph 10 CFR 50.55a(b)(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. This requirement applies to the new repair weld attaching the replacement half-sleeve to the pressurizer shell.

Pursuant to 10 CFR 50.55a(g)(4), ASME Code Class 1, 2, and 3 components (including supports) will meet the requirements, except the design and access provisions and the preservice examination requirements, set forth in the ASME Code, Section XI, “Rules for Inservice Inspection of Nuclear Power Plant Components,” to the extent practical within the limitations of design, geometry, and materials of construction of the components. The regulations require that inservice examination of components and system pressure tests conducted during the first 10-year interval and subsequent intervals comply with the requirements in the latest edition and addenda of Section XI of the ASME Code incorporated by reference in 10 CFR 50.55a(b) 12 months prior to the start of the 120-month interval, subject to the limitations and modifications listed therein. The SONGS third 10-year ISI interval began on August 18, 2003, and is scheduled to end on August 17, 2013.

3.0 RELIEF REQUEST ISI-3-11, REVISION 1

3.1 System/Component(s) for Which Relief is Requested:

ASME Section XI, 1995 Edition through the 1996 Addenda, Class 1, Category B-P, Pressurizer, Pressure Retaining Boundary, Item Number B15.20. There are 30 heater sleeve penetrations through the lower head of the Pressurizer vessel in SONGS, Units 2 and 3.

3.2 Code Requirements:

ASME Code, Section XI 1995 Edition through 1996 Addenda, IWA-4410 requires repairs to be made in accordance with the owner's requirements and the original construction code

(ASME III) of the component or system. Later editions and addenda of the construction code, either in its entirety or portions thereof, and Code Cases may be used. If repair welding cannot be performed in accordance with these requirements, the applicable alternative requirements of IWA-4600 may be used.

The third 10-year ISI interval for SONGS, Units 2 and 3 follows the ASME Code Section XI, 1995 Edition, 1996 Addenda. The construction code for SONGS, Units 2 and 3 is ASME Code Section III, 1971 Edition, and 1971 Summer Addenda.

3.3 Proposed Alternative:

In accordance with 10 CFR 50.55a(a)(3)(i), SCE is requesting relief from the following portion of ASME Section XI, IWA-4410 and its referenced IWA-4600 to perform Pressurizer heater sleeve penetration repairs at SONGS, Units 2 and 3:

"Alternatively, the applicable requirements of IWA-4600 may be used for welding. . . . "

In lieu of performing the repair using the alternative welding techniques described in IWA-4600, SCE is proposing to perform a portion of the repair with a remotely operated welding machine, utilizing the machine GTAW process and the ambient temperature temper bead method with 50E F minimum preheat temperature and no PWHT, as described in Code Case N-638. SCE is requesting the use of Code Case N-638 with two deviations.

Code Case N-638 provides relief to allow use of machine GTAW with ambient temperature preheat and no PWHT when draining of the vessel is impractical. Although it is not impractical to drain the vessel at SONGS, Units 2 and 3, the licensee still seeks to use the ambient temperature temper bead method with 50E F minimum preheat temperature and no PWHT due to dose considerations. The licensee states that this philosophy is in accordance with the SONGS ALARA program. Code Case N-638 also requires a surface examination and volumetric examination (ultrasonic testing (UT)) of a 5-inch band of base metal surrounding the weld repair area after the 48 hour hold time. The licensee proposes that only a surface examination of the 5-inch band surrounding the weld (dye penetrant testing (PT) or magnetic particle testing (MT)) will be performed.

In addition to the use of Code Case N-638, with exceptions listed above, SCE proposes two additional alternatives to the requirements of the ASME Code. The licensee intends to perform a system leak test using the provisions in ASME XI, IWA-4540(a)(2), 1998 Edition through 2000 Addenda in lieu of a hydrostatic pressure test as required by ASME Section III, NB-6111.1. In lieu of the requirements of ASME Section IX, IWA-4610(a) to use thermocouples and recording instruments to monitor process temperatures, SCE also proposes to use a contact pyrometer.

3.4 Basis for Relief (As Stated):

> The basis for the relief request is that the use of an ambient temperature temper bead welding process provides an equivalent acceptable level of quality and safety when compared to the welding process in ASME, Sections XI and III, while offering substantial savings in accumulated radiation dose. In support of this conclusion, the process is described below, followed by technical justification for

the technique, as well as the expected dose savings.

1. <u>Description of the process</u>

Figure 1 [of the licensee's October 15, 2004, submittal] provides a general overview of the configuration.

a) Volumetric examinations or visual inspections for leakage/boric acid deposits of the Pressurizer heater sleeve penetrations may identify a need to repair a pressurizer heater sleeve. SCE plans to use remote machine processes similar to those used previously at other facilities, including Crystal River Unit 3, South Texas Project, Arkansas Nuclear One, Unit 1, and Millstone.

b) The sleeve will be cut close to the pressurizer shell. A portion of the sleeve inside the vessel bore will then be removed by machining and the area around the sleeve will be prepared for the application of the weld pad by grinding smooth and performing a surface examination (PT or MT) and ultrasonic examination of the area to be welded and the 5 inch wide band surrounding the weld area. [Prior to welding, a sacrificial plug is installed into the vessel bore to act as a backing for the weld pad and allows the licensee to fill the vessel with water if it desires]

c) A weld pad will be applied to the surface of the pressurizer shell using the ambient temperature temper bead weld process and GTAW method as described in Code Case N-638. The weld pad is to be applied as a weld buildup centered on the existing sleeve opening.

d) The weld pad will be prepared suitable for nondestructive examination (NDE). The pad and its heat affected zone (HAZ) below the pad will be volumetrically examined (UT) to the extent practical. The weld pad and a 5-inch wide band surrounding the weld pad will also be surface examined (PT or MT). The examinations and acceptance criteria will be in accordance with ASME III, 1995 Edition through 1996 Addenda, NB-5000.

   Ultrasonic examinations, before and after welding, of the full parent material thickness beneath the weld pad, to the extent practical, are performed to discern laminar type indications therein. Laminar type indications observed will be recorded and evaluated to assure the structural integrity of the modification configuration is not adversely affected.

e) The center of the weld pad [including the sacrificial plug] will be ground or machined to re-establish a free path into the pressurizer penetration. The weld pad will be prepared to accept the new sleeve using a "J" groove partial penetration weld.

f) The new sleeve will be inserted and welded using conventional welding and NDE techniques (manual GTAW and progressive PT). This weld is in full ASME construction code compliance and relief from code requirements is not required.

2. Justification

a) As low as reasonably achievable (ALARA)

Experience gained from the performance of similar repairs/ modifications at other plants indicate that remote automated repair methods reduce the radiation dose to repair personnel and still provide acceptable levels of quality and safety. SCE is aware that ASME has revised Code Case N-638 to reflect the acceptability of this method for ALARA considerations as well as the inability to drain the vessel. SCE recognizes the importance of ALARA principles and this remote repair method is being proposed for the possibility of repairing pressurizer heater sleeves at SONGS.

This approach for the repair of pressurizer sleeves will significantly reduce radiation dose to repair personnel while still maintaining acceptable levels of quality and safety according to the licensee. SCE estimates the dose accumulated providing access, installing heating pads and performing the preheat and post weld heat treatment required by the construction code would be approximately 1.8 REM per sleeve repair. Assuming that only one sleeve requires repair, use of the ambient temperature temper bead process results in a reduction of approximately 1.8 REM for the repair.

b) Procedure Qualification

Results of procedure qualification work undertaken to date on low alloy steel base material indicate that the ambient temperature temper bead process produces sound and tough welds. Industry experience also indicates that the machine GTAW ambient temper bead process has the capability of producing acceptable welds on P-No.3 Group No. 3 ferric steel base materials. Westinghouse-PCI (PCI), Welding Services (WSI), and Framatome ANP (FANP) have all qualified the welding process and procedures for this specific application in accordance with code and code case requirements prior to its use at SONGS.

These Code Case N-638 qualifications were performed at room temperature on P-No. 3 Group No. 3 base materials with ERNiCrFe-7 weld filler and similar low heat input controls that will be used for this repair application. These qualifications did not include a post weld heat soak. The successful qualification of the ambient temperature temper bead welding process demonstrates that the proposed alternative provides an acceptable level of quality and safety.

To ensure the acceptability of the welding process procedures for the SONGS application, SCE will review the chosen contractor's welding procedure specification and qualification records and verify the qualifications meet all Code and Owner's Requirements and Code Case N-638. Additionally, SCE will require either a mock-up demonstration or documentation that a representative mock-up demonstration has been previously performed.

c) Weld Quality

The proposed alternative repair technique has been demonstrated as an acceptable method for performing Pressurizer sleeve repairs. The ambient temperature temper bead technique has been approved by the ASME committee per Code Case N-638. The ambient temperature temper bead technique has also been previously approved by the NRC as having an acceptable level of quality and safety and used successfully at several utilities (Three Mile Island, Crystal River Unit 3, Millstone, St. Lucie, ANO, South Texas Project, and others). This Code Case has been approved in Regulatory Guide 1.147, Revision 13. This approval indicates that the methodology is capable of producing quality in-situ repairs.

As documented in EPRI Report GC-1 11050, research shows that carefully controlled heat input and bead placement allow subsequent welding passes to relieve stress and temper the HAZ of the base material. The use of the machine GTAW temper bead process will allow precise control of heat input, bead placement, bead size, and contour as compared to the SMAW process. The very precise control over these factors afforded by the machine GTAW process provides effective tempering of the HAZ. The research in the EPRI Report and numerous procedure qualification tests performed on P-No. 3, Group No. 3 by the industry have shown that acceptable weld quality and HAZ impact toughness can be obtained using machine GTAW, ambient preheat, three controlled temper bead layers, and no post weld heat treatment.

Typically, preheat and post weld heat treatment are used to mitigate the effects of the solution of atomic hydrogen in ferritic materials prone to hydrogen embrittlement cracking. The machine GTAW temper bead process uses a welding process that is inherently free of hydrogen. The GTAW process relies on bare welding electrodes and bare wire filler metal with no flux to trap moisture. An inert gas blanket provides shielding for the weld and surrounding metal, which protects the region during welding from the atmosphere and the moisture it may contain and typically produces porosity free welds. In accordance with the weld procedure qualification, welding grade argon is used for the inert gas blanket. To further reduce the likelihood of any hydrogen evolution or absorption, specific controls will be used to ensure the welding electrodes, filler metal, and weld region are free of all sources of hydrogen. Argon flow rates are adjusted to assure adequate shielding of the weld without creating a venturi affect that might draw oxygen or water vapor from the ambient atmosphere into the weld.

d) Preheat and Interpass Temperature Measurement

Due to the location of the repair and area radiation dose rate, the placement of thermocouples for monitoring weld interpass temperature is determined to be not beneficial based on dose savings. Therefore, thermocouples are not planned for use to monitor interpass temperature during welding. Preheat and interpass temperatures for the weld pad will be measured using a contact pyrometer. Interpass temperature will be monitored for the first three layers of each repair location. On the first repair location, the interpass temperature measurements will be taken every three to five passes. At subsequent repair locations, interpass temperature measurements will be taken every six to ten passes. Heat input beyond the third layer will not have a metallurgical affect on the low alloy steel HAZ.

e) Examination

The pressure test provisions being used from ASME XI, IWA-4540(a)(2), 1998 Edition, through 2000 Addenda mandate that NDE methodology and acceptance criteria from ASME III, 1992 Edition or later be used. All examinations will be performed in accordance with ASME III, 1995 Edition through 1996 Addenda, NB-5000, using personnel qualified in accordance with IWA-2300 and/or NB-5500.

The area to be welded, plus a 5 inch surrounding band, will be surface examined (PT or MT) both prior to and following welding. All post weld exams will be performed after the required 48 hour hold time. The entire volume of the weld pad, to the extent practical, will be scanned from the face of the pad, using examination angles of 00, 450 RL, 600 RL and an OD creeping wave. The examination volume shall include the weld-deposited material and the ferritic vessel HAZ.

Ultrasonic examination, before and after welding, of the full parent material thickness beneath the weld pad, to the extent practical, will be performed to discern laminar type indications therein. Laminar type indications observed will be recorded and evaluated to assure the structural integrity of the modification configuration is not adversely affected.

Because this is a surface application of the temper bead process, there will be minimal impact to the volume of metal of the Pressurizer vessel in the area surrounding the weld. Since this weld is applied to the exterior surface of the Pressurizer, there is no additional useful information that can be gained by a volumetric examination of the area surrounding the weld. The weld and HAZ below will be post weld volumetrically examined to the extent possible. This reduction in the post welding inspection will provide additional dose reduction for this repair while still ensuring sound weld metal is deposited and that the process has not introduced flaws in the base material.

f) Corrosion

The automated repair method described above leaves an area of ferritic low alloy steel at the outside diameter (OD) of the sleeve [inside diameter (ID) of the sleeve bore] exposed to the primary coolant. The effect of corrosion on the exposed area, including reduction in vessel wall thickness, has been evaluated by Aptech Engineering Services and concurred with by SCE (SONGS Document M-DSC-402). The analysis shows that the total corrosion is insignificant when compared to the thickness of the vessel shell. SCE has determined that the expected extremely low rate of material loss will provide an acceptable level of safety.

g) Stresses

Design stress analysis of the modified heater sleeve weld attachments was performed (see Enclosure 4). The stress analysis demonstrates that the modified heater sleeve configuration complies with the criteria of NB-3000, ASME Section III, 1971 through Summer 1971 Addenda, as described in the calculations referenced in Enclosure 4, using design and service conditions applicable to the Pressurizer.

Therefore, based on the discussion above, SCE has determined that the proposed alternative provides an acceptable level of quality and safety while reducing radiation exposure to as low as reasonably achievable.

3.5 Evaluation:

The licensee proposes to perform repair utilizing a half-nozzle repair method with a remotely operated weld tool, using the machine GTAW process and the ambient temperature temper bead method with a 50E F minimum preheat temperature and no PWHT, as described in Code Case N-638 with two exceptions. Code Case N-638 has been approved for use by the NRC in Regulatory Guide 1.147, Revision 13. In lieu of the requirements of ASME Section XI, IWA-4610(a) to use thermocouples and recording instruments to monitor process temperatures, SCE proposed to use a contact pyrometer. The licensee also proposed to perform a system leak test using the provisions in ASME XI, IWA-4540(a)(2), 1998 Edition through 2000 Addenda in lieu of a hydrostatic pressure test.

Code Case N-638 provides for the use of machine GTAW with ambient temperature preheat and no PWHT when draining the vessel is impractical for operational or radiological reasons. Although draining the pressurizer at SONGS, Units 2 and 3 is not impractical, the methodology of Code Case N-638 can be applied to obtain a significant reduction in radiation dose for the reasons stated in Section 3.4 of this safety evaluation. Code Case N-638 has included the statement about not draining the vessel so that repairs could be made on reactor vessels not drained for operational or radiological reasons, such as the case with SONGS. Therefore, the licensee’s request and justification for use of machine GTAW with ambient temperature preheat and no PWHT, without draining the pressurizer, is acceptable.

Paragraph IWA-4610(a) in ASME Section IX requires that preheating and interpass temperature be monitored using thermocouples and recording instruments. As an alternative to this Code requirement, the licensee proposes that, measurement of preheat and interpass temperature will be accomplished as follows: preheat and interpass temperatures for the weld pad will be measured using a contact pyrometer. Interpass temperature will be monitored for the first three layers of each repair. On the first repair location, the interpass temperature measurements will be taken every three to five passes. Subsequent repair locations will monitor interpass temperature every six to ten passes. Code Case N-638 requires that, for the welding of the pressurizer, the preheat temperature shall be 50E F (minimum) prior to depositing the first weld layer. For the first three layers, the interpass temperatures shall be at least 50E F but less than 150E F. The interpass temperature of each remaining layer shall be at least 50E F but less than 350E F prior to depositing the subsequent weld layers. The preheat temperature required for this welding is 50E F. This temperature is to be maintained on a weldment inside a building which normally is above 50E F. Therefore, preheat measurement by this alternate method is acceptable. The maximum interpass temperatures required for this welding (150E F for the first three layers, and a maximum interpass temperature of 350E F for the balance of welding), can easily be measured with a contact pyrometer. Also, the large mass of the pressurizer coupled with the low heat input GTAW process should help to ensure that the maximum interpass temperature will not be exceeded and with the alternate temperature measurement methods, a close control will be maintained on these temperatures. Therefore, this type of temperature measurement provides an acceptable level of quality and safety.

To accomplish the repair, the licensee will utilize the half-nozzle repair method which has been successfully employed in the past at other nuclear power plants. The repair is accomplished by cutting the sleeve close to the pressurizer shell and then machining out a portion of the sleeve inside the vessel bore. The weld pad area is ground smooth and the area prepared for surface welding (PT or MT) and ultrasonically examined which would include a 5 inch wide band surrounding the weld area. A sacrificial plug is installed into the bore before welding begins. The weld pad will be applied to the surface of the pressurizer shell using the ambient temperature temper bead weld process using the GTAW method as described in Code Case N-638. The weld pad made of Alloy 52 filler metal will be applied as a weld buildup centered on the existing nozzle opening overlapping the installed sacrificial plug. When welding is complete, the weld pad surface will be prepared for NDE. The pad and its HAZ below the pad will be volumetrically examined to the extent practical. The weld pad and a 5 inch wide band of the pressurizer shell surrounding the weld pad will be also surface examined (PT or MT).

The surface and ultrasonic examinations and acceptance criteria proposed by the licensee will meet the requirements of article NB-5000 of ASME Code, Section III, 1995 Edition through 1996 Addenda. Therefore, the examinations are acceptable. In addition, UT, before and after welding, of the full parent material thickness beneath the weld pad, will be performed to detect laminar type indications if present in the base metal. Laminar type indications, if detected will be recorded and evaluated to ensure that the structural integrity of the weld repair is not affected. This is acceptable because the UT will verify that weld buildup is not applied in close proximity to laminations and thus the structural integrity of the weld repair is ensured. The center of the weld pad along with the sacrificial plug will be ground or machined to re-establish a free path into the pressurizer penetration. The weld pad will be prepared to accept the new nozzle using a J groove partial penetration Alloy 52 weld. The new nozzle made of Inconel 690 material will be inserted and welded using ASME Code approved welding and examined with NDE methods like manual GTAW and progressive PT. A PT examination will be performed on the machined weld preparation surface.

In lieu of a system hydrostatic test, the licensee will perform a system pressure test in accordance with IWA-4540(a)(2) of the 1998 Edition through 2000 Addenda of the ASME Section XI. The staff finds this acceptable as it has approved the use of the 1998 Edition through the 2000 Addenda of Section XI with no restrictions on IWA 4540(a)(2).

Based on the above, the NRC staff finds the licensee's proposed weld repair process acceptable for repair of pressurizer nozzles at SONGS, Units 2 and 3. This is based on the fact that the repair process utilizes remotely operated weld tool, employing the machine GTAW temper bead method with 50E F minimum preheat temperature and no post weld heat treatment, as described in Code Case N-638, which has been previously approved by the NRC. The staff has also previously approved the use of remote machine processes to do weld repairs that have been successfully accomplished at Crystal River Unit 3, South Texas Project, Arkansas Nuclear One, Unit 1, and Millstone nuclear power plants. As a result, the NRC staff concludes that the licensee has proposed an acceptable alternative to the requirements of the ASME Section XI Code.

3.6 Conclusion:

Based on the above evaluation of the licensee's submittal, the NRC staff determined that the licensee has provided an acceptable alternative to the requirements of ASME Code, Section XI, and Code Case N-638. Therefore, pursuant to 10 CFR 50.55a(a)(3)(i) the licensee's proposed alternative is authorized for the repair of pressurizer nozzles during the third 10-year ISI interval at SONGS, Units 2 and 3.

All other requirements of the ASME Code, Section III and XI for which relief has not been specifically requested and approved remain applicable, including third party review by the Authorized Nuclear Inservice Inspector.

4.0 RELIEF REQUEST ISI-3-12

4.1 System/Component(s) for Which Relief is Requested:

ASME Section XI, 1995 Edition through the 1996 Addenda, Class 1, Category B-P, Pressurizer, Pressure Retaining Boundary, Item Number B15.20. There are 30 heater sleeve penetrations through the lower head of the pressurizer vessel in SONGS, Units 2 and 3.

4.2 Code Requirements:

The third 10-year ISI interval for SONGS, Units 2 and 3, follows the ASME Code Section XI, 1995 Edition, 1996 Addenda. The construction code for SONGS, Units 2 and 3, is ASME Code Section III, 1971 Edition, and 1971 Summer Addenda.

ASME Section XI, IWA-4611.1 requires in part that, "Defects shall be removed or reduced in size in accordance with this Paragraph." Furthermore, IWA-4611.1 allows that ". . . the defect removal and any remaining portion of the flaw may be evaluated and the component accepted in accordance with the appropriate flaw evaluation rules of Section XI."

ASME Section XI, IWA-3300 requires characterization of flaws detected by inservice examination.

ASME Section XI, IWB-2420 requires successive examinations of flaws evaluated in accordance with IWB 3132.3 or IWB-3142.4.

4.3 Proposed Alternative:

The proposed repair for the pressurizer heater sleeves does not include removal of any flaws in the remnant sleeves or J-groove partial penetration welds because removal of the flaws would incur excessive radiation dose for repair personnel. Therefore, per the requirements of ASME Section XI, IWA-4611.1, the cracks must be evaluated using the appropriate flaw evaluation rules of ASME Section XI.

The licensee requested relief from IWA-3300 because it intends to eliminate successive examinations of the remnant J-groove welds or the sleeves. Thus, the actual dimensions of a potential or an existing flaw will not be fully determined. If a flaw is not fully characterized, the requirements for successive inspections of IWB-2420 become futile in that there is no reference point from which to evaluate changes in the flaw characteristics. Therefore, the licensee also requested relief from IWB-2420. In lieu of fully characterizing the existing cracks, SCE used worst-case assumptions to conservatively estimate the crack extent and orientation and evaluated the crack using the rules of IWB-3600.

SCE proposes to implement Relief Request ISI-3-12 during the third 10-year ISI interval which began on August 18, 2003, and is scheduled to end on August 17, 2013.

4.4 Basis for Relief (As Stated):

> Volumetric examinations or visual inspections of the Pressurizer heater sleeve penetrations may identify a need to repair the pressurizer heater sleeve as follows:
>
> 1. Mechanical removal of a portion of the existing sleeve.
>
> 2. Application of a weld pad (or weld buildup) using F-No. 43 to the Pressurizer shell (P-No. 3, Group 3) base material.

3. Machining the weld pad to accept the new alloy 690 sleeve (P-No. 43).

4. Installing the replacement sleeve by using conventional manual gas tungsten arc welding (GTAW) and a "J" groove partial penetration weld.

The existing sleeve(s) and weld(s) will no longer function as the pressure boundary. However, the possible existence of cracks in these welds mandates that the potential for flaw growth be evaluated. The requirements of IWA-461 1.1 allow two options for determining the disposition of discovered cracks. The subject cracks are either removed as part of the repair process or left as-is and evaluated per the rules of IWB-3600. The repair design dictates that the inside weld and sleeve portion be left intact inside the vessel.

The assumptions of IWB-3500 are that the cracks are fully characterized to be able to compare the calculated crack parameters to the acceptable parameters provided in IWB-3500. In the alternative being proposed, the acceptance of the postulated crack is calculated based on the two inputs of expected crack orientation and the geometry of the weld.

Typically, an expected crack orientation is evaluated based on prevalent stresses at the location of interest. Using worst case (maximum) assumptions with the geometry of the as-left weld, the postulated crack is assumed to begin at the inside surface of the heater sleeve and penetrates the heater sleeve wall, and through to the intersection of the vessel inner diameter surface and the vessel sleeve penetration bore and propagate into the vessel wall low alloy steel. The depth and orientation are worst-case assumptions for cracks that may occur in the remaining J-groove partial penetration weld configuration. It is assumed that the "as-left" condition of the remaining J-groove weld includes degraded or cracked weld material.

A fracture mechanics evaluation has been performed (Calculation M-DSC-402) in accordance with ASME Section XI evaluation procedures of IWB-3600. The analysis determines if a degraded J-groove weld material could remain in the vessel, with no examination to size any flaws that might remain following the repair. Since the hoop stresses in the J-groove weld are higher than the axial stresses, the preferential direction for cracking is axial, or radial relative to the sleeve. It is postulated that a radial crack in the Alloy 182 weld metal would propagate by Primary Water Stress Corrosion Cracking (PWSCC) through the weld to the interface with the low alloy steel shell. It is fully expected that such a crack would then arrest at the weld-to shell interface.

Crack growth through the Alloy 182 material would tend to relieve the residual stresses in the weld as the crack grows to its final size. Although residual stresses in the shell material are low, it is assumed that a weld flaw formed by PWSCC could grow into the low alloy steel material by fatigue. This flaw will form a continuous radial corner flaw that would propagate into the low alloy steel shell by fatigue crack growth under cyclic loading conditions. Flaw evaluations are performed for a postulated radial corner crack. Hoop stresses are used since they are perpendicular to the plane of the crack. The life of the repair is determined based on fatigue crack growth and crack growth per year of operation. It has been calculated as 40 years of additional service. The final flaw size meets the fracture toughness requirements of the ASME Code using an upper shelf value of 200 ksi in$^{1/2}$ for unirradiated ferritic materials. The results of the analyses indicate that it is acceptable to leave the alloy 600 heater sleeve and original attachment J-groove weld in the vessel, even with the possibility that cracks exist in the weld for 40 years of service.

As noted above, radial cracks are postulated to occur in the weld due to the dominance of the hoop stress at this location. The occurrence of transverse cracks that could intersect the radial cracks is considered remote. There are no identified forces that would drive a transverse crack. Only thermal and welding residual stresses could cause a transverse crack to grow. However, the presence of radial cracks limits the growth potential of the transverse cracks. The radial cracks would relieve the potential transverse crack driving forces. Hence, it is unlikely that a series of transverse cracks could intersect a series of radial cracks resulting in any fragments becoming dislodged. Therefore the release of debris generated by a cracked weld is highly unlikely.

Additionally, SCE has previously evaluated the consequences of loose parts of similar or larger dimensions and mass being carried into the reactor vessel and concluded that the probability of damage to any RCS component is not significant (reference Action Request (AR) 960901028, assignment 8). For the heater sleeves in the pressurizer, the sleeve remnant is prevented from becoming a loose part by the pressurizer heater penetrating through the center of the remnant. In the unlikely event that a small part of the heater sleeve remnant breaks away, the density of the loose part material is significantly greater than that of the water, and the loose part would tend to settle to the bottom of the pressurizer. Flow velocities in the pressurizer are relatively low and are not likely to transport loose pieces of metal to the surge line. Additionally, the surge line nozzle is equipped with a surge screen, with half-inch holes. The evaluation in Action Request (AR) 960901028, assignment 8 concluded that no damage is expected in the event that the loose part does not remain in the bottom of the reactor.

The cited evaluations provide an acceptable level of safety and quality in insuring that the Pressurizer shell remains capable of performing its design function with flaws existing in the original J-groove weld. See Enclosure 4 for a summary of the supporting analyses.

Justification for Granting Relief

Removal of the cracks in the existing J-groove partial penetration welds would incur excessive radiation dose for repair personnel. With the installation of the new pressure boundary welds previously described, the original function of the J-groove partial penetration welds is no longer required. It is well understood that the cause of the cracks in the subject J-groove welds is Primary Water Stress Corrosion Cracking (PWSCC). As shown by industry experience, the low alloy steel wall of the Pressurizer impedes crack growth by PWSCC. SCE believes the alternative described will provide an acceptable level of quality and safety when compared to the code requirements in IWB-3500 to characterize the cracks left in service. Using flaw tolerance techniques, it has been demonstrated that the assumed worst case crack size will not grow to an unacceptable depth into the Pressurizer shell low alloy steel base material over the life of the repair. Thus, the Pressurizer shell can be accepted per the requirements of IWA-4611.1.

4.5 Evaluation:

4.5.1 Evaluation of the Repair Design

The licensee evaluated the half-nozzle design for the pressurizer heater sleeves in accordance with the 1989 Edition of ASME Section III NB-3200. The licensee did not request relief on the design requirements of the ASME Section III; however, for completeness, the staff evaluated the repair design per ASME Section III NB-3200.

The licensee used the outermost sleeve (52 degree intersection angle with the pressurizer bottom head) as a bounding case in its stress analysis. Nine analysis sections of the J-groove repair weld were evaluated to ASME Code requirements for general and local membrane, primary plus secondary stress limits for maximum stress range, and fatigue usage. The analyzed regions include the sleeve near the attachment weld, the attachment weld throat, and the weld pad near the attachment weld. These three sections were evaluated at three locations around the sleeve circumference, specifically the 0 degree or downhill side, the 90 degree side, and the 180 degree or uphill side. The analysis is based on a 40-year design life commencing when the actual repair is performed.

In the original pressurizer design, the pressure boundary is the J-groove attachment weld on the inside surface of the bottom head. The proposed repair requires the removal of the lower portion of the original sleeve by cutting at approximately the mid-wall location. A new Alloy 690 sleeve of the same dimensions is inserted into the penetration and attached to the pressurizer bottom head. The new attachment weld is a J-groove weld at the outside surface of the pressurizer bottom head. The J-groove is machined on a weld pad, which is deposited on the exterior of the bottom head as part of the weld repair procedures. When installed, a vertical gap is maintained between the original sleeve stub, which will remain in service, and the new sleeve. As a result of the proposed repair, the pressure boundary is moved from the original interior J-groove weld to the outside J-groove/weld pad connection between the pressurizer bottom head and the Alloy 690 sleeve.

The licensee performed finite element analyses and closed form calculations to calculate the stresses in the sleeve and weld following ASME Code rules. The licensee stated that all calculated stresses meet the ASME Code stress limits. All evaluated regions of the half-nozzle repair satisfied the general and local membrane, and primary plus secondary stress limits of ASME Section III NB-3222.2 of 3.0Sm (Sm is the stress intensity) at all nozzle regions except for the uphill side weld section at the outside surface. At that location, the local primary membrane stress (P_L) + primary bending stress (P_B) + secondary membrane plus bending stress (Q) exceeded 3.0Sm.

The licensee had to evaluate thermal stress ratcheting for the uphill weld using procedures in NB-3222.5 because the stress range with thermal bending included did not satisfy the limits of 3.0Sm. Under certain combinations of steady state and cyclic loadings there is a possibility of large distortions developing as the result of ratchet action; that is, the deformation increases by a nearly equal amount for each cycle. The allowable thermal stress range from NB-3222.5 for preventing thermal ratcheting was evaluated and shown to exceed the calculated thermal stress range at this location. Therefore, the stress limits on maximum stress range for normal and upset conditions have been satisfied.

The calculated fatigue usage factors for the nine half-nozzle repair locations (both inside and outside surfaces) were all within the ASME Section III required limit of 1.0. The highest fatigue usage computed was 0.038 for the weld throat on the uphill side on the outside surface. Therefore, the fatigue usage for the heater sleeve repair is acceptable to ASME Code requirements for a 40-year design life for the repair.

After sleeve repair, the licensee proposes to perform system leakage tests and VT-2 inspections every refueling outage as required by ASME Code. In addition, the bottom of the pressurizer, including the surge line, the 30 heater sleeves, and the instrument nozzles will continue to be maintained as an inspection point in the licensee’s "Reactor Coolant System Alloy 600 Inspection" procedure. This area will also continue to be inspected per the licensee’s "Boric Acid Leak Inspection" procedure. Both the "Reactor Coolant System Alloy 600 Inspection" and "Boric Acid Leak Inspection" are performed at each refueling outage. Gaps in the insulation allow observation of the partial penetration weld and heater-to-heater sleeve fillet weld; however, the entire weld pad surface will not be inspected on a routine basis. The applicable ISI requirements for the new heater sleeve J-groove weld are given in ASME XI, Table IWA-2500-1, Examination Category B-P, item B15.20. A system leakage test and visual, VT-2, examination are required to be performed prior to plant start up following each reactor refueling outage.

The licensee has shown that the proposed repair satisfies the ASME Code Section III allowable stress and fatigue requirements for a 40-year design life. This includes the requirements for all design conditions, maximum stress range for normal and upset conditions (including thermal ratchet limits, and fatigue usage factor), emergency conditions, and testing conditions. The staff finds that the licensee’s proposed repair design of the pressurizer heater sleeves satisfies the requirements of ASME Section III and the licensee’s proposed inspection of the repaired pressurizer heater sleeves follows the requirements of the ASME Section XI.

4.5.2 Flaw Evaluation

4.5.2.1 Linear Elastic Fracture Mechanics Calculations

The licensee analyzed a worse-case flaw in the remnant sleeves and J-groove welds in accordance with ASME Section XI IWB-3600. The staff reviewed the following key areas of the licensee’s flaw evaluation: flaw characterization, applied loadings, residual stresses, the stress intensity factor, and final flaw sizes.

Flaw Characterization

The licensee assumed that the postulated crack initiates at the inside surface of the heater sleeve; penetrates the heater sleeve wall, through the intersection of the pressurizer inner diameter surface, the J-groove weld, and the sleeve penetration bore; and propagates into the pressurizer bottom head base metal. The initial flaw depth is assumed to be 1.0 inch which covers the entire thickness of the J-groove weld and places the crack tip within the base metal of the pressurizer bottom head. A flaw is postulated at both the uphill and downhill locations of the bottom head. The flaw plane is assumed to be axial-radial with respect to the sleeve. Since the hoop stresses in the J-groove weld are higher than the axial stresses, the preferential direction for cracking is axial, or radial relative to the sleeve. The licensee stated that this flaw orientation is the more likely orientation for a crack initiating in the sleeve and growing across the J-groove weld, and therefore the more limiting case.

The licensee postulated that the crack is initiated by PWSCC and propagates into the pressurizer base metal by fatigue under cyclic loads. Thus, the life of the repair is determined based on fatigue crack growth and crack growth per year of operation.

Regarding a staff question concerning the technical basis of the initial flaw size, the licensee, in a letter dated December 2, 2004, responded that the depth of the J-groove weld is about 5/16 inch for the outermost heater sleeve, and the thickness of the cladding is 7/16 inch. Thus, the J-groove weld preparation lies entirely within the cladding. The distance between the mid-point of the weld surface to the pressurizer base metal is about 0.64 inch on the uphill side of the outermost sleeve based on a clad thickness of 7/16 inch and a weld fillet radius of 3/16 inch. The corresponding distance on the downhill side is smaller. The center of the postulated comer crack is located at the intersection of the sleeve inside surface and the line representing the vessel head inside surface. The distance from the center to the base metal is less than 0.5 inch. Thus, the crack tip will be located in the base metal if a crack depth of 1.0 inch is postulated. The staff finds that the postulated initial flaw size is conservative, and therefore, is acceptable.

Applied Loading

The licensee applied the eight transient conditions, including design basis, normal operating, and upset conditions on the postulated flaw. All transients are based on the pressurizer design specification, which contains heat-up and cool-down limits for the pressurizer that are consistent with, but separate from, the heat-up and cool-down limits for the reactor vessel. The licensee also included the cooldown transient with flooding which is also known as pressurizer in-surge. This transient has high temperature differentials and would generate high thermal loadings on the flaw.

For the fatigue crack growth calculation, the licensee used the crack growth curves in a reactor water environment as shown in Appendix A to ASME Section XI. The staff finds that the licensee has followed the applied loading requirements in ASME Section XI IWB-3600 in its flaw evaluation.

Residual Stresses

The residual stresses in the J-groove weld and pressurizer base metal affect crack growth. The staff asked the licensee to discuss the modeling of the residual stresses in the analysis, the attenuation of the residual stresses, and the assumptions made on the tensile and compressive residual stresses.

In a letter dated December 2, 2004, the licensee responded to a staff inquiry that the weld residual stresses are combined with the applied stresses. In the calculation of the stress intensity factor, the licensee stated that they are considered in the same manner as the applied stresses. All stresses are effectively considered as primary stresses. The stress intensity factor was computed for the total stress including residual stresses. The peak tensile stresses occur mainly in the J-groove weld and the point where the tensile residual stress attenuates to zero is taken at the clad to base metal interface.

The licensee stated that the distribution of the residual stresses is calculated using a finite element analysis. The residual stresses attenuate very quickly with distance from the J-groove weld. The attenuation occurs in both the axial direction along the sleeve and the circumferential distance away from the weld. The licensee assumed that the peak residual stress would be on the order of the yield strength of the Alloy 600 material. This assumption is consistent with measured residual stresses in as-welded heater sleeve mockups. The residual hoop stress near the inside diameter surface of the sleeve was determined to be in the range of 36 to 73 ksi. In the mockup, the nominal yield strength of the sleeve material was 64 ksi, which was then reamed to create a cold-worked condition. The licensee stated that this assumption is also justified based on the finite element analysis results. The finite element analysis results indicate that the local residual plus operating hoop stress is in the range of 50 to 75 ksi at the J-groove region and within the sleeve. It is expected that the residual stresses would be somewhat less than this range when the operating stress (i.e., pressure) is subtracted from the total stress. Further, a survey of supplied sleeve material indicated the room temperature yield strength ranged between 38 to 63.5 ksi. The licensee stated that a 60 ksi yield strength value was used in the calculation and was judged to be a conservative estimate of yield strength at operating temperatures.

The licensee stated that the basis for the assumption that the compressive residual stress is 50 percent of the yield strength is based on the finite element analysis results which indicate that the ratio between peak tensile and compressive hoop stresses is approximately 2:1. The effect of residual stresses would be to change the mean stress (i.e., R-ratio equal to Kmin/Kmax) for fatigue. Tensile residual stresses would lead to a higher value of R, which in turn increase the rate of crack growth. Likewise, compressive residual stresses would lower the R value and subsequently decrease the rate of crack growth. Because the postulated flaw is large relative to the depth of the clad on the inside surface of the pressurizer, and the crack tip residing in the alloy steel head material would be within the compressive zone, the residual stresses were conservatively ignored in the fatigue crack growth analysis.

Stress Intensity Factor

The licensee stated that the stress intensity factor of the postulated crack is calculated by the BIGIF program, which is published by Electric Power Research Institute in 1978. The BIGIF program uses the weight function, or influence function, method in computing the stress intensity factor for complex (nonlinear varying) stress fields acting on cracked bodies. The stress intensity factor is calculated by integrating over the crack for a given crack face stress, σ[x], with the weight function, h_i[x,a]. The weight function is a function of spatial position, x, and crack size, a, and also depends on the specified boundary conditions, component geometry, and crack front position. The weight functions for various flaw geometries are contained within the BIGIF program. The flaw geometries contained in the BIGIF program include both 1-dimensional and 2-dimensional flaw shapes including buried and surface elliptically shaped crack fronts. The BIGIF program accepts crack dimensions, stress distribution data, and fatigue crack growth rate parameters as input for a given problem. The program then performs the numerical integration to compute values such as the stress intensity factor, stress intensity factor versus crack depth distributions, and final crack size dimensions following the flaw growth analysis.

The licensee stated that the BIGIF program has been used to perform flaw evaluations for both allowable flaw size and flaw growth calculations required by ASME Section XI procedures. The same basic approach has been used for flaw evaluations of the control rod drive mechanism nozzles and instrumentation nozzles for the reactor pressure vessel at SONGS. The BIGIF program was benchmarked against closed-form solutions and numerical results from finite element and boundary integral equations as part of the computer code development. Also, the analytical procedures for numerical integration associated with flaw growth calculations have been verified by test cases. Approximately 30 test cases have been used to verify the BIGIF program. The BIGIF program is maintained under the licensee's contractor (APTECH) nuclear quality assurance program, which has been periodically audited by utilities.

ASME Section XI, IWB-3612 specifies that the stress intensity factor should have a safety margin of /10 for normal/upset conditions, and /2 for emergency/faulted conditions. The licensee stated that the calculation of the stress intensity factor in determining the allowable flaw depth is based on all applied stresses (pressure and thermal) and residual weld stresses. The licensee stated that there is no structural [safety] factor applied to the calculation of the stress intensity factor. However, a factor of /10 for normal/upset conditions, and /2 for emergency/faulted conditions, is applied to the fracture toughness value. These flaw evaluation acceptance criteria are in accordance with IWB-3612 and are analytically equivalent to applying the structural factors as direct multiplying factors on the stress intensity factor.

ASME Section XI, IWB-3613 specifies that the stress intensity factor should have a safety margin of /2 for conditions of bolt-up and pressurization not exceeding 20 percent of the design pressure during which the minimum temperature of the reactor coolant is not less than RT_{NDT} + 60E F. The staff asked the licensee to discuss whether this criterion is satisfied. In the December 2, 2004, letter, the licensee responded that RT_{NDT} of the reactor vessel closure head material, SA-533B-1, will be less than 20E F, which is based on the value found in NRC report, NUREG-0577. Regarding the existence of the plant-specific material data to support an RT_{NDT} value of 20E F, the licensee stated that there were no drop weight tests performed on the pressurizer bottom head plate material for either SONGS unit. Charpy impact tests were performed at a test temperature of +10E F and its vendor used the data to estimate RT_{NDT}. The estimated value for RT_{NDT} is +30E F based on guidance in NRC Branch Technical Position MTEB 5-2 which is part of NRC Standard Review Plan 5.3.2, "Pressure Temperature Limits." An RT_{NDT} of + 30E F does not change the results of the flaw calculation. The pressurizer bottom head will be at upper shelf conditions for normal operating conditions if RT_{NDT} is +30E F. The upper shelf conditions are favorable for the pressurizer base metal to resist potential flaw growth. The licensee responded that because the acceptance criterion used / 10 as the safety margin for all loads, the criterion of IWB-3613 is met. The staff finds that the licensee's calculation of the stress intensity factor follows IWB-3600, and, therefore, is acceptable.

Final Flaw Size

On the basis of a 40-year design life commencing when the repair is performed, the licensee calculated final flaw depths to be 1.21 inches and 1.25 inches for the uphill side and downhill side of the nozzle, respectively. The allowable depth for the postulated flaw is 1.42 and 1.52 inches for the nozzle uphill side and weld downhill side, respectively. The pressurizer bottom head has a minimum wall thickness of 3.875 inches (not counting cladding thickness of 7/16 inch). This shows that the pressurizer base metal has sufficient wall thickness when compared to the allowable flaw depth to provide safety margin for crack growth. The staff finds that the final crack depths for both postulated flaws are within the allowable and, therefore, are acceptable.

4.5.2.2 Elastic Plastic Fracture Mechanics Calculations

The licensee also performed an elastic-plastic fracture mechanics calculations based on the method shown in the ASME Section XI Appendix K. The staff has reservations regarding the use of the Appendix K method in the ASME Section XI in the flaw evaluation of the pressurizer base metal because the Appendix K method was developed to address the postulated flaws in the reactor vessel beltline region. The flaw geometry in the J-groove welds in the pressurizer nozzles is not the same as the flaw geometry in the reactor beltline region. The safety factors required in the Appendix K method may not be applicable to the postulated flaws and they are not the same between the Appendix K method and the IWB-3600/Appendix A method as discussed above. The linear-elastic fracture mechanics analysis of the pressurizer sleeve prescribed in IWB-3600/Appendix A is more conservative than the elastic-plastic fracture mechanics analysis in Section XI Appendix K.

In its response to the staff concern dated December 2, 2004, the licensee stated that the purpose of the ASME Section XI, Appendix K calculations was to verify the ASME Section XI Appendix A and IWB-3600 analyses that the assumptions made on residual stress were indeed conservative. The licensee stated that the Appendix K procedures are appropriate as an alternate demonstration for flaw acceptance because the analysis conditions for the pressurizer heater sleeve are consistent with the analysis scope of Appendix K for the following reasons: (a) Appendix K evaluates the adequacy of fracture toughness of the material to resist fracture of a flaw. The size of the postulated flaw assumed for the pressurizer bottom head is on the order of the postulated flaw to be used in an Appendix K evaluation for fracture; (b) The Appendix K procedures are for conditions where upper shelf behavior is expected. The pressurizer bottom head region will be at upper shelf temperatures for the design transients for normal and upset conditions under evaluation for the heater sleeve J-groove weld; and (c) The structural [safety] factors of 1.4 on pressure and 1.0 on thermal stress are specified within Appendix K procedures. In the calculations performed for the J-groove weld, structural factors of 3.16 on pressure and 1.0 on thermal stress were conservatively used.

The licensee stated that its flaw calculations determined that the allowable flaw sizes satisfied the structural factors of / 10 and / 2 following the flaw acceptance criteria of IWB-3612. In performing the linear-elastic fracture mechanics calculations, some assumptions were made as to the level and extent of tensile residual stresses based on finite element stress results. Further, the combination of residual and applied stresses created unrealistically high peak stresses and the Appendix A calculations considered limiting peak stresses to the yield strength of the sleeve material. As an independent check on these analysis assumptions, the calculation for allowable flaw size was also performed following the elastic-plastic fracture mechanics procedures and criteria provided in ASME Section XI Appendix K.

The licensee’s elastic-plastic fracture mechanics calculation showed that the residual stresses assumed in its linear-elastic fracture mechanics calculation to be conservative. The licensee’s linear-elastic fracture mechanics calculations showed that the postulated flaws satisfy the requirements of ASME Section XI, IWB-3600. The licensee did not rely on the Appendix K method to qualify by analysis the postulated crack in the J-groove weld. Therefore, the staff does not object to the licensee’s use of ASME Section XI Appendix K to verify the flaw evaluation that was based on the ASME Section XI Appendix A method.

The staff finds that the final flaw size meets the fracture toughness requirements of the ASME Code Section XI, IWB-3600. The results of the analyses indicate that it is acceptable to leave a section of the alloy 600 heater sleeves and attachment J-groove welds in the pressurizer, even with the possibility that cracks exist in the weld for additional 40 years of service.

4.5.3 Evaluation of Potential Loose Parts and Corrosion

In addition to the flaw evaluation, the licensee evaluated the potential for loose parts and corrosion as a result of the sleeve repair.

Loose Parts Consideration

The licensee evaluated a potential scenario where the remnant weld may disintegrate by the interaction of transverse cracks and radial cracks. The resulting fragments may fall into the bottom (inside surface) of the pressurizer. As noted above, radial cracks are postulated to occur in the J-groove weld due to the dominance of the hoop stress at this location. The occurrence of transverse cracks that could intersect the radial cracks is considered remote. There are no identified forces that would drive a transverse crack. Only thermal and welding residual stresses could cause a transverse crack to grow. However, the presence of radial cracks limits the growth potential of the transverse cracks. The radial cracks would relieve the potential transverse crack driving forces. Hence, it is unlikely that a series of transverse cracks could intersect a series of radial cracks resulting in any fragments becoming dislodged. Therefore the release of debris generated by a cracked J-groove weld is highly unlikely.

Additionally, the licensee has previously evaluated the consequences of loose parts of similar or larger dimensions and mass being carried into the reactor vessel and concluded that the probability of damage to any reactor coolant system component is not significant. For the heater sleeves in the pressurizer, the sleeve remnant is prevented from becoming a loose part by the pressurizer heater penetrating through the center of the remnant. In the unlikely event that a small part of the heater sleeve remnant breaks away, the density of the loose part material is significantly greater than that of the water, and the loose part would tend to settle to the bottom of the pressurizer. Flow velocities in the pressurizer are relatively low and are not likely to transport loose pieces of metal to the surge line. Additionally, the surge line nozzle is equipped with a surge screen, with half-inch holes, to catch any loose parts that may damage the reactor coolant system. The licensee concluded that no damage is expected in the event that the loose part does not remain in the bottom of the pressurizer. The staff agrees with the licensee’s conclusion that loose parts will not likely to occur from the proposed remnant sleeves and J-groove welds.

Corrosion Consideration

The half-nozzle design will leave a small gap between the original nozzle and replacement nozzle in the penetration. The staff asked the licensee to discuss whether this gap would be exposed to the primary coolant and the trapped coolant in the gap would lead to crevice corrosion in the penetration. In a letter dated December 2, 2004, the licensee responded that the half sleeve repair leaves the sleeve bore in the base metal exposed to primary water, which could potentially cause the base metal to corrode. The licensee evaluated the effect of corrosion on the half-nozzle repair geometry for pressurizer and steam generator instrumentation nozzles. This calculation is also applicable for the heater sleeve penetrations. The corrosion depths were calculated at the gap between the halves of the heater sleeve and in the crevice region at the nozzle-to-pad weld. The corrosion rate for borated water in contact with the alloy steel head was conservatively determined as 0.0017 inch per year for the bottom head from corrosion test data applicable to SONGS. The depth of corrosion was assumed to be uniform and the extent of corrosion around the hole circumference was conservatively taken as 360 degrees. Based on this analysis, the total corrosion depth including fatigue after 40 years of service was shown to be less than the allowable corrosion depth established by the analysis. Based on the licensee’s analysis, the staff finds that the potential for corrosion of the sleeve penetration at the gap between the existing sleeve and new sleeve is small and acceptable.

4.6 Conclusion

On the basis of information submitted by the licensee, the staff has determined that compliance with the ASME Code requirements regarding flaw characterization and successive examinations of the remnant sleeves and welds is impractical. The licensee's evaluation has also shown that the worse-case flaw in the remnant sleeves and welds is acceptable with respect to the requirements of ASME Section XI IWB-3600. Therefore, pursuant to 10 CFR 50.55a(g)(6)(i), relief is granted from the requirements of ASME Code, Section XI, IWA-3300 and IWB-2420 pertaining to the remnant heater sleeves and remnant welds in the pressurizer through the end of the third inservice inspection interval at the SONGS, Units 2 and 3, which is scheduled to end on August 17, 2013.

All other requirements of the ASME Code, Section III and XI for which relief has not been specifically requested and approved remain applicable, including third party review by the Authorized Nuclear Inservice Inspector.

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