December 14, 2006

Mr. Richard M. Rosenblum
Senior Vice President and Chief Nuclear Officer
Southern California Edison Company
San Onofre Nuclear Generating Station
P.O. Box 128
San Clemente, CA 92674-0128

SUBJECT: SAN ONOFRE NUCLEAR GENERATING STATION, UNIT 3 - RE: THIRD 10-YEAR INSERVICE INSPECTION INTERVAL, REQUESTS FOR RELIEF FROM THE REQUIREMENTS OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS BOILER AND PRESSURE VESSEL CODE (TAC NOS. MD1128 AND MD1129)

Dear Mr. Rosenblum:

By letter dated April 7, 2006, Southern California Edison (SCE, the licensee) submitted relief requests ISI-3-19 and ISI-3-20, requesting U.S. Nuclear Regulatory Commission (NRC) approval to perform repairs on the pressurizer lower shell temperature nozzle at San Onofre Nuclear Generating Station, Unit 3 (SONGS 3) and the use of alternatives to certain American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (Code), Section XI requirements.

Specifically, Relief Request ISI-3-19, seeks relief from the requirements of Articles IWA-4410 and IWA-4600 of Section XI of ASME Code, 1995 Edition through the 1996 Addenda, to perform weld repairs on the pressurizer lower shell temperature nozzle. The licensee proposed to perform the repair utilizing a half-nozzle repair method with a remotely operated weld tool, using the machine Gas Tungsten Arc Welding process, an ambient temperature temper bead method with 50 °F minimum preheat temperature and no post weld heat treatment, as described in ASME Code Case N-638-1, with an exception involving nondestructive examination requirements. In addition, the licensee also proposed an alternative to the requirements of ASME Code, Section XI, IWA-4610(a), pertaining to preheat and interpass temperature monitoring.

Relief Request ISI-3-20 seeks relief from the 1995 Edition through the 1996 Addenda of ASME Code, Section XI, IWA-3300, Flaw Characterization, and IWB-2420, Successive Inspections. The licensee believes that with the installation of a new pressure boundary weld, the function of the original J-groove partial penetration weld is no longer required, and the alternative described in the proposed relief request will provide an acceptable level of quality and safety when compared to the ASME Code requirements in IWB-3500 to characterize the cracks left in service. Therefore, in lieu of fully characterizing any remaining cracks and performing successive examinations to validate flaw stability, SCE proposes to utilize worst-case assumptions as described in the relief request, to conservatively estimate the crack extent and orientation.

The NRC staff authorizes the alternative proposed by SCE in accordance with 50.55a(a)(3)(i) of Title 10 of *Code of Federal Regulations*, which states that the proposed alternatives may be used when authorized by the Director of the Office of Nuclear Reactor Regulation if the applicant demonstrates that the proposed alternatives would provide an acceptable level of quality and safety.

Therefore, Relief Requests ISI-3-19 and ISI-3-20 are authorized for the mid-cycle outage for SONGS 3. Due to the immediate need of this relief request, the NRC staff granted the verbal authorization for the use of this relief request on April 27, 2006.

The staff's safety evaluation is enclosed.

Sincerely,

/RA/

David Terao, Chief
Plant Licensing Branch IV
Division of Operating Reactor Licensing
Office of Nuclear Reactor Regulation

Docket No. 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-3-19 AND ISI-3-20

SOUTHERN CALIFORNIA EDISON COMPANY

SAN ONOFRE NUCLEAR GENERATING STATION, UNIT 3

DOCKET NO. 50-362

1.0 INTRODUCTION

By letter dated April 7, 2006 (Agencywide Documents Access and Management System (ADAMS) Accession Number ML061010230), pursuant to paragraph 50.55a(a)(3)(i) of Title 10 of the *Code of Federal Regulations* (10 CFR), Southern California Edison Company (SCE, 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, Unit 3 (SONGS 3).

In relief request ISI-3-19, the licensee sought relief from the requirements of Articles IWA-4410 and IWA-4600 of Section XI of American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (Code), 1995 Edition through the 1996 Addenda, to perform weld repairs on the pressurizer lower shell temperature nozzle. The licensee proposed to perform the repair utilizing a half-nozzle repair method with a remotely operated weld tool, using the machine Gas Tungsten Arc Welding (GTAW) process, an ambient temperature temper bead method with 50 °F minimum preheat temperature and no post weld heat treatment, as described in ASME Code Case N-638-1. Code Case N-638-1 has been approved with a condition for use by the Nuclear Regulatory Commission (NRC) under Regulatory Guide (RG) 1.147, "Inservice Inspection Code Case Acceptability, ASME [Code,] Section XI, Division 1," Revision 14. The Code Case provides relief to allow the use of machine GTAW with ambient temperature preheat and no post weld heat treatment (PWHT). The licensee intends to apply Code Case N-638-1 with one exception. This exception involves nondestructive examination (NDE) requirements. The licensee also proposed an alternative to the requirements of ASME Code, Section XI, IWA-4610(a), pertaining to preheat and interpass temperature monitoring.

In relief request ISI-3-20, the licensee requested 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 the flaw. The licensee also requested relief from IWB-2420 which requires successive inspections of components containing flaws, which have been accepted for continued service.

2.0 REGULATORY EVALUATION

The ISI requirements of the ASME Code Class 1, Class 2, and Class 3 components in nuclear plants are to be performed in accordance with the ASME Code, Section XI and applicable editions 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 50.55a(a)(3) of 10 CFR 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 50.55a(c)(1) of 10 CFR 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 Code. This requirement applies to a new repair weld attaching the replacement half-nozzle 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 3 third 10-year ISI interval began on August 18, 2003, and is scheduled to end on August 17, 2013.

3.0 RELIEF REQUEST ISI-3-19

3.1 System/Component(s) for which Relief is Requested

ASME Code, Section XI, 1995 Edition through the 1996 Addenda, Class 1, Category B-P, Pressure Retaining Boundary, Item Number B15.20 applies to the pressurizer lower shell temperature nozzle. The nozzle is 1-inch nominal pipe size (NPS) and is located on the side of the vessel.

3.2 Code Requirements

ASME Code, Section XI, 1995 Edition through the 1996 Addenda, IWA-4410 requires repairs to be made in accordance with the owner's requirements and the original Construction Code (ASME Code, Section III) of the component or system. Later editions and addenda of the Construction Code, either in its entirety or portions thereof and relevant 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 3 follows the ASME Code, Section XI, 1995 Edition through the 1996 Addenda. The construction code for SONGS 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 Code, Section XI, IWA-4410 and its referenced IWA-4600 to perform a pressurizer lower shell temperature nozzle repair at SONGS 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 50 °F minimum preheat temperature and no PWHT, as described in Code Case N-638-1.

Code Case N-638-1 provides relief to allow use of machine GTAW with ambient temperature preheat and no PWHT. Code Case N-638-1 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-638-1, with exceptions listed above, SCE proposes the additional alternatives to the requirements of the Code. In lieu of the requirements of ASME Code, Section IX, IWA-4610(a) to use thermocouples and recording instruments to monitor process temperatures, SCE proposes to use a contact pyrometer.

3.4 Basis for Relief

The licensee contends 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 Code, Sections XI and III, while offering substantial savings in accumulated radiation dose. In support of its conclusion, the licensee provided a description of the repair process as detailed below:

a) 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 nozzle will be cut close to the vessel exterior surface. A portion of the nozzle inside the vessel bore will then be removed by machining and the area around the nozzle will be prepared for the application of the weld pad by an abrasive disc or flapper wheel and surface examination (PT or MT) and ultrasonic examinations of the area to be welded and the 5-inch wide band surrounding the weld area.

c) A weld pad will be applied to the surface of the pressurizer lower shell using the ambient temperature temper bead weld technique and GTAW process as described in Code Case N-638-1. The weld pad is to be applied as a weld buildup centered on the existing nozzle opening.

d) The weld pad will be suitably prepared for NDE. The pad and the heat affected zone (HAZ) below the pad will be UT examined 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). UT examinations of the full parent material thickness beneath the weld pad will, to the extent practical, be performed both before and after welding to detect laminar type indications in the examination boundary. Observed laminar-type indications will be recorded and evaluated to assure the structural integrity of the modification configuration is not adversely affected.

   SCE will follow the NRC's condition of approval of ASME Code Case N-638-1 as described in RG 1.147, Revision 14, "UT examinations shall be demonstrated for the repaired volume using representative samples which contain construction type flaws. The acceptance criteria of NB-5330 of Section III edition and addenda approved in 10 CFR 50.55a apply to all flaws identified within the repaired volume."

e) The approximate center of the weld pad will be machined to re-establish a free path into the nozzle bore of the vessel. A J-groove partial penetration weld preparation will be machined into the weld pad for the attachment weld of the new nozzle.

f) The new nozzle will be inserted and welded in place using conventional welding and NDE techniques (manual GTAW and progressive PT). Note that this weld is in full compliance with the construction code (ASME Code III) and, therefore, requires no relief from the existing code requirements.

Experience gained from the performance of similar repairs/modifications at other plants indicates that remote automated repair methods reduce the radiation dose to repair personnel and still provide acceptable levels of quality and safety. SCE recognizes the importance of as low as reasonably achievable principles and this remote repair method is being proposed for the repair of the pressurizer lower shell temperature nozzle at SONGS.

This approach for the repair of the pressurizer lower shell temperature nozzle will reduce radiation dose to repair personnel while still maintaining acceptable levels of quality and safety. SCE estimates the dose accumulated in Unit 3 by installing heating pads, performing the preheating and postheating, removing the heating pads, and performing NDE of the heating pad locations required by the existing code rules would be approximately 1 rem.

Preheat and Interpass Temperature Measurement

Due to the location of the repair and area radiation dose rate, the licensee has determined that the placement of welded thermocouples for monitoring weld interpass temperature is determined to be not beneficial based on dose savings. Therefore, welded 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 at 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. The heat input from layers beyond the third layer will not have a metallurgical affect on the low-alloy steel HAZ.

Examination

All NDE will be performed in accordance with ASME Code, Section III, 1995 Edition with the 1996 Addenda, NB-2500 (for base materials) and NB-5000 (for welds).

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 finished surface of the welded pad and a 5-inch band surrounding the pad will be surface examined (MT or PT) and the weld pad will be examined volumetrically (UT). The entire volume of the weld pad, to the extent practical, will be scanned from the face of the pad, using examination angles of 0°, 45° refracted longitudinal (RL), 60° RL, and an outside diameter (OD) creeping wave. The examination volume shall include the weld-deposited material and the ferritic vessel HAZ.

UT examinations of the full parent material thickness beneath the weld pad will, to the extent practical, be performed both before and after welding to detect laminar type indications in the examination boundary. 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 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. After the welding, both the weld and HAZ will be 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.

The licensee believes 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 Code, Sections XI and III, while offering substantial savings in accumulated radiation dose.

3.5 Staff Evaluation

The licensee proposed to use a half-nozzle repair method with remotely operated weld equipment, using the machine GTAW process, the ambient temperature temper bead method with a 50 °F minimum preheat temperature and no PWHT for the pressurizer lower level instrument nozzle repairs. In support of the proposed repair design, SCE is requesting relief from the applicable Code edition and addenda of the ASME Code, Section XI, which requires a PWHT at elevated temperature. ASME Code Case N-638-1 provides for machine GTAW temper bead weld repairs at ambient temperature using dissimilar materials, without the need for PWHT. The licensee is requesting permission to use ASME Code Case N-638-1, "Similar and Dissimilar Metal Welding Using Ambient Temperature Machine Temper Bead Technique." This Code Case was conditionally approved in RG 1.147, Revision 14, dated August 2005. SCE agreed to meet the conditions required by RG 1.147. Code Case N-638-1 requires a surface examination and 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 PT or MT) will be performed after the 48-hour hold time. Also, in lieu of the requirements of ASME Code, Section XI, IWA-4610(a) which requires the use of thermocouples and recording instruments to monitor process temperatures, SCE proposes to use a contact pyrometer. 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. A complete description of the licensee's proposed repair can be found in Section 3.4 above.

Because this is a surface application of the temper bead process, the staff agrees with the licensee's position that 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 base metal area surrounding the weld after the 48-hour hold time. Therefore, only the weld and HAZ will be post-weld volumetrically examined.

Code Case N-638-1 was originally written to be applied to the repair of partial and full penetration groove welds. However, nothing in the Code Case precludes its use in other applications, such as the current SCE application of an alloy 52 weld pad deposited over the OD of the pressurizer. The welding principles involved and application of the weld filler metal are the same as for a groove weld design. When performing a full penetration groove weld between two pieces of thick low-alloy steel (over 1 inch thick) using a low-alloy steel filler metal, there can be significant residual stresses built up in the base metal from contraction of the weldment. These stresses can cause distortion and cracking of the base metal a significant distance from the weld groove. To make certain that these types of defects do not remain in the weld area away from the weld groove, the Code Case has extended the area of the NDE well into the base metal. The filler metal used in the subject repair is alloy 52, which is more ductile than the low-alloy steel. The thickness of filler metal applied to the pressurizer shell is much less than the pressurizer shell thickness. Therefore, due to the more ductile weld filler metal and the much thinner weld being applied to the pressurizer shell, the residual stresses accumulated in the base metal from contraction of the weldment will be much less than that for a full penetration groove weld. UT examination of large areas of base metal outside the weld area, as required by the Code Case, provide no additional information for the licensee's repair since the examination would be in base metal (which is unaffected by the repair and this area has already been examined before the welding). The surface examination will still be performed on this area after the 48-hour hold time.

In addition, in accordance with the condition required by RG 1.147, SCE will also perform UT examination demonstrations using samples which represent the repaired volume. These samples will contain construction type flaws which are more pertinent to the type of weld being performed. This additional performance demonstration will provide the required level of quality and safety.

Paragraph IWA-4610(a) in ASME Code, Section XI, requires that preheat and interpass temperatures be monitored using thermocouples and recording instruments. As an alternative to this requirement, the licensee proposes to use a contact pyrometer to measure the preheat and interpass temperature. The 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. On all subsequent repair locations, the interpass temperature will be monitored every six to ten passes. Code Case N-638-1 requires that the preheat temperature shall be 50 °F (minimum) prior to depositing the first weld layer. For the first three layers, the interpass temperatures shall be at least 50 °F but less than 150 °F. The interpass temperature of each remaining layer shall be at least 50 °F but less than 350 °F prior to depositing the subsequent weld layers. The 50 °F preheat temperature is to be maintained on a weldment inside a building which normally is above 50 °F. Therefore, preheat measurement by this alternate method is acceptable. The maximum interpass temperatures required for the licensee's repair (150 °F for the first three layers and a maximum interpass temperature of 350 °F for the balance of welding) can easily be measured with a contact pyrometer because the surface of the weld is accessible to the contact pyrometer probe. Also, the large mass of the pressurizer coupled with the low-heat input GTAW process should help to ensure that the maximum interpass temperature is not exceeded. Additionally, with the alternate temperature measurement methods, close control will be maintained on these temperatures. Therefore, this type of temperature measurement will provide an acceptable level of quality and safety.

Based on the above evaluation, the staff has determined that the licensee's proposed alternative to the requirements of ASME Code Case N-638-1 for the half-nozzle repair method is acceptable, because it provides an acceptable level of quality and safety.

3.6 Conclusions

Based on the information provided in the licensee's submittal, the NRC staff has determined that the licensee has provided an acceptable alternative to the requirements of ASME Code, Section XI, and Code Case N-638-1. Therefore, pursuant to 10 CFR 50.55a(a)(3)(i), the licensee's proposed alternative, Relief Request ISI-3-19, is authorized for the repair of pressurizer nozzles during the third 10-year ISI interval at SONGS 3. All other requirements of the ASME Code, Sections 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-3-20

4.1 System/Component(s) for which Relief is Requested

The licensee proposed Relief Request ISI-3-20 for the repair of 1-inch NPS lower shell temperature instrument nozzle of the pressurizer. The pressurizer lower shell temperature nozzle with associated attachment weld is part of the primary pressure boundary and is an ASME Code Class 1 component. Examination Category B-P, Item No. B15.20, of Table IWB-

2500-1 of the ASME Code, Section XI, applies to the original and modified pressurizer lower shell temperature instrument nozzle.

4.2 Applicable ASME Code

The ASME Code, Section XI, 1995 Edition through the 1996 Addenda, is the code of record for the third 10-year ISI interval.

4.3 Applicable ASME Code Requirements

Subarticle IWA-4611.1 in the 1996 Addenda of the ASME Code, Section XI, requires that defects shall be removed or reduced in size. However, Subarticle IWA-4611.1 also allows any remaining portion of the flaw to be evaluated and the component to be accepted if it complies with the appropriate flaw evaluation rules of Section XI. ASME Code, Section XI, Subarticle IWA-3300 requires that flaws detected by inservice examination have their dimensions determined and characterized. ASME Code, Section XI, Subarticle IWB-2420 requires the reexamination and reevaluation of existing flaws in accordance with Subarticle IWB-3132.3 or IWB-3142.4 of the ASME Code, Section XI, in successive inspection intervals.

4.4 Licensee's Alternate Criteria for Acceptability

The proposed half-nozzle repair of the pressurizer lower shell temperature nozzle does not include the removal of any potential flaws in the remnant of the original nozzle or its J-groove partial penetration attachment weld. The licensee has performed a flaw evaluation in accordance with Subarticle IWA-4611.1.

The licensee requested relief from ASME Code, Section XI, Subarticle IWA-3300, because the size of any flaws present in the original pressurizer lower shell temperature nozzle or J-groove attachment welds will not be determined or characterized. The proposed alternative specifies that in lieu of meeting the requirements of IWA-3300, a crack with the worst-case extent and orientation is assumed to exist in the J-groove weld and the nozzle.

The licensee requested relief from ASME Code, Section XI, Subarticle IWB-2420, because no additional inspections will be performed to monitor the flaw stability. The proposed alternative specifies that in lieu of meeting the requirements of IWB-2420, the acceptability of the worst-case crack is demonstrated for the 40 years in accordance with the requirements of the ASME Code, Section XI, Subarticle IWB-3600.

4.5 Licensee's Basis for Relief

The licensee stated that 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, the function of the original J-groove partial penetration welds is no longer required.

The licensee stated that the requirements of Subarticle IWA-4611.1 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 Subarticle IWB-3600. The proposed repair design dictates that the original nozzle remnant and its attachment weld be left intact inside the pressurizer vessel. The assumptions of Subarticle IWB-3500 are that the cracks are fully characterized in order to be able to compare the calculated crack parameters to the acceptable parameters provided in IWB-3500. In the proposed alternative, the acceptance of the postulated crack is calculated based on 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 (conservative) assumptions with the geometry of the remnant weld, the postulated crack is assumed to initiate at the inside surface of the instrument nozzle, penetrate the nozzle wall, continue through to the intersection of the vessel inner diameter surface and the vessel nozzle bore by primary water stress-corrosion cracking (PWSCC). The crack is assumed to grow into the pressurizer shell by fatigue. The depth and orientation are worst-case assumptions for cracks that may occur in the remaining J-groove partial penetration weld. The licensee assumed that the “as left” condition of the remaining J-groove weld includes degraded weld and nozzle material.

The licensee performed fracture mechanics evaluations in accordance with ASME Section XI, Subarticles IWB-3600 and IWB-3700. The licensee concluded that degraded J-groove weld material could remain in the pressurizer 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 nozzle. It is postulated that a radial crack in the Alloy 182 weld metal would propagate by 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.

The licensee stated that 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 continue to extend into the low-alloy steel material due to cyclic loading. 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.

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 of 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$\sqrt{in}$ for unirradiated ferritic materials. The results of the analyses indicate that it is acceptable to leave the original Alloy 600 instrument nozzle remnant and original attachment J-groove weld in the pressurizer, even with the possibility that cracks exist in the weld for 40 years of service.

The licensee also evaluated the possibility of transverse cracks which could intersect with radial cracks and cause loose parts in the pressurizer. As noted above, radial cracks are postulated to occur in the weld due to the dominance of the hoop stress at this location. The licensee states that 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.

The licensee evaluated the consequences of loose parts of similar or larger dimensions and mass in the pressurizer being carried into the reactor vessel and concluded that the probability of damage to any reactor coolant system component is not significant. 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 into the reactor vessel via the pressurizer surge line. Additionally, the surge line nozzle is equipped with a surge screen (with half-inch holes) to trap loose parts. The licensee concluded that no damage is expected in the event that the loose part does not remain in the bottom of the reactor.

4.6 Implementation Schedule

The licensee proposed to implement Relief Request ISI-3-20 during the third ISI interval, which began on August 18, 2003, and is scheduled to end on August 17, 2013.

4.7 Staff's Evaluation

The proposed alternative for the repair of the pressurizer lower shell temperature nozzle is based on a residual stress analysis (Reference 1), a flaw evaluation (Reference 2), and a corrosion analysis (Reference 3). In lieu of requirements of Subarticles IWA-3300 and IWB-2420, the licensee performed a flaw evaluation in accordance with Subarticle IWB-3600 and supplemental calculations based on elastic-plastic fracture mechanics. The staff reviewed the licensee's flaw evaluations and stress analyses to verify that the proposed alternative would provide an acceptable level of quality and safety for the operation of the pressurizer.

The licensee calculated the effect of residual stresses due to welding and thermal transient stresses in the existing J-groove weld of the pressurizer shell as discussed in Reference 1. The licensee simulated the residual stress associated with fabricating the lower level nozzle penetration repair. The simulation included loading due to welding, thermal stress relief, hydrostatic testing, operating conditions, final residual stress, and the repair. The results show that the high-tensile-hoop stresses in the weld and buttering dissipate and become compressive within a short distance into the pressurizer base metal from the interface between the butter and pressurizer shell. The compressive stresses are favorable in this situation because they would restrict the propagation of the postulated flaw in the pressurizer shell. The results of the residual stress and thermal transient analyses were used to evaluate flaw stability in the fracture mechanics calculations discussed below.

Using the residual and thermal stresses calculated from Reference 1, the licensee analyzed the acceptability of an assumed flaw in the existing J-groove weld propagating into low-alloy steel base material as discussed in Reference 2. In Attachment I to Reference 2, the licensee assumed an initial flaw starting at the inside surface of the remnant nozzle. The initial flaw is assumed to propagate through the nozzle wall into the J-groove weld and butter due to PWSCC (i.e., the entire J-groove weld was assumed cracked). The tip of the initial crack is assumed to be located at the interface between the butter and the pressurizer shell base metal. The licensee assumed that the flaw would propagate into the pressurizer base metal by fatigue. The licensee evaluated the postulated flaw at the uphill and downhill locations on a plane perpendicular to the circumferential direction of the pressurizer lower head. The flaw was calculated to grow in the pressurizer shell for 40 years following the weld overlay installation using design pressure and temperature transient loading.

Once the final flaw crack size was determined, the licensee used elastic-plastic fracture mechanics to determine the flaw stability in the pressurizer shell. The flaw stability is based on the J-integral approach and safety factors of 3 on the pressure and 1.5 on thermal and residual loads. The licensee's calculation showed that the applied J-value for the final flaw size is less than the J-value of the pressurizer shell base metal by a factor of more than 3. This means that the postulated flaw will be stable and that the pressurizer base metal has sufficient fracture toughness to resist rapid propagation of the postulated flaw. The licensee concluded that a postulated crack growth through the entire, existing J-groove weld would be within the allowable limits, which is acceptable for 40 years following the weld overlay installation.

In reviewing the licensee's residual stress analysis in Reference 1, the staff determined that the finite element model of the pressurizer shell nozzle geometry is consistent with the as-built drawing of the nozzle. The staff reviewed various transients that were used in the licensee's analysis, including heatup, cooldown with flooding, reactor trip, loss of secondary pressure, loading/unloading, and leak test. The staff determined that the transients are consistent with the design basis. The staff also verified that the material specifications and associated material properties used in the licensee's analyses are consistent with the design specification.

The licensee stated that the finite element model was verified by comparing the analytical results of the model with the experimental and field data that were available at the time. The licensee's verification study of the finite element model showed that the locations of observed cracking correlated well with regions of highest stress in the analytical model. The verification study shows that the finite element model is acceptable to be used in the SONGS application. The staff finds that the licensee's residual stress evaluation is acceptable because the appropriate modeling and loading conditions were included in the analysis.

In reviewing the licensee's flaw evaluation in Reference 2, the staff determined that the licensee performed linear elastic fracture mechanics calculations in accordance with Subarticle IWB-3600 of the ASME Code, Section XI. The licensee also used elastic-plastic fracture mechanics to demonstrate the stability of the postulated flaw. The four issues relating to the licensee's flaw evaluation are discussed below.

The first issue is related to the licensee's use of elastic-plastic fracture mechanics in the flaw stability calculation. The staff noted that licensees who had repaired nozzle cracking of their reactor vessels and pressurizers have found that use of a postulated flaw in the reactor vessels or pressurizers could not satisfy certain safety margins of Subarticle IWB-3600. As an alternative, licensees have used elastic-plastic fracture mechanics to demonstrate flaw stability. The staff has approved the use of elastic-plastic fracture mechanics in lieu of linear elastic fracture mechanics (as required in the ASME Code, Subarticle IWB-3600) to demonstrate flaw stability in the reactor vessel and pressurizer (References 4 and 7, respectively).

In the staff's review of flaw stability calculations for the reactor vessel of Arkansas Nuclear One, Unit 1 (ANO-1) (Reference 4), and the pressurizer of Palo Verde, (Reference 7), the staff found that the licensees' calculated safety factors for postulated cracks in the J-groove weld were less than the required safety factor of $\sqrt{10}$, as specified in Subarticle IWB-3613 of the ASME Code, Section XI. The low-calculated safety factors were a result of conservatism, which stems from the magnitude and modeling of the residual weld stresses applied as a constant load on the crack face. Additional conservatism stems from the use of linear elastic fracture mechanics. The linear elastic fracture mechanics of Subarticle IWB-3600 is inherently conservative when applied to low-alloy steel because it does not consider the ductility of low-alloy steel. The licensees' low-calculated safety factors do not imply that the structural integrity of the reactor vessel is compromised but rather that the safety factors are a reflection of the conservatism in the analytical approach and assumptions. Therefore, the NRC staff allowed the use of elastic-plastic fracture mechanics to demonstrate the flaw stability in the reactor vessel and pressurizer because it concluded that elastic-plastic fracture mechanics is appropriate as applied to low-alloy steel of the reactor vessel and pressurizer for the specific flaw configuration and loading. The licensee for SONGS has shown that the calculated safety factor for the postulated flaw in the SONGS pressurizer shell also is less than that required by the ASME Code safety margins of IWB-3600. The NRC staff finds that the flaw configuration and assumptions for the SONGS half-nozzle repair are similar to the flaw configuration and assumptions in References 4 and 7. Therefore, the staff concludes that it is acceptable for the licensee to use elastic-plastic fracture mechanics to demonstrate the flaw stability in its pressurizer shell.

The second issue is related to the licensee's use of a safety factor of $\sqrt{2}$ for the cooldown transient event in its flaw evaluation to satisfy the requirements of Subarticle IWB-3600. The licensee stated that the use of a safety factor of $\sqrt{2}$ for the normal and upset conditions, when the internal pressure is less than 20 percent, was suggested by ASME Code Interpretation XI-1-04-03. The staff does not recognize ASME Interpretations and does not agree with the licensee's use of a safety factor of $\sqrt{2}$ on the stress intensity factor for the cooldown transient event. As required in the ASME Code, Subarticle IWB-3612, a safety factor of $\sqrt{10}$ must be applied to the stress intensity factor derived under the normal and upset load conditions. Subarticle IWB-3613(a) does allow the use of a safety factor of $\sqrt{2}$ but only when it is used for flanges and shell regions near structural discontinuities.

In addition, the licensee used the K_{IC} value per Subarticle IWB-3613 of the 2005 Addenda to the 2004 Edition of the ASME Code, Section XI, for the allowable crack tip stress intensity factor at zero load conditions. The value of K_{Ia} is required in Subarticle IWB-3613 of the 1995 Edition of the ASME Code and is more conservative than the K_{IC} value. The staff has not approved the use of the 2005 Addenda to the 2004 Edition of the ASME Code, Section XI. Also, licensees who wish to use editions of the ASME Code later than those approved for the current ISI interval need to request the NRC approval prior to use, as specified in NRC Regulatory Issue Summary 2004-16. Nevertheless, the licensee has demonstrated flaw stability in the pressurizer shell based on elastic-plastic fracture mechanics. The staff finds that the licensee's use of a safety factor of $\sqrt{2}$ per ASME Code interpretation XI-1-04-03 and its use of the K_{IC} value instead of K_{Ia} becomes moot because the licensee used elastic-plastic fracture mechanics to demonstrate flaw stability which is acceptable for this application.

The third issue is related to whether the base metal of the SONGS 3 pressurizer bottom shell has sufficient resistance to crack propagation. Resistance to crack propagation depends on the fracture toughness of a material which, in this case, is measured by the upper shelf Charpy energy of the pressurizer base metal. Because of the vintage of the SONGS plant, the licensee has no upper shelf Charpy energy data for the pressurizer base metal, which is usually obtained at high test temperature (e.g., >150 ^{o}F) in the Charpy V-notch tests. The available Charpy energy data for the pressurizer shell were taken at a relatively low temperature (+10 ^{o}F) and in the plate longitudinal (rolling) direction. However, the Charpy energy values at the transverse direction are needed for the flaw stability calculations. The licensee converted the Charpy energy in the longitudinal direction to the transverse direction in accordance with the procedures described in NRC Standard Review Plan, Section 5.3.2, “Pressure-Temperature Limits.” The equivalent Charpy energy values for SONGS 3 are 22, 23, and 25 foot pounds (ft-lbs) at 30 percent shear fracture appearance for all tests.

As discussed in Reference 4, in order to support the ANO-1 submittal, Entergy provided the complete Charpy energy versus temperature data from the Grand Gulf reactor vessel material. Entergy stated that the materials of the ANO-1 and Grand Gulf reactor vessel heads are comparable. The plate materials for both plants are SA-533, Grade B, Class 1 and were supplied by the same steel company, Lukens Steel. Entergy superimposed the ANO-1 Charpy energy data on the Grand Gulf Charpy energy graph and showed that the ANO-1 data fit the general trend of the Grand Gulf Charpy energy data. For the upper shelf Charpy energy for ANO-1, Entergy extrapolated a lower bound Charpy energy of 94 ft-lbs from the Grand Gulf data.

As discussed in Reference 4, in the evaluation of the ANO-1 submittal, the staff performed an independent analysis of the Charpy energy values by reviewing surveillance capsule reports of reactor vessel material specimens and final safety analysis reports of various nuclear plants. The staff found that the ANO-1 Charpy test data are consistent with the Charpy energy data from other Babcock and Wilcox reactor vessels with the same SA-533 plate material. The staff also found in Electric Power Research Institute report, TR-113596, that the upper shelf Charpy energies of SA-533 plate materials fabricated by Lukens Steel between 1966 and 1974 ranged from 91 ft-lb to 177 ft-lb. The mean upper shelf energy was calculated to be 127 ft-lb with one standard deviation of 15 ft-lb. The upper shelf energy at 2 standard deviations from the mean was 97 ft-lb, which represents the 95-percent confidence interval value. The lower the upper shelf energy used in the elastic-plastic fracture mechanics calculation, the more conservative the flaw stability results will be. That is, if a crack can be shown to be stabilized at a lower upper shelf energy value, the crack will become stabilized at a higher upper shelf energy value. Therefore, the staff found that an upper shelf energy of 94 ft-lb used by Entergy was acceptable because the 94 ft-lb energy value is conservative as compared to the 95-percent confidence value of 97 ft-lb.

The licensee stated that the SONGS 3 pressurizer was fabricated by the same Lukens Steel company and pressurizer base metal is made of the same SA-533, Grade B, Class 1 low-alloy steel as that of the ANO-1 reactor vessel. On the basis of the staff’s acceptance of the 94 ft-lb upper shelf energy value for the ANO-1 reactor vessel, the licensee used 94 ft-lb for the SONGS pressurizer. The staff finds that it is acceptable for the licensee to use an upper shelf energy of 94 ft-lbs in its flaw stability calculation.

The fourth issue is related to the licensee’s proposed safety factors (i.e., safety factors of 3 on the pressure and 1.5 on thermal loading) for its elastic-plastic fracture mechanics calculations. The subject safety factors are lower than the ASME Code, Section XI, safety factor of $\sqrt{10}$ (as specified in IWB-3613) because the same safety factor, is applied to the stress intensity factor derived from the primary stresses (pressure) and secondary stresses (thermal). The licensee believes that this results in an overly conservative allowable stress intensity factor when the predominant loading mechanism in the J-groove weld is highly localized and due to residual stresses, which are considered as the secondary stresses. The staff accepted the use of the proposed safety factors of 3 on pressure loading and 1.5 on thermal loading in the approval of

ANO-1 nozzle repair. Therefore, the staff finds that the proposed safety factors are acceptable for SONGS because the flaw configuration and loading are similar between SONGS and ANO-1. The staff concludes that the proposed safety factor will provide an adequate margin for the structural integrity of the pressurizer lower shell.

The staff finds that the licensee’s flaw stability evaluation is acceptable because the evaluation assumed a worst-case flaw originating in the nozzle, propagating through the J-groove weld and into the pressurizer base metal. The staff concludes that the licensee has demonstrated by analysis that the proposed half-nozzle repair will not significantly affect the structural integrity of the pressurizer base metal.

In addition to the flaw stability evaluation discussed above, the licensee also performed an analysis to demonstrate the long-term acceptability of the half-nozzle configuration, considering the potential corrosion of the low-alloy steel shell material which will be exposed to primary system borated water (Reference 3). The half-nozzle repair will result in a 1/16-inch gap inside the pressurizer nozzle (bore) penetration between the original nozzle stub and the new half nozzle. The primary coolant could become trapped in the gap which could cause corrosion of the pressurizer base metal inside the nozzle penetration. To evaluate the potential for corrosion, the licensee modeled local corrosion as a circumferential planar groove within the pressurizer nozzle penetration. The groove represents the 1/16-inch gap between the original nozzle stub and the new half nozzle inside the pressurizer nozzle penetration. The degradation would consist of the loss of metal in the annulus between the nozzle and shell penetration. The integrity of the nozzle attachment was determined as a function of the location of borated water corrosion within the pressurizer bore penetration, and the depth and length of the gap. The licensee also simulated a crevice between the weld attachment pad and the pressurizer shell in which localized boric water corrosion was assumed to occur. The licensee used the general approach of ASME Code, Section XI, Appendix H, to perform a limit load-based evaluation including fatigue crack growth on the nozzle in the pressurizer. The allowable corrosion depths were computed at the gap region between the new nozzle and the remnant nozzle stub, and in the crevice region at the nozzle-to-pad weld. The licensee demonstrated that the projected corrosion depths in the gap and crevice regions are within the allowable corrosion depths after 40 years. The staff finds that the licensee has demonstrated that the potential for borated water corrosion as a result of the half-nozzle repair will not affect the integrity of the pressurizer bottom head/lower shell.

The staff finds that the licensee has performed an acceptable flaw evaluation in accordance with Subarticle IWA-4611.1. Subarticle IWA-3300 of the ASME Code, Section XI, requires characterization of the size of the flaw if it was found during an inservice examination. Subarticle IWB-2420 requires existing flaws be reexamined and reevaluated in accordance with Subarticle IWB-3132.2 or IWB-3142.4 of the 1995 Edition through the 1996 Addenda of the ASME Code, Section XI. However, it is difficult to characterize and examine the remnant J-groove welds and remnant nozzle stubs which are located inside the pressurizer penetration. Therefore, the licensee proposed to assume a worst-case flaw in the J-groove weld and to demonstrate by analysis the flaw stability. On the basis of its flaw evaluation and conservative flaw size assumption, the licensee has demonstrated that the structural integrity of the pressurizer shell will be maintained. Therefore, subsequent inservice examination of the J-groove attachment weld as required by Subarticle IWB-2420 would not be needed.

The staff concludes that the structural integrity of the pressurizer is demonstrated to be adequate under the proposed pressurizer nozzle repair and that the borated water corrosion will not affect the pressurizer shell base metal significantly.

5.0 CONCLUSIONS

On the basis of the above evaluation, the staff concludes that the proposed alternative in Relief Request ISI-3-20, pertaining to the remnant J-groove welds of the lower shell temperature nozzle in the 1-inch NPS lower shell temperature instrument nozzle of the pressurizer at SONGS 3, will provide an acceptable level of quality and safety. Therefore, pursuant to 10 CFR 50.55a(a)(3)(i), the staff authorizes the proposed Relief Request ISI-3-20 for the remaining third 10-year ISI interval at SONGS 3.

All other requirements of the ASME Code, Sections 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.

6.0 REFERENCES

1. M-DSC-412, Revision 0, Pressurizer Thermowell Nozzle Welding And Transient Analysis, ADAMS Accession No. ML062620172.

2. M-DSC-414, Revision 0, Pressurizer Lower Level and Thermowell Nozzles J-Weld Fracture Mechanics Evaluation, ADAMS Accession No. ML061090522.

3. M-DSC-360, Revision 0, Evaluation Of Half-Nozzle Repair for Pressurizer and Steam Generator Inst. Nozzles Under Long-Term Service Conditions SONGS 2 and 3, ADAMS Accession No. ML061090479.

4. NRC Letter to Entergy dated September 29, 2004, “Arkansas Nuclear One, Unit No. 1 - Re: Proposed Alternatives to Weld Repair and Examination Requirements for Repairs on Reactor Vessel Head Penetration Nozzles (TAC No. MB9660),” ADAMS Accession No. ML042890174.

5. Entergy Letter to the NRC dated May 4, 2004,“Request for Alternative ANO1-R&R-006- Proposed Alternative to ASME Weld Examination Requirements for Repairs Performed on Reactor Vessel Head Penetration Nozzles,” ADAMS Accession No. ML041410519.

6. Arizona Public Service Company Letter to the NRC dated June 15, 2004, “Palo Verde Nuclear Generating Station (PVNGS) Units 1, 2, and 3 . . . 10 CFR 50.55a Alternative Repair Requests for the PVNGS Pressurizers: Relief Requests 28 and 29,” ADAMS Accession No. ML041750296.

7. NRC letter to Arizona Public Service Company dated November 5, 2004, “Palo Verde Nuclear Generating Station, Units 1, 2, and 3 - Relief Request No. 29 Re: Remnant

Sleeves(s) Flaw Evaluation (TAC No. MC3606, MC3607, and MC3608)," ADAMS Accession No. ML043130170.

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