October 6, 2005

Mr. Gregg R. Overbeck
Senior Vice President, Nuclear
Arizona Public Service Company
P. O. Box 52034
Phoenix, AZ 85072-2034

SUBJECT: PALO VERDE NUCLEAR GENERATING STATION, UNIT 3 RELIEF REQUEST NO. 33: REQUEST TO USE ALTERNATIVES TO TEMPERATURE REQUIREMENTS FOR A PORTION OF THE PRESSURIZER BASE METAL (TAC NO. MC7342)

Dear Mr. Overbeck:

By letter dated June 19, 2005, as supplemented by letters dated June 21 and June 28, 2005, Arizona Public Service (APS) Company submitted Relief Request No. 33, requesting relief from certain American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (Code) requirements at Palo Verde Nuclear Generating Station (Palo Verde), Unit 3. The request for relief would allow alternatives to ASME Section III, Subsection NB-1120, "Temperature Limits," for a portion of the Palo Verde Unit 3 pressurizer base material surrounding the heater sleeves that was subjected to temperatures above those for which design stress intensity values are given in the Code. On June 21, 2005, the Nuclear Regulatory Commission (NRC) staff granted verbal authorization of the proposed alternative in order to support startup of Palo Verde Unit 3. The June 21, 2005, letter was submitted to formally docket information previously given in a teleconference by APS in support of verbal authorization of the proposed alternative.

Based on the enclosed Safety Evaluation, the NRC staff has determined that the licensee's proposed alternatives provide an acceptable level of quality and safety, in accordance with 50.55a(a)(3)(i) of Title 10 of the *Code of Federal Regulations*. The impact of heating the pressurizer base material up to 779 °F for up to 3,700 hours may be determined using: (a) ASME Code Section III, Subsection NB analysis methods, (b) stress rupture properties from Table 4 and Figure 3 in ASME Code Case N–499-2, (c) the design stress intensity values given in ASME Code Case N-499-2 Table 1 and Figure 1, except that the design stress intensity value at 750 °F shall be 24.6 kips per square inch (ksi) and the value at 800 °F shall be 23.3 ksi, and (d) the design fatigue data points and curves in Table 8 and Figure 11 from ASME Code Case N-499-2.

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.

Sincerely,

/RA/
Daniel S. Collins, Acting Chief, Section 2
Project Directorate IV
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Docket No. STN 50-530

Enclosure: Safety Evaluation

cc w/encl: See next page

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.

Sincerely,

/RA/
Daniel S. Collins, Acting Chief, Section 2
Project Directorate IV
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

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cc w/encl: See next page

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SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

INSERVICE INSPECTION PROGRAM RELIEF REQUEST NO. 33

ARIZONA PUBLIC SERVICE COMPANY, ET AL.

PALO VERDE NUCLEAR GENERATING STATION, UNIT 3

DOCKET NO. STN 50-530

1.0 INTRODUCTION

By letter to the Nuclear Regulatory Commission (NRC) dated June 19, 2005 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML051800261), as supplemented by letters dated June 21 (ADAMS Accession No. ML051790349) and June 28, 2005 (ADAMS Accession No. ML051890145), Arizona Public Service Company (APS or the licensee) submitted Relief Request No. 33, requesting relief from certain American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (Code) requirements at Palo Verde Nuclear Generating Station (Palo Verde or PVNGS), Unit 3.

The request for relief would allow alternatives to ASME Section III, Subsection NB-1120, "Temperature Limits," for a portion of the Palo Verde Unit 3 pressurizer base material surrounding the heater sleeves that was subjected to temperatures above those for which design stress intensity values are given in the Code.

On June 21, 2005, the NRC staff granted verbal authorization of the proposed alternative in order to support startup of Palo Verde Unit 3. The June 21, 2005, letter was submitted to formally docket information previously given in a teleconference by APS in support of verbal authorization of the proposed alternative. This verbal authorization was to be followed up by the NRC staff's final review and written authorization.

2.0 BACKGROUND

The Palo Verde Unit 3 pressurizer has 36 heater sleeves attached to the bottom head. During the Unit 3 fall 2004 refueling outage, the original Alloy 600 heater sleeves were replaced with Alloy 690 heater sleeves to address concerns with primary water stress corrosion cracking. The Unit 3 pressurizer heaters were removed and replaced with new heaters, provided by Framatome ANP, Inc. (Framatome). These new heaters began failing shortly after the Palo Verde Unit 3 startup in November 2004. Palo Verde Unit 3 was shut down for reactor coolant pump maintenance and replacement of nine pressurizer heaters on May 23, 2005. During preparations for startup from this outage, five more Framatome heaters failed and the decision was made by the licensee to replace all of the Framatome heaters with heaters from a different manufacturer prior to starting up. On June 15, 2005, Framatome notified APS that during the heater failure investigation, it was discovered that the heaters had been incorrectly fabricated with a longer heating element than the design specification. The longer heating elements, covered by the heater sheaths, extended down into the heater sleeves and pressurizer shell, exposing the sleeves and shell to elevated temperatures.

During the period of time when the incorrect heaters were in operation, the licensee determined that the pressurizer base material surrounding the heater sleeves was subjected to temperatures above 700 °F and up to 779 °F for up to 3,700 hours. The pressurizer base material is SA-533, Grade A, Class 1. The highest temperature for which design stress intensity values are given for this material is 700 °F, as stated in ASME Section III, Article NB-1000, Subsection NB-1120, “Temperature Limits.” Therefore, APS requested approval of an alternative to ASME Section III, Subsection NB-1120 for evaluating the portion of the Palo Verde Unit 3 pressurizer base material surrounding the heater sleeves that was subjected to temperatures above those for which design stress intensity values are given in the ASME Code.

3.0 REGULATORY REQUIREMENTS

The regulations in 50.55a of Title 10 of the *Code of Federal Regulations* (10 CFR), require that systems and components of nuclear power plants be designed and constructed in accordance with the rules provided in the ASME Code. The regulation at 10 CFR 50.55a(c) requires reactor coolant pressure boundary components to meet the requirements for Class 1 components in Section III of the ASME Code. The applicable ASME Code Section III requirements for Palo Verde Unit 3 are found in the 1971 Edition, with 1973 Winter Addenda. Pursuant to 10 CFR 50.55a(a)(3), proposed alternatives to the ASME Code requirements can be used when authorized by the NRC if the licensee demonstrates that: (1) the proposed alternative would provide an acceptable level of quality and safety, or (2) compliance with the specified requirements would result in hardship or unusual difficulty without a compensating increase in the level of quality and safety.

4.0 RELIEF REQUEST NO. 33, PROPOSED ALTERNATIVES TO TEMPERATURE REQUIREMENTS FOR A PORTION OF THE PRESSURIZER BASE METAL

4.1 Code Requirements

Sub-article NB-1120, ASME Section III 1971 Edition, with 1973 Winter Addenda, states the following:

“The rules of Subsection NB shall not be used for items which are to be subjected to metal temperatures other than those for which design stress intensity values are given in Tables I.1.0. Above those temperatures, the creep and stress rupture characteristics of the materials permitted to be used become significant factors which are not presently covered by the rules of this Subsection. Fatigue design curves and specified methods for fatigue analysis are not applicable above 700°F for materials covered by Fig. I-9.1, above 800°F for materials covered by Fig. I-9.2, and above 500°F for materials covered by Fig. I.9.3."

4.2 Licensee's Reason for the Relief Request (As Stated)

It has been determined at this time that the pressurizer base material surrounding the heater sleeves was subjected to temperatures above 700°F and up to 779°F for up to 3,700 hours. The pressurizer base material is SA-533, Grade A, Class 1. The highest temperature for which design stress intensity values are given for this material is 700°F, as stated in ASME Section III, Article NB-1000, Subsection NB-1120, "Temperature Limits." Therefore, APS requests approval of alternatives to ASME Section III, Sub-Section NB-1120 for the portion of the PVNGS Unit 3 pressurizer base material surrounding the heater sleeves that was subjected to temperatures above those for which design stress intensity values are given in the Code.

4.3 Licensee's Proposed Alternatives (As Stated)

1. For the portion of the Unit 3 pressurizer base material that was exposed to temperatures above 700EF, proposed alternative 1 is to use the requirements of NH-3211(c) and (d) which state that the experimental and analytical methods of Subsection NB remain applicable if the designer demonstrates that the elevated temperature service parameters (time, stress level, and temperature) do not introduce significant creep effects.

2. For the portion of the Unit 3 pressurizer base material that was exposed to temperatures above 700EF, proposed alternative 2 is to use the applicable material properties of SA-533 grade B material from Table 4 and Figure 3 given in Code Case N-499-2 for Stress Rupture Properties.

3. For the portion of the Unit 3 pressurizer base material that was exposed to temperatures above 700EF, proposed alternative 3 is to use applicable design stress intensity values given in the Code Case N-499-2 Table 1 and Figure 1 for SA-533 Grade B material to be used for SA-533 Grade A material up to 779EF for up to 3,700 hours, except that the design stress intensity value (S_m) at 750EF shall be 24.6 ksi and the value at 800EF shall be 23.3 ksi, as indicated in Table 2.4 of the Oak Ridge National Laboratory [ORNL] Letter 0409-49-90 dated April 20, 1990 (Ref. 1). Also Table 8 and Figure 11 from Code Case N-499-2 can be used for fatigue analysis for those temperatures over 700EF.

5.0 TECHNICAL EVALUATION

ASME Code Section III, Subsection NH-3211(c) and (d)

ASME Code Section III, Subsection NH-3211(c) and (d) state that the experimental and analytical methods of ASME Code Section III, Subsection NB remain applicable if the designer demonstrates that the elevated temperature service parameters (time, stress level, and temperature) do not introduce significant creep effects.

To determine whether the SA-533, Grade A, Class 1 pressurizer base material experienced significant creep, the licensee: (a) demonstrated that the stress rupture data for SA-533, Grade A material is equivalent to the stress rupture data for SA-533, Grade B material and (b) compared exposure time (3700 hours) and maximum temperature (779 °F) of the pressurizer at the calculated stress level for the pressurizer (20.3 ksi) to stress rupture time from the time-dependent design stress intensity factor (S_t) for SA-533, Grade B, Class 1 material from ASME Code Case N–499-2.

ASME Code Case N-499-2 specifically addresses SA-533, Grade B, Class 1 plate, while the bottom head of the Palo Verde Unit 3 pressurizer was fabricated from SA-533, Grade A, Class 1 material. The nominal composition of SA-533, Grade B is defined as Mn-1/2Mo-1/2Ni while SA-533, Grade A is defined as Mn-1/2Mo. Both grades have a specified minimum yield strength of 50 ksi and a specified minimum tensile strength of 80 ksi. The design stress intensity values for both Grades A and B of SA-533 in Table 1.1 of Appendix I of Section III are identical.

The allowable stress values for SA-533 material in ASME Code Section VIII are identical for the two grades up to 800 °F. However, at temperatures from 850 °F to 900 °F, the allowable stress values are slightly higher for the Grade A material than for the SA-302, Grade C, which is equivalent in nominal composition to the SA-533, Grade B. Allowable stresses for the SA-533, Grade A material at temperatures of 900 °F and above are values obtained from time dependent properties. Allowable stresses for the SA-302, Grade C material at temperatures of 850 °F and above are values obtained from time dependent properties.

The licensee concludes that based on the equivalence of the mechanical properties of SA-533, Grade A and B in both the time-independent and time-dependent temperature regimes, the properties given in ASME Code Case N-499-2 for SA-533, Grade B can be applied equally to the SA-533, Grade A material of the pressurizer head.

In addition, the licensee provided stress rupture data (Ref. 2) to demonstrate that the stress rupture data for SA-533, Grade A material is equivalent to the stress rupture data for SA-533, Grade B material. Table III and Figure 3 from Reference 2 contains stress rupture data for SA-533, Grade A and B material. This data indicates the stress rupture properties for SA-533, Grade A and B materials are equivalent.

ASME Code Case N–499-2 contains S_t values for up to 3000 hours for SA-533, Grade B, Class 1 material. To further evaluate whether the pressurizer head exposure could have produced any significant creep effects, S_t values for longer times were developed based on the 2/3 of minimum rupture criteria used to establish time-dependent allowables for ASME Code Section III, Subsection NH (Ref. 3). Figure 3 in the licensee's June 28, 2005, letter compares the pressurizer stress and time/temperature exposure to the S_t values for 700 °F, 750 °F, 800 °F, and 850 °F and exposures up to 1,000,000 hours. The 3700 hours of exposure for the pressurizer at 20.3 ksi represents only about 1.2 percent of the time for the extrapolated St value at 800 °F. Since the S_t values for 779 °F would be greater than those at 800 °F, the pressurizer exposure time would be expected to have less than 1.2 percent of the time to produce rupture. Since the exposure time of the pressurizer is less than 1.2 percent of the time to produce rupture, the exposure of the pressurizer at 779 °F for 3700 hours produced insignificant amount of creep.

Since the stress rupture properties for SA-533, Grade A and B materials are equivalent and the exposure of the pressurizer at 779 °F for 3700 hours produced insignificant amount of creep, the NRC staff finds that, in accordance with ASME Code Section III, Subsection NH-3211(c) and (d), ASME Code Section III, Subsection NB analysis methods may be utilized to determine the impact of heating the pressurizer base material.

Stress Rupture Properties from Table 4 and Figure 3 in ASME Code Case N-499-2

Table 4 and Figure 3 in ASME Code Case N–499-2 are equivalent and indicate the expected minimum stress-to-rupture as a function of temperature and time for SA-533, Grade B, Class 1 material for temperatures up to 1000 °F and up to 100,000 hours. The data used for determining these stress-to-rupture values are contained in Table 3.1 of Reference 4. This data was initially reported in Reference 5. The modified "Larson-Miller creep parameter fit to the stress rupture data" in Table 3.1 of Reference 4 is shown in Figure 3.2, "Larson-Miller Correlation for Rupture Average and Minimum," of Reference 4. The minimum stress rupture values for each time and temperature value are obtained by calculating the corresponding value for the Larson-Miller Parameter (P-R) and the associated stress value from Figure 3.2. These values are shown in Figure 3.7, "Minimum Stress to Rupture as a Function of Time and Temperature," and Table 3.8, "Minimum Stress-to-Rupture Values, ksi," of Reference 4. The values shown in Figure 3.7 and Table 3.8 of Reference 4 are the same as those contained in Table 4 and Figure 3 of ASME Code Case N-499-2. Since the data was derived from minimum values from stress rupture test data from SA-533, Grade B material and the analysis followed the Larson-Miller methodology, the NRC staff finds that the Table 4 and Figure 3 values are acceptable for determining the impact of time and temperature on the stress rupture properties of the pressurizer base material.

Design Stress Intensity Factors

The licensee proposes to use the design S_m values given in ASME Code Case N-499-2 Table 1 and Figure 1, except that the S_m value at 750 °F shall be 24.6 ksi and the value at 800 °F shall be 23.3 ksi, for evaluating the impact of operating the pressurizer at temperatures up to 779 °F for 3,700 hours. Table 1 in ASME Code Case N–499-2 provides the allowable stress intensity values (S_{mt}) for SA-533, Grade B, Class 1 and SA-508, Class 3 material. These allowable S_{mt} values were derived by ORNL and were based on the tensile data in Table 2.1, "Tensile Properties of SA533B Cl 1- SR=0.0016/min," in Reference 4. In Table 2.1, average yield and tensile strength values were calculated at each temperature. These average values were then used to generate the ratio analysis for yield and tensile strength by normalizing to the room temperature minimum specified yield and tensile strength of 50 ksi and 80 ksi, respectively. The ratio analysis is shown in Figures 2.3 of Reference 4. The yield and tensile strength values derived from the ratio analysis and the calculated S_m values are shown in Table 2.4, "Allowable Stresses (S_m) vs. Temperature for SA533B," of Reference 4. Design stress intensity values at any temperature are no larger than the least of the following:

(a) one-third of the specified minimum tensile strength at room temperature;
(b) one-third of the tensile strength at temperature;
(c) two-thirds of the specified minimum yield strength at room temperature;
(d) two-thirds of the yield strength at temperature,

The one-third of the tensile strength at temperature criterion is the most limiting, so the values shown in Table 2.4 are equal to one-third of the tensile strength derived in the ratio analysis. Since this method of analysis is the method used by the ASME Code to determine the allowable S_{mt} for ASME Code materials, the use of these values is acceptable to the NRC staff. In reviewing this data the NRC staff determined that the allowable values in Table 2.4 of Reference 4 were less than the values in Table 1 of ASME Code Case N–499-2 at temperatures of 750 °F and 800 °F. The NRC staff recommended that these lower values (24.6 ksi at 750 °F and 23.3 ksi at 800 °F) be utilized since they are conservative and were determined to be applicable by ORNL.

Figure 1 of ASME Code Case N–499-2 identifies the allowable stress intensity values (S_m and S_t). The determination of the S_m values are described above. The S_t in Figure 1 of ASME Code Case N–499-2 are the same as the values reported in Table 2 of ASME Code Case N–499-2. The S_t values are calculated from the criteria of A.3, "Time Dependent Design Stress Intensity," provided in Appendix A of Reference 6. Appendix A is also included as Attachment 7.3 of Reference 4. The time dependent design stress intensity, S_t, is determined from the minimum of:

1. two-thirds of the minimum stress to rupture in time, t;
2. 80 percent of the minimum stress to tertiary creep in time t; and
3. minimum stress to produce 1 percent strain in time t.

Larson-Miller correlations for each of these criteria are included in Figures 3.2 of Reference 4. The three criteria are compared for a time of 1000 hours in Figure 3.4, "Minimum Stress vs. Temperature for 1% Creep, 80% Tertiary Creep and 67% Rupture," of Reference 4. At lower temperatures the values are controlled by the stress-rupture criteria. At higher temperatures and longer times, the 1 percent strain criteria becomes controlling. The derived S_t values are shown in Table 3.6, "S_t-Allowable Stress Intensity Values, 1000 psi," of Reference 4. The values in Table 3.6 are the S_t values in Table 2 and Figure 1 of ASME Code Case N-499-2. Since this method of analysis is the method used by the ASME Code to determine the allowable stress intensity factor S_t for ASME Code materials, the use of these values is acceptable to the NRC staff. It should be noted that these values are not controlling because the controlling allowable stress intensity factor is the S_m value, which is lower than the S_t value at temperatures less than 800 °F.

Fatigue Analysis

The licensee proposes to use the design fatigue data points and curves in Table 8 and Figure 11 from ASME Code Case N-499-2 for evaluating the impact of operating at temperatures over 700 °F. Table 8 and Figure 11 from ASME Code Case N-499-2 provide the allowable number of cycles as a function of strain range at 1000 °F. The strain range vs. number of cycles fatigue curve in Figure 11 and the associated tabular values of strain range and number of cycles are taken from Figure 5.1, "Fatigue data at 1000F for SA533B," of Reference 4. Since these values are similar to those in ASME Code Section III for SA-533, Grade B material, the NRC staff finds that they are acceptable for use in the evaluation of the pressurizer.

6.0 CONCLUSION

The NRC staff has reviewed the licensee's proposed Relief Request No. 33. Based on the data supplied by the licensee, the NRC staff has concluded that the impact of heating the pressurizer base material up to 779 °F for up to 3,700 hours may be determined using: (a) ASME Code Section III, Subsection NB analysis methods, (b) stress rupture properties from Table 4 and Figure 3 in ASME Code Case N–499-2, (c) the design stress intensity values given in ASME Code Case N-499-2 Table 1 and Figure 1, except that the design stress intensity value (S_m) at 750 °F shall be 24.6 ksi and the value at 800 °F shall be 23.3 ksi, and (d) the design fatigue data points and curves in Table 8 and Figure 11 from ASME Code Case N-499-2.

Based on the NRC staff's review of the information submitted by the licensee, the NRC staff concludes that the licensee's proposed alternatives provide an acceptable level of quality and safety. Therefore, pursuant to 10 CFR 50.55a(a)(3)(i), the licensee's proposed alternatives are authorized for Palo Verde Unit 3.

All other ASME Code, Section XI requirements for which relief was not specifically requested and approved in this relief request remain applicable, including third-party review by the Authorized Nuclear Inservice Inspector.

7.0 REFERENCES

1) Oak Ridge National Laboratory Letter 0409-49-90 regarding submission of data package for SA-533 Grade B, Class 1 plates, SA-508 Class 3 forgings and their weldments, dated April 20, 1990.

2) A. W. Pense and R. D. Stout, "Characterization of Heat Treated Pressure Vessel Steels for Elevated Temperature Service," Symposium on Heat-Treated Steels for Elevated Temperature Service, September 1966.

3) Criteria for Design of Elevated Temperature Class 1 Components in Section III, Division 1, of the ASME Boiler and pressure Vessel Code, ASME, May 1976.

4) Oak Ridge National Laboratory Letter 0409-49-90 regarding submission of data package for SA-533 Grade B, Class 1 plates, SA-508 Class 3 forgings and their weldments, dated April 20, 1990.

5) DOE-HTGR-88383, "Tensile and Creep Properties of SA533 Grade B Class 1 Steel," December 1989.

6) ASME Publication, "Criteria for Design of Elevated Temperature Class 1 Components in Section III, Division 1, of the ASME Boiler and Pressure Vessel Code," May 1976.

Principal Contributor: Barry Elliot

Date: October 6, 2005

cc:
Mr. Steve Olea
Arizona Corporation Commission
1200 W. Washington Street
Phoenix, AZ 85007

Douglas Kent Porter
Senior Counsel
Southern California Edison Company
Law Department, Generation Resources
P.O. Box 800
Rosemead, CA 91770

Senior Resident Inspector
U.S. Nuclear Regulatory Commission
P. O. Box 40
Buckeye, AZ 85326

Regional Administrator, Region IV
U.S. Nuclear Regulatory Commission
Harris Tower & Pavillion
611 Ryan Plaza Drive, Suite 400
Arlington, TX 76011-8064

Chairman
Maricopa County Board of Supervisors
301 W. Jefferson, 10th Floor
Phoenix, AZ 85003

Mr. Aubrey V. Godwin, Director
Arizona Radiation Regulatory Agency
4814 South 40 Street
Phoenix, AZ 85040

Mr. Craig K. Seaman, Director
Regulatory Affairs
Palo Verde Nuclear Generating Station
Mail Station 7636
P.O. Box 52034
Phoenix, AZ 85072-2034

Mr. Hector R. Puente
Vice President, Power Generation
El Paso Electric Company
310 E. Palm Lane, Suite 310
Phoenix, AZ 85004

Mr. John Taylor
Public Service Company of New Mexico
2401 Aztec NE, MS Z110
Albuquerque, NM 87107-4224

Mr. Thomas D. Champ
Southern California Edison Company
5000 Pacific Coast Hwy Bldg D1B
San Clemente, CA 92672

Mr. Robert Henry
Salt River Project
6504 East Thomas Road
Scottsdale, AZ 85251

Mr. Jeffrey T. Weikert
Assistant General Counsel
El Paso Electric Company
Mail Location 167
123 W. Mills
El Paso, TX 79901

Mr. John Schumann
Los Angeles Department of Water & Power
Southern California Public Power Authority
P.O. Box 51111, Room 1255-C
Los Angeles, CA 90051-0100

Brian Almon
Public Utility Commission
William B. Travis Building
P. O. Box 13326
1701 North Congress Avenue
Austin, TX 78701-3326

Karen O'Regan
Environmental Program Manager
City of Phoenix
Office of Environmental Programs
200 West Washington Street
Phoenix AZ 85003