APS

Palo Verde Nuclear
Generating Station

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U.S. Nuclear Regulatory Commission
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References: 1) Letter dated June 11, 1999, "Request for Additional Information on Generic Letter 95-07, Pressure Locking and Thermal Binding of Safety-Related Power-Operated Gate Valves," from USNRC, to J. M. Levine, APS

2) Letter 102-04355-CDM, dated October 8, 1999, "Response to Generic Letter 95-07, Request for Additional Information," from C. D. Mauldin, APS, to USNRC

Dear Sirs:

**Subject:** **Palo Verde Nuclear Generating Station (PVNGS)**
**Units 1, 2, and 3**
**Docket Nos. STN 50-528/529/530**
**Supplemental Response to Generic Letter 95-07, Request for Additional Information**
**(TAC Nos. M93497, M93498, M93499)**

In Reference 1, the NRC requested that Arizona Public Service Company (APS) provide additional information for their review of APS' response to Generic Letter 95-07, "Pressure Locking and Thermal Binding of Safety-Related Power-Operated Gate Valves." The requested information was submitted to the NRC in Reference 2. On December 7, 1999, following the review of this information, the need for further information was discussed with the NRC staff. This requested information is provided in the accompanying enclosures.

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No commitments are being made to the NRC by this letter. If you have any questions, please contact Scott A. Bauer at (623) 393-5978.

Sincerely,

David Mauldin

CDM/SAB/JAP/kg

Enclosures

cc: E. W. Merschoff (w/ enclosure 1 only)
M. B. Fields (w/ enclosures)
J. H. Moorman (w/ enclosure 1 only)

# ENCLOSURE 1

# RESPONSE TO GENERIC LETTER 95-07, "PRESSURE LOCKING AND THERMAL BINDING OF SAFETY-RELATED POWER-OPERATED GATE VALVES," REQUEST FOR ADDITIONAL INFORMATION

## OVERVIEW

Following the NRC's review of the Arizona Public Service Company's (APS) October 8, 1999 response to a Request for Additional Information (RAI) for Generic letter 95-07, Pressure Locking and Thermal Binding of Safety-Related Power-Operated Gate Valves, the NRC requested additional clarification of several issues. During the research to provide this clarification some limitations of the Palo Verde Nuclear Generating Station (PVNGS) Pressure Locking (PL) model were identified. The PVNGS PL model calculates the limiting postulated PL loads based on PVNGS design basis conditions. The identified limitations did not affect the identified corrective actions for PVNGS valves but resulted in adjustments to the model and calculated margins. These adjustments resulted in shifting of the load bias in the PVNGS model from the line pressure loads to the residual loads and utilizing a more conservative steady state thermal pressurization rate to ensure long term compliance.

The PVNGS PL model was found not to conservatively predict the PL test results for the 6" 600 lb. Walworth flexible wedge gate valve tested by INEEL (Ref: NUREG/CR-6611). This is primarily attributed to the characteristics of the relatively flexible Walworth valve gate in comparison to the PVNGS Anchor/Darling and Borg-Warner valve gates. Comparisons of the PVNGS PL model to the more rigid 10" 900 lb. Crane and 4" 2500 lb. Westinghouse flexible wedge gate valve Commonwealth Edison PL test results found the PVNGS model to conservatively predict these PL loads. It was determined that the Crane flexible wedge gate valve test results were more comparable to the relatively rigid PVNGS Anchor/Darling and Borg-Warner gate valves. This was attributed to the valve gate stiffness as determined by the combined stiffness contribution of the disk thickness and the hub-to-seat diameter ratio. This analysis indicates that the PVNGS PL model should be restricted to the PVNGS Anchor/Darling and Borg-Warner flexible wedge gate valves since the PL model is sensitive to the gate disk and hub dimensions in the analyzed PVNGS design basis pressure and temperature ranges.

The review of these additional test results confirmed that maintenance of an appropriate margin between actuator capacity and the PVNGS PL model calculated required thrust is prudent to account for model uncertainties. In addition, static peak cracking design limits are established and appropriate instrument errors are applied to these design limits to ensure that residual seating loads combined with postulated PL loads do not exceed actuator capability. The adjustments to the PVNGS PL model did not result in any significant non-conservative changes to the calculated margins.

This enclosure provides the response to the three specific items that the NRC requested as a follow-up to the PVNGS letter dated October 8, 1999, "Response to Generic Letter 95-07, Request for Additional Information" (APS Letter 102-04355-CDM). These specific items are summarized and addressed below.

## ITEM 1:

- It appears for certain conditions that the PVNGS PL model loads trend opposite to test results. A review of the data for the PVNGS PL model applied to the INEEL test results found data points where the calculated PL loads increased as the differential pressure between the piping and bonnet decreased. (Ref: Calculation 13-MC-ZZ-217, Rev. 2, Attachment 6)

## APS RESPONSE:

### PVNGS PRESSURE LOCKING MODEL DP LOAD TREND

APS re-evaluated the PVNGS PL model, specifically the relationships between the calculated PL load and the differential pressure between the average line pressure and the bonnet pressure. APS found that the PVNGS PL model was biased such that the term used to calculate the effect of the difference between upstream and downstream line pressures tended to overpredict these loads referred to as hub loads. This was most noticeable for valves where the ratio of the hub radius to disk seat radius approached one. Therefore, an adjustment was made to the method of calculating the hub load that better accounts for the distribution of loads between the upstream and downstream seats. In addition an offsetting adjustment to the residual loads was made where a slightly higher residual load is expected to contribute to the total PL loads. The revised loading components are described below. All other PVNGS PL model loading components continued to be calculated as described in PVNGS response dated October 8, 1999 to Generic Letter 95-07 Request for Additional Information (APS Letter 102-04355-CDM). APS has revised the PVNGS PL model calculation 13-MC-ZZ-217, Rev. 3 (Enclosure 2) to reflect this adjustment in the model.

### ADJUSTED HUB LOAD

The hub load accounts for the additional load at the valve stem due to increased friction at the interface of the valve gate and valve body seats as a result of the differential pressure between the upstream and downstream piping. The calculation of this component loading utilizes the 40%/60% reaction load distribution between the upstream and downstream surfaces that was established by testing and presented for the Electric Power Research Institute (EPRI) Motor Operated Valve (MOV) Performance Prediction Model (PPM) Program (Ref: EPRI TR-103237, November 1994; page 5-11).

The hub load ($F_{hub}$) can be expressed as:

$$(F_{hub}) = (Q_{ad} + Q_{au}) * P_L * \mu$$

where:

$\underline{Q_{ad}}$ is the equivalent force/inch due to the unbalanced piping pressure load exerted at the perimeter of the downstream valve disk. The unbalanced piping pressure load is proportional to the difference between 60% of the upstream pressure ($0.6P_{up}$) and 40% of the downstream pressure ($0.4P_{down}$). This bending force is modeled at the valve seat of the downstream disk. The term is developed from Roark's model of a thin flat circular homogeneous plate with the outer edge simply supported and the inner edge guided (Ref: Roark's Formulas for Stress and Strain, 1989; page 400) and EPRI PPM test data. This term is proportional to the differential pressure between 60% of the upstream pressure ($0.6P_{up}$) and 40% of the downstream pressure ($0.4P_{down}$) and to the seat radius.

$\underline{Q_{au}}$ is the equivalent force/inch due to the unbalanced piping pressure load exerted at the perimeter of the upstream valve disk. The unbalanced piping pressure load is proportional to the difference between 60% of the downstream pressure ($0.6P_{down}$) and 40% of the upstream pressure ($0.4P_{up}$). This bending force is modeled at the valve seat of the upstream disk. The term is developed from Roark's model of a thin flat circular homogeneous plate with the outer edge simply supported and the inner edge guided (Ref: Roark's Formulas for Stress and Strain, 1989; page 400) and EPRI PPM test data. This term is proportional to the differential pressure between 60% of the downstream pressure ($0.6\ P_{down}$) and 40% of the upstream pressure ($0.4\ P_{up}$) and to the seat radius.

$\underline{P_L}$ is the circumference of the disk seat. This term is equal to twice the value of Pi ($\pi$) times the mean radius of the valve disk seat (a).

$\underline{\mu}$ is the coefficient of friction at the valve seat. This term is proportional to the valve factor (VF) and the cosine of the seat angle ($\theta$) and inversely proportional to 1 minus the valve factor (VF) times the sine of the seat angle ($\theta$). This derivation was developed from the equations for differential pressure load presented in EPRI's Application Guide for Motor-Operated Valves in Nuclear Power Plants (Ref: EPRI NP-6660-D 1990; pages 5-11 & 5-22). The values used for the valve factors are based on test results.

## ADJUSTED RESIDUAL LOAD

The residual load ($F_{resid}$) is the load opposing valve opening caused by wedging the valve disk into the seat by the thrust of the prior closing valve stroke. The residual load ($F_{resid}$) accounts for the relaxation in the wedging load which occurs when stem motion is initiated in the open direction. This load is modeled as being replaced by increasing proportions of the bonnet pressure induced loads. This relationship has been determined from an analysis of the Commonwealth Edison test results. The residual load is calculated by taking the established static peak cracking load and multiplying it by an empirically derived residual load factor. The residual load factor is a function of the ratio of bonnet pressure load to the effective closing load. The effective closing load is determined by dividing the established static peak cracking by 0.67 to account for 33% static wedging load relaxation. This method for accounting for relaxation is similar to the unwedging load coefficient utilized in the Electric Power research Institute (EPRI) Motor Operated Valve (MOV) Performance Prediction model (PPM) Program (Ref: EPRI TR-103237, November 1994; page 5-11). A Dimensional Correlation term is multiplied by a coefficient, which represents the observed linear rate at which the residual load percentage decreases as the ratio of the bonnet pressure and effective closing thrust is increased. The resulting equations are presented below.

The residual load ($F_{resid}$) can be expressed as:

$(F_{resid}) = SPC * F_{rspc}$

where:

<u>SPC</u> is the Static Peak Cracking, which is the pullout force with no line pressure and bonnet pressure effects. This is conservatively estimated as 67% of the prior closing force. It is adjusted for instrument error and established as a field setpoint limit to be verified when valve setpoints are checked.

$\underline{F_{rspc}}$ is the Fractional Residual Load of Static Peak Cracking. It is an empirically derived factor that accounts for the replacement by bonnet pressure load at increasing ratios of bonnet pressure loads to effective closing loads. This term is developed from the following equation:

$(F_{rspc}) = 1\text{-}0.15(DC_{resid})$

$\underline{DC_{resid}}$ is the Dimensional Correlation factor of residual load and is an empirically derived coefficient that accounts for an observed reduction in the measured residual load due to a proportional replacement by the effect of the bonnet pressure ($P_B$) induced force. It is proportional to the ratio of bonnet pressure loads to effective closing loads. The -0.15 coefficient represents the slope of the bounding line of decreasing residual load components as a function of the ratio of bonnet pressure loads to prior effective closing force ($F_{eff.closing}$).

$\underline{F_{eff.closing}}$ is the effective closing force that is proportional to the instrument error adjusted static peak cracking limit divided by an EPRI established constant of 0.67 that is a function of the valve seat angle ($\theta$) to account for relaxation. The static peak cracking is the required opening force with zero line pressure ($P_{up} = P_{down} = 0$) and zero bonnet pressure ($P_B = 0$). The static peak cracking is sometimes identified as static unwedging thrust or static unseating force.

**ITEM 2:**

- The thermal pressurization rate used in the PVNGS PL model appears nonconservative compared to the theoretical and steady state pressurization rate identified in the INEEL test results. It can not be verified that all field conditions will result in entrained air that is attributed to initial lower thermal pressurization rates at the start of the heatup of trapped bonnet fluid.

## APS RESPONSE:

### PVNGS PRESSURE LOCKING THERMAL PRESSURIZATION MODEL

All but one set of valves in each unit that are subject to thermal pressurization conditions have been modified to provide bonnet pressure relief devices. For these modified valves thermal pressurization rates are not an issue since the relief devices will relieve at the specified setpoint of the relief devices regardless of the time it takes for the bonnet pressure to reach that point. However, PVNGS motor operated valves SI-604/609, HPSI Hot Leg Injection valves, which are required to open to establish long term cooling, were evaluated to have acceptable capability when compared to the required loads derived from the adjusted PVNGS PL model. Modifications of these valves to provide bonnet relief devices were not required. Based on the NRC concerns about utilization of the lower pressurization rates for long term compliance, APS has re-evaluated the loads on these valves utilizing the more conservative steady state pressurization rates identified in the INEEL test. These valves still were found to have enough capacity to overcome the increased pressurization rates and resulting loads. APS has revised the PVNGS PL model calculation 13-MC-ZZ-217, Rev. 3, to utilize the higher INEEL steady state pressurization rate of 50 psig/°F throughout the analysis.

**ITEM 3:**

- The PVNGS PL model was validated utilizing the Commonwealth Edison 10" 300 lb. Borg-Warner gate valve PL test results. This test valve was not subject to simultaneous line and bonnet pressures. The INEEL Walworth 6" 600 lb. test gate valve results were found not to be consistent with the Borg-Warner test results due to the more flexible disk dimensions of the Walworth valves. Therefore, the NRC requested that the PVNGS PL model be compared to the test results of a more rigid valve, like the Commonwealth Edison Crane or Westinghouse valve, that was subject to PL tests with line pressure.

## APS RESPONSE:

### PVNGS PRESSURE LOCKING MODEL COMPARISON WITH CRANE/WESTINGHOUSE FLEXIBLE WEDGE GATE VALVE TEST RESULTS

APS compared PVNGS PL model results to both the 10" 900 lb. Crane and 4" 2500 lb. Westinghouse flexible wedge gate valve Commonwealth Edison test results. These test results were found in Commonwealth Edison letter dated May 24, 1996 (Ref: ADOCK 05000237). The PVNGS model predicted PL loads that were increasingly conservative for increasing values of bonnet pressure. Attachment 6 of PVNGS PL calculation 13-MC-ZZ-217, Rev. 3 (Enclosure 2), was updated to include the comparison with the 10" 900 lb. Crane valve. The Crane valve test comparison is presented since these results are deemed to be more representative, since the valve dimensional characteristics more closely resemble the PVNGS Anchor/Darling and Borg-Warner valves and these test results were obtained with line pressure.