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102-04700-CDM/SAB/RJR
May 8, 2002

U.S. Nuclear Regulatory Commission
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11555 Rockville Pike
Rockville, MD. 20852

References: (1) Letter 102-04500-CDM/SAB/RKB, "Reactor Vessel Material Surveillance Capsule," dated October 20, 2000 from Mr. Carl D. Mauldin, APS to USNRC.
(2) Letter 102-03340-WLS/SAB/JRP, "Reactor Vessel Material Surveillance Capsule," dated April 26, 1995 from Mr. William L. Stewart, APS to USNRC.
(3) Letter 102-02919-WFC/RAB/JRP, "Reactor Vessel Material Surveillance Capsule," dated April 15, 1994 from Mr. William F. Conway, APS to USNRC.
(4) Letter "Palo Verde Nuclear Generating Station, Units 1, 2, and 3 – Regarding Reactor Vessel Material Surveillance Capsule Reports (TAC No. MB0396)," dated April 27, 2001, from NRC to Mr. G. R. Overbeck, APS.

Dear Sirs:

**Subject: Palo Verde Nuclear Generating Station (PVNGS)
Units 1, 2, and 3
Docket Nos. STN 50-528/529/530
APS' Response to the Information Requested Regarding Reactor Vessel Material Surveillance Capsule Reports**

On May 8, 2001, Arizona Public Service Company (APS) received Reference 4 from the NRC. This letter stated that the NRC staff had reviewed the Reactor Vessel Material Capsule reports transmitted by References 1, 2, and 3. In Reference 4, the NRC indicated that it appeared that the Ferret code had been used to adjust the measured neutron fluence from the analysis of the material surveillance capsules. The NRC also stated that the use of the Ferret code could cause the reported fluence values to be underestimated by as much as 17 percent. Because of this uncertainty, the NRC requested APS to provide the following within one year of the receipt of the letter in reference 4 (May 8, 2001):

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1. The neutron fluence values for the three units based on the capsule reports using an adjustment code that has been approved for this use by the NRC staff,
2. A justification of the use of the Ferret code for adjusting the measured neutron fluence from the material surveillance capsules without underestimating the neutron fluence, or
3. Update the pressure/temperature (P/T) limits for the three units to account for the 17 percent underestimation of the neutron fluence values.

APS has reviewed the information contained in References 1 - 4 and discussed the reported discrepancies with the contract support group that performed the analysis. Through this review, APS has determined that the Ferret code adjustment was not applied to the Unit 1 calculated fluence values. However, because of the known deficiencies in the Evaluated Nuclear Data File Part B, Revision IV (ENDF/B-IV) (used in the Unit 2 and Unit 3 calculations), the ENDF/B-IV calculations were normalized by applying a bias factor to the calculated (not the measured) fluences of Unit 2 and Unit 3. As a result, the use of the FERRET based bias factor increased the calculated fluence for Units 2 and 3.

Although these neutron fluence values were transmitted to APS and reported in References 1 - 3, this information was not used to change any P/T curve. The current PVNGS P/T curves for Units 1, 2, and 3 continue to be based on the initially predicted design basis peak end-of-life fluence value of $3.29E^{19}$ n/cm^2. This predicted fluence value at 32 EFPY is approximately twice the value of the most conservative PVNGS calculated fluence value ($1.64E^{19}$ n/cm^2) identified in WCAP 15589. No new P/T curves are required as a result of the analysis in the WCAP reports.

The enclosure provides clarification of the information requested by Reference 4.

There are no commitments being made to the NRC by this letter. Should you have any questions, please contact Thomas N. Weber at (623) 393-5764.

Sincerely,

GRO/SAB/RJR/kg

Enclosure: APS' Response to the Requested Information

cc:

E. W. Merschoff	(NRC Region IV)
J. N. Donohew	(NRR Project Manager)
J. H. Moorman	(NRC Resident Inspector)

ENCLOSURE

APS' Response to the Requested Information

APS' Response to the Requested Information

This is the Arizona Public Service Company (APS) response to information requested by Nuclear Regulatory Commission (NRC) letter "Palo Verde Nuclear Generating Station, Units 1, 2, and 3 – Regarding Reactor Vessel Material Surveillance Capsule Reports (TAC No. MB0396)," dated April 27, 2001.

Background

The NRC letter dated April 27, 2001, raised questions relative to the use of the least squares adjustment (Ferret code) in the determination of reactor vessel fluence. The scope of the questions encompassed fluence assessments provided by Westinghouse Electric Company, LLC., in WCAP-15589 (Unit 1), WCAP-13935 (Unit 2), and WCAP-14208 (Unit 3). In the interval between the issuance of the WCAPs for Units 2 and 3 and the WCAP for Unit 1, a significant methods upgrade took place in the fluence evaluation methodology. This upgrade was brought about by the release of improved transport cross-section libraries based on the Evaluated Nuclear Data File Part B, Revision VI (ENDF/B-VI) evaluated data files. As a result of this methods improvement, the NRC staff question as it applies to WCAP-15589 will be addressed separately from its application to WCAPs 13935 and 14208.

WCAP 15589 (Unit 1)

The fluence values listed in Table 6-13 of WCAP 15589 were taken directly from the results of benchmarked plant specific neutron transport calculations that were not modified by the results of the surveillance capsule dosimetry evaluations. Direct comparisons of the calculated to measured reaction rates, as well as with the results of the least squares evaluation (FERRET code) of the dosimetry sets, were only used to demonstrate that the measurements and calculations agree within the 20% uncertainty criterion specified in Regulatory Guide (RG) 1.190, "Calculational and Dosimetry Methods for Determining Pressure Vessel Neutron Fluence" (Previous drafts were DG-1053 and DG-1025).

For PVNGS Unit 1, WCAP 15598 calculated fluence values were recommended for use in the reactor vessel integrity assessments. The application of the least squares adjustment procedure (FERRET code) had no impact on the calculated values.

WCAP 13935 (Unit 2) and WCAP 14208 (Unit 3)

For Palo Verde Unit 2 (WCAP 13935) and Unit 3 (WCAP 14208), The neutron fluence evaluations were completed prior to the release of ENDF/B-VI neutron transport cross-sections. Therefore, the calculations included in the dosimetry evaluations documented in these two reports used the transport cross-sections based on the ENDF/B-IV evaluated data files. These ENDF/B-IV cross-sections had known deficiencies in the iron inelastic scattering cross-sections that resulted in a tendency

toward an under-prediction of the calculated fluence that increased with penetration through iron and steel.

As a result of this known tendency toward under-prediction, it was common practice to normalize the ENDF/B-IV calculations to the results of dosimetry evaluations. The ENDF/B-IV calculations were normalized for PVNGS Units 2 and 3 vessel fluence.

In the case of Palo Verde Unit 2, this procedure resulted in a bias factor of 1.07 being applied to the calculated results. In the case of Palo Verde Unit 3, the corresponding bias factor applied to the calculated results was 1.01. These bias factors were obtained by taking the reciprocal of the C/M ratios provided in Table 6-12 of WCAPs-13935 and 14208, respectively.

For Palo Verde Unit 2 and Unit 3, the use of the FERRET code based bias factor resulted in an increase in the calculated fluence. The BE/C ratio of 0.83 observed in the Unit 1 analysis does not apply to the Unit 2 and Unit 3 calculations that were based on ENDF/B-IV cross-sections.

NRC Requested Information:

Provide the neutron fluence values for the three units based on the capsule reports using an adjustment code that has been approved for this use by the NRC staff.

APS Response

The neutron fluence values provided in WCAP 13935, 14208, and 15589 remain valid. The methods used to develop those values are described below.

WCAP-15589 (Unit 1)

In Table 6-13 of WCAP-15589, values of both calculated and best estimate fast neutron (E > 1.0 MeV) fluence are provided. The calculated fluence values extracted from Table 6-13 of WCAP-15589 are summarized as follows:

Table 1: Calculated Fast Neutron (E > 1.0 MeV) Neutron Fluence at the Pressure Vessel Inner Radius - Palo Verde Unit 1

Time (efpy)	Neutron Fluence (E>1.0 MeV) (n/cm^2)				
	0 Deg.	15 Deg.	30 Deg.	42.3 Deg.	45 Deg.
9.81	3.71E+18	4.64E+18	4.75E+18	5.59E+18	5.58E+18
15	5.09E+18	6.37E+18	6.70E+18	8.10E+18	8.10E+18
32	9.60E+18	1.20E+19	1.31E+19	1.63E+19	1.64E+19
40	1.17E+19	1.47E+19	1.61E+19	2.02E+19	2.02E+19
45	1.31E+19	1.63E+19	1.80E+19	2.26E+19	2.27E+19
54	1.55E+19	1.93E+19	2.14E+19	2.70E+19	2.70E+19

These calculated fluence values were recommended for use in all reactor vessel integrity assessments. The application of the least squares adjustment procedure (FERRET code) had no impact on these calculated values.

The fluence values listed in Table 1 were taken directly from the results of benchmarked plant specific neutron transport calculations that were in no way modified by the results of the surveillance capsule dosimetry evaluations. As noted below, direct comparisons of calculated to measured reaction rates, as well as with the results of the least squares evaluation (FERRET code) of the dosimetry sets, were used only to demonstrate that the measurements and calculations agree within the 20% uncertainty criterion specified in RG 1.190.

In WCAP-15589, comparisons of calculated with measured reaction rates were provided on two levels. In the first instance, direct comparisons of calculated and measured sensor reaction rates were made independent of the use of the FERRET code. These comparisons, extracted from Table 6-10 of WCAP-15589, are listed in Table 2.

Table 2: Comparison of Measured and Calculated Sensor Reaction Rates from Palo Verde Unit 1 Surveillance Capsule Dosimetry Sets

	Foil Reaction Rate [rps/a]		
	Meas.	Calc.	M/C
Reaction	Capsule W137		
Cu-63(n,alpha)Co-60	4.39E-17	4.79E-17	0.92
Ti-46(n,p)Sc-46	6.38E-16	7.39E-16	0.86
Fe-54(n,p)Mn-54	3.36E-15	4.10E-15	0.82
Ni-58(n,p)Co-58	4.26E-15	5.33E-15	0.80
	Capsule W38		
Cu-63(n,alpha)Co-60	3.81E-17	4.02E-17	0.95
Ti-46(n,p)Sc-46	4.82E-16	6.20E-16	0.78
Fe-54(n,p)Mn-54	2.62E-15	3.44E-15	0.76
Ni-58(n,p)Co-58	3.62E-15	4.48E-15	0.81
Linear Average			0.84
% Std Dev.			8.0

The comparisons listed in Table 2 show that the average measured to calculated (M/C) ratio for the eight foils from the two surveillance capsules withdrawn to date was 0.84 with an associated standard deviation of 8.0%. The measured results are lower than the calculated values and within the 20% uncertainty criterion specified in RG 1.190.

The second level of comparison for calculated and measured reaction rates involved the results of the least square adjustment procedure (Ferret code). In the least squares approach (FERRET code), the calculated and measured reaction rates are combined

to produce a best estimate of the neutron flux (E > 1.0 MeV) at the measurement locations. The results of the least squares evaluation (FERRET Code) are then compared with the transport calculation results to demonstrate compliance with the 20% acceptance criterion stated in RG 1.190.

The best estimate to calculated (BE/C) fluence comparisons for the dosimetry sets withdrawn from Palo Verde Unit 1 is provided in Table 3. These comparisons were extracted from Table 6-12 of WCAP-15589.

Table 3: Comparison of Best Estimate and Calculated Fast Neutron (E > 1.0 MeV) Fluence from Palo Verde Unit 1 Surveillance Capsule Dosimetry Sets

Neutron Fluence (E > 1.0 MeV) [n/cm^2]				
Capsule	Best Est.	Calc.	BE/C	% Std Dev
W137	3.72E+18	4.33E+18	0.86	7.0
W38	6.32E+18	7.85E+18	0.80	7.0
Average			0.83	7.0

The average BE/C ratio observed for the Palo Verde Unit 1 surveillance capsules withdrawn to date is 0.83 with an associated standard deviation of 7.0%. Again, this comparison demonstrates compliance with the RG 1.190 criterion of 20%. Furthermore, the average BE/C ratio of 0.83 obtained from the least squares adjustment (FERRET code) is in excellent agreement with the average M/C ratio of 0.84 that was obtained by direct comparison of calculated and measured reaction rates. This level of agreement between the two approaches indicates that there is no bias introduced by the application of the FERRET code.

Also provided in Table 6-13 of WCAP-15589 are best estimate values of pressure vessel exposure that were obtained by normalizing the calculated fluence to the results of the least squares evaluations. These results are summarized in Table 4.

Table 4: Best Estimate Fast Neutron (E > 1.0 MeV) Neutron Fluence at the Pressure Vessel Inner Radius - Palo Verde Unit 1

Time	Neutron Fluence (E>1.0 MeV) (n/cm^2)				
(efpy)	0 Deg.	15 Deg.	30 Deg.	42.3 Deg.	45 Deg.
9.81	3.08E+18	3.87E+18	3.96E+18	4.65E+18	4.65E+18
15	4.23E+18	5.30E+18	5.58E+18	6.74E+18	6.74E+18
32	7.99E+18	1.00E+19	1.09E+19	1.36E+19	1.36E+19
40	9.76E+18	1.22E+19	1.34E+19	1.68E+19	1.68E+19
45	1.09E+19	1.36E+19	1.50E+19	1.88E+19	1.89E+19
54	1.29E+19	1.61E+19	1.78E+19	2.24E+19	2.25E+19

The fluence values listed in Table 4 were provided for information and potential future use. They are not currently accepted by the NRC Staff and, therefore, were not recommended for use in reactor vessel integrity assessments.

WCAPs-13935 (Unit 2) and 14208 (Unit 3)

The neutron fluence evaluations provided in WCAPs-13935 and 14208 were completed prior to the release of ENDF/B-VI neutron transport cross-sections. Therefore, the calculations included in the dosimetry evaluations documented in these two reports used the available transport cross-sections based on the ENDF/B-IV evaluated data files. The ENDF/B-IV cross-sections had known deficiencies in the iron inelastic scattering cross-sections that resulted in a tendency toward an underprediction of the calculated fluence which increased with penetration through iron and steel. As a result of this known tendency toward underprediction, it was common practice to normalize the ENDF/B-IV calculations to the results of dosimetry evaluations.

In the case of Palo Verde Unit 2, this procedure resulted in a bias factor of 1.07 being applied to the calculated results. In the case of Palo Verde Unit 3, the corresponding bias factor applied to the calculated results was 1.01. These bias factors were obtained by taking the reciprocal of the C/M ratios provided in Table 6-12 of WCAPs-13935 and 14208, respectively.

For both Palo Verde Unit 2 and Unit 3, the use of the FERRET code based bias factor resulted in an increase in the calculated fluence. The BE/C ratio of 0.83 that was observed in the Unit 1 analysis does not apply to the Unit 2 and Unit 3 calculations that are based on ENDF/B-IV cross-sections.

NRC Requested Information:

Provide a justification of the use of the FERRET code for adjusting the measured neutron fluence from the material surveillance capsules without underestimating the neutron fluence, or provide an update of the pressure/temperature (P/T) limits for the three units to account for the 17 percent underestimation of the neutron fluence values.

APS Response

The FERRET code adjustment was not applied to either the Unit 1 calculated or measured fluence values. However, because of the known deficiencies in ENDF/B-IV (used in the Unit 2 and 3 calculations), the ENDF/B-IV calculations were normalized by applying a bias factor to the calculated (not the measured) fluences of Unit 2 and Unit 3. The use of the FERRET code based bias factor resulted in an increase in the calculated fluence for Units 2 and 3.

The current PVNGS P/T curves for Units 1, 2, and 3 continue to be based on the initially predicted design basis peak-to-peak fluence value of $3.29E^{19}$ n/cm^2. This predicted fluence value at 32 EFPY is approximately twice the value of the most

conservative PVNGS calculated fluence value ($1.64E^{19}$ n/cm^2) identified in WCAP 15589. No new P/T curves are required as a result of the analysis in the WCAP reports.

The fluence updates for Units 2 & 3 will be performed coincident with the next capsule withdrawal for these units, as has been done for Unit 1. These updates will be performed using ENDF/B VI (or the most currently approved method). The current tentative schedule for capsule analysis is provided below and detailed in PVNGS UFSAR Section 5.3.1.6.6, "Withdrawal Schedule."

Unit 2	Capsule 5	12 - 15 EFPY	2R12 spring of 2005
Unit 3	Capsule 5	12 - 15 EFPY	3R11 fall of 2004

References

(1) Letter 102-04500-CDM/SAB/RKB, "Reactor Vessel Material Surveillance Capsule," dated October 20, 2000 from Mr. Carl D. Mauldin, APS to USNRC.
(2) Letter 102-03340-WLS/SAB/JRP, "Reactor Vessel Material Surveillance Capsule," dated April 26, 1995 from Mr. William L. Stewart, APS to USNRC.
(3) Letter 102-02919-WFC/RAB/JRP, "Reactor Vessel Material Surveillance Capsule," dated April 15, 1994 from Mr. William F. Conway, APS to USNRC.
(4) Letter "Palo Verde Nuclear Generating Station, Units 1, 2, and 3 – Regarding Reactor Vessel Material Surveillance Capsule Reports (TAC No. MB0396)," dated April 27, 2001, from NRC to Mr. G. R. Overbeck, APS.
(5) Letter 161-02990-WFC/JST, "Proposed Technical Specification Amendment to Sections 3.4.1.3,.3.4.1.41, 3.4.8.1, 3.4.8.3, 4.4.8.3.1, and B3/4.4.8 to Incorporate Requirements of Generic Letter 88-11 "NRC Position on Radiation Embrittlement of Reactor Vessel Materials and it Impact on Plant Operations," dated March 13, 1990, William F. Conway, APS to NRC.
(6) Letter "Issuance of Amendment No. 52 to Facility Operating License No. NPF-41, Issuance of Amendment No. 38 to Facility Operating License No. NPF-51, Issuance of Amendment No. 24 to Facility Operating License No. NPF-74 for Palo Verde Nuclear Generating Station, Units 1, 2, and 3 (TAC Nos. 71527, 71528, and 71529)," dated July 25, 1990, from NRC to W. F. Conway APS.