Attachment 2

Westinghouse Calculation CN-MRCDA-15-13-NP, Rev. 0, *Qualification of Palo Verde Unit 3 Reactor Coolant Pump Replacement Instrumentation Nozzle*

WESTINGHOUSE ELECTRIC COMPANY LLC

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Title: Qualification of Palo Verde Unit 3 Reactor Coolant Pump Replacement Instrumentation Nozzle

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0	See EDMS	This –NP version adds proprietary brackets and the proprietary information has been redacted.

Table of Contents

List of Tables

List of Figures

1.0 Background and Purpose

During the 3R18 spring 2015 refueling outage at Palo Verde Nuclear Generating Station (PVNGS) Unit 3, visual examinations of the reactor coolant pump 2A (RCP) suction safe end revealed evidence of leakage in the annulus between the outer surface of the Inconel 600 instrument nozzle and the bore on the suction safe end. The most likely location of the flaw(s) is in the primary water stress corrosion cracking-susceptible Alloy 82/182 weld and Inconel 600 instrument nozzle, along their fusion line inside the safe end bore. The Alloy 600 instrument nozzle is attached with a partial penetration weld to the inside of the RCP 2A suction safe end.

The purpose of this calculation note is to qualify the structural integrity of the instrumentation nozzle repair (including the attachment weld), per Section III of the ASME Code [6], for one fuel cycle (18 months). The half-nozzle replacement technique will be used, as shown in [3]. The existing nozzle will be removed and bored into to insert a replacement nozzle, as shown in [3]. The new nozzle will be attached to the RCP safe end with a J-groove weld with fillet weld buildup. This replacement half-nozzle and attachment weld will become the new pressure boundary on the outer surface of the RCP suction safe end. Figure 1-1 shows the layout of the new nozzle design.

The Palo Verde Unit 3 nozzle will be qualified by a comparison of the nozzle loading criteria and reconciliation of the applied transients with the PLANT X loadings. PLANT X is a Combustion Engineering-designed plant that is similar in design to Palo Verde Unit 3 and is appropriate for comparison. Where differences between the plants exist, they are noted and dispositioned herein.

A flaw evaluation of the original weld will be documented in a separate calculation note.

This calculation note was created and verified in accordance with Westinghouse Level II Procedures WEC 3.2.6 and WEC 3.3.3, as well as Level III Procedure ES 3.2.1.

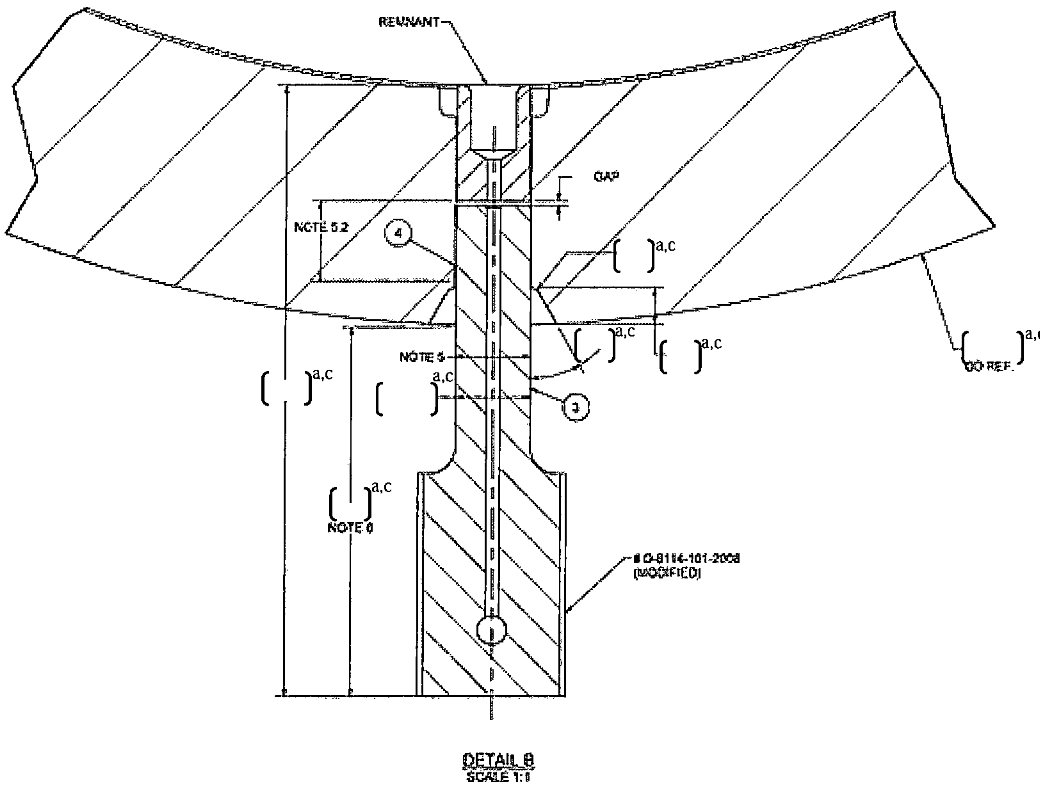

Figure 1-1: Replacement Instrumentation Nozzle Layout

2.0 Summary of Results and Conclusions

The evaluations in this calculation note show that the instrumentation replacement half-nozzle and new attachment weld meet all of applicable criteria of the ASME Code [6].

2.1 Instrumentation Replacement Half-nozzle

The replacement instrumentation nozzle was qualified by comparison to the equivalent analysis of the PLANT X instrumentation nozzle [1]. The instrumentation nozzle qualification in [1] considered all applicable nozzle loadings, including transient pressure and temperature secondary stresses.

Table 5-4 summarizes the worst-case primary stresses in the instrumentation replacement half-nozzle. All nozzle stresses are significantly below the allowable ASME Code values.

2.2 Attachment Weld Sizing and Qualification

The J-groove attachment weld was designed in accordance with Section NB-3351.4 of the ASME Code [6]. It meets or exceeds all of the sizing requirements shown in Figure NB-4244(d)-1(c). The weld was qualified under the assumption that the nozzle hole will increase in size due to corrosion over time. The weld was qualified for the resulting weld throat if the nozzle hole reaches a diameter of [ ]^{a,c} inches.

The J-groove attachment weld was structurally qualified by considering all applicable loading on the weld, which is now on the exterior surface of the RCP suction safe end. As shown in Section 5.4.2, the maximum stress intensity in the weld is [ ]^{a,c} ksi for normal operating conditions with operating basis earthquake (OBE), which is below the allowable normal operating stress of 17.0 ksi. Also shown in in Section 5.4.2, the maximum stress intensity for faulted conditions is [ ]^{a,c} ksi, which is below the faulted allowable stress of 40.8 ksi.

2.3 Fatigue Usage

The replacement instrumentation nozzle and attachment weld were qualified by comparison to the fatigue analysis in [1]. The maximum fatigue usage in [1] was [ ]^{a,c}, which is well below the allowable usage of 1.0. Based on the comparison of plant parameters and nozzle loading, the PLANT X analysis in [1] is applicable to the Palo Verde Unit 3 instrumentation nozzle and attachment weld. Additionally, the PLANT X instrumentation nozzle was designed for the full operating life of the plant, while the Palo Verde Unit 3 instrumentation replacement nozzle and weld need only be qualified for 18 months of operation. Therefore, the fatigue usage meets the ASME Code allowable.

2.4 Vibration Assessment

An evaluation of the replacement nozzle and attached Class 2 piping has confirmed that there is no concern for resonant vibration of the replacement nozzle, weld, or attached piping. The lowest natural frequency of the Class 2 piping line with the replacement nozzle is [ ]^{a,c} Hz.

3.0 References

1. Westinghouse Calculation Note, CN-NPE-06-XXXX-03, Rev. 1, "- Structural Evaluations of the RCP Pressure Tap Nozzles," April 16, 2015.
2. Westinghouse Drawing, 8130-102-2001, Rev. 05, "Pump Casing – 'A'."
3. Westinghouse Drawing, E-14473-220-001, Rev. 0, "Pump Casing – A Pressure Tap Nozzle Modification Assembly."
4. Westinghouse Drawing, C-14473-220-002, Rev. 0, "Replacement Pressure Tap Nozzle."
5. Westinghouse Drawing, E-8111-101-2002, Rev. 00, "Pump Casing - A."
6. ASME Boiler and Pressure Vessel Code, Section III, Nuclear Power Plant Components, 1974 Edition with No Addenda.
7. Westinghouse Letter, LTR-ME-15-30, Rev. 2, "ASME Code Section XI Reconciliation for Arizona Public Service (APS), Palo Verde Nuclear Generating Station (PVNGS) Unit 3 Replacement Instrumentation Nozzle," April 16, 2015.
8. Westinghouse Design Specification, 14273-PE-480, Rev. 06, "Project Specification for Reactor Coolant Pumps for Arizona Nuclear Power Projects Units 1, 2 and 3," November 11, 2003.
9. Westinghouse Design Specification, 14273-PE-140, Rev. 15, "Project Specification for Reactor Coolant Piping and Fittings for Arizona Nuclear Power Project," June 25, 2007.
10. Combustion Engineering Design Specification, 00000-PE-140, Rev. 04, "General Specification for Reactor Coolant Pipe and Fittings," May 25, 1977.
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12. Combustion Engineering Design Specification, SYS80-PE-480, Rev. 02, "Specification for Standard Plant for Reactor Coolant Pumps," May 10, 1978.
13. Westinghouse Calculation Note, CN-CI-03-53, Rev. 2, "Seismic Analysis of the Reactor Coolant System for PVNGS Units 1, 2 and 3 with RSG and Power Uprate," December 14, 2004.
14. Palo Verde Nuclear Generating Station Document, 13-MC-RC-503, Rev. 9, "RCS – RCP Pressure Differential System," October 22, 2010.
15. Palo Verde Nuclear Generating Station Document, 13-P-ZZG-0012, Rev. 48, "Piping Material Classification," September 11, 2014.
16. BW/IP International, Inc. Drawing, 77540, Rev. N, "Valve Assy ¾ In. Type 1586 Lb. Globe S.W. Cres."
17. Palo Verde Nuclear Generating Station Drawing, 03-P-RCF-149, Rev. 2, "Containment Building Isometric Reactor Coolant System RCP Pressure Differential System."

18. Palo Verde Nuclear Generating Station Document, 13-PN-0204, Rev. 21, "Fabrication and Installation of Nuclear Piping Systems for the Arizona Public Company Palo Verde Nuclear Generating Station Unit 1, 2 and 3," May 2, 2014.

19. Bechtel Power Corporation Drawing, 13-RC-075-H00A, Rev. 1, "Pipe Support Assembly."

20. Westinghouse Calculation Note, CN-CI-03-55, Rev. 0, "Branch Line Pipe Break Analysis for PVNGS Units 1, 2 and 3 with RSGs and Power Uprate," October 17, 2003.

21. Westinghouse Calculation Note, V-ME-C-085, Rev. 006, "Branch Line Pipe Break Analysis for PVNGS with Replacement Steam Generator," October 4, 2000.

22. Westinghouse Letter, LTR-SST-10-58, Rev. 2, "ANSYS 12.1 Release Letter," October 2, 2012.

23. American National Standard, ANSI B16.11 - 1973, "Forged Steel Fittings, Socket-Welding and Threaded," 1973.

24. CE-KSB Pump Co. Inc Drawing, C-8000-101-2017, Rev. 02, "Wall Static Pressure Nozzle Suction." (See Appendix C.)

25. Palo Verde Nuclear Generating Station Units 1, 2, and 3 Update Final Safety Analysis Report, Rev. 17B, January 2015.

26. Westinghouse Letter, LTR-SST-13-12, Rev. 0, "Software Release Letter for PIPESTRESS 3.7.0 (included in the PepS 4.0 Package) for the Windows 7 System State," November 8, 2013.

27. ASME Boiler and Pressure Vessel Code, Section III, Division 1, 1974 Edition Up to and Including 1975 Winter Addenda.

28. ASME Boiler and Pressure Vessel Code, Section III, Division 1, 1998 Edition Up to and Including 2000 Addenda.

29. NUS Corporation Design Report, NUS-2058, Rev. 02, "System 80 Reactor Coolant Pump Design Analysis Design, Upset, and Emergency Conditions," October 29, 1979.

30. Email from Douglas Berg (APS) to Sarah E. Lax (Westinghouse) and James P. Burke (Westinghouse), "Support 3RC075H00A," April 15, 2015. (See Appendix C.)

4.0 Calculations

4.1 Limits of Applicability

The results of this calculation note are only applicable to the loop 2A RCP at Palo Verde Unit 3. The replacement nozzle and attachment weld are qualified for 18 months of plant life.

4.2 Open Items

This calculation note contains no open items.

4.3 Method Discussion

The purpose of this calculation note is to qualify the instrumentation replacement nozzle and the replacement attachment weld. The nozzle and weld are qualified by comparison to the similar analysis of the PLANT X RCP pressure tap nozzle evaluations [1], except for the primary stresses in the attachment weld. The primary stresses in the weld are calculated by a closed-form solution.

PLANT X is a Combustion Engineering-designed plant that is similar in design to Palo Verde Unit 3 and is appropriate for comparison. Where differences between the plants exist, they are noted and dispositioned herein.

4.3.1 Instrumentation Nozzle Qualification

The instrumentation nozzle at PLANT X is nearly identical to the replacement nozzle at Palo Verde Unit 3. To apply the nozzle qualification from PLANT X to the Palo Verde Unit 3 nozzle, the following items are must be reconciled:

- instrumentation nozzle geometry
- instrumentation nozzle mechanical loads
- RCP temperature and pressure transients
- RCP seismic spectra and branch line pipe break (BLPB). Note that BLPB is equivalent to a loss of coolant accident, the term BLPB will be used herein.
- ASME Code year and material properties

4.3.2 Attachment Weld Qualification

The attachment weld is also qualified by comparison to the analysis in [1]. However, the attachment weld for the Palo Verde Unit 3 replacement nozzle is in a different location than the PLANT X nozzle. Figure 4-1 shows the location of each weld.

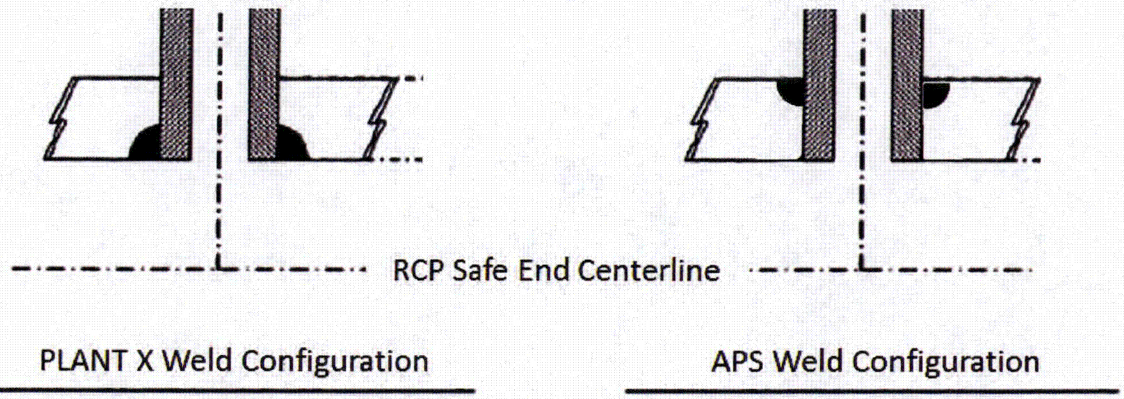


Figure 4-1: PLANT X and Palo Verde Unit 3 Instrumentation Nozzle Layout

The Palo Verde Unit 3 half-nozzle repair weld is a partial penetration weld on the outside surface of the RCP suction safe end. However, the PLANT X attachment weld is on the inside surface of the RCP suction safe end. Therefore, the mechanical loading on the weld will be different. A full evaluation of the weld primary stresses due to mechanical loads is included in this calculation note. The effects of transient stresses on the weld are reconciled with the PLANT X evaluation [1]. Because the Palo Verde Unit 3 nozzle weld is on the outside surface of the RCP nozzle, the impact of the thermal and pressure transient loads will be less significant than those on the PLANT X attachment weld.

The mechanical loads considered in the structural evaluation of the Palo Verde Unit 3 instrumentation nozzle weld are:

1. Instrumentation Nozzle Mechanical Loads

   The applied mechanical loads are in the global plant coordinate system. See Section 4.6 for a description of the nozzle load inputs. These loads are converted into four components (with respect to the instrumentation nozzle): nozzle axial force, shear force, bending moment, and torsion.

2. Pressure Stresses Imparted on Weld from RCP Suction Safe End: Hoop, Axial, and Radial Suction Safe End Stresses

   The radial stress at the location of the attachment weld will be negligible. Therefore, the maximum hoop and axial stress are applied directly to the weld. Hoop and axial stresses are calculated for a thin-walled cylinder according to Equations 1 and 2.

$$\sigma_{hoop} = \frac{PR}{t_{wall}} \quad \textbf{Equation 1}$$

$$\sigma_{axial} = \frac{PR}{2\,t_{wall}} \quad \textbf{Equation 2}$$

In Equations 1 and 2:

P = design pressure (psi)

R = suction safe end radius (in)

t_{wall} = suction nozzle thickness

3. Mechanical Loads Imparted on Weld from RCP Suction Safe End

   Stresses are calculated in the RCP safe end due to applied piping loads. The maximum axial stress is then added to the axial pressure stress discussed in item 2. Shear and torsional piping loads on the RCP safe end do not impact the attachment weld.

4. Blow-off (Thrust) Pressure Load on Instrumentation Nozzle

   The blow-off pressure is calculated as the force acting on the instrumentation nozzle from the internal RCP pressure projected onto the nozzle.

5. Inertial Seismic and BLPB Load on Instrumentation Nozzle

   The replacement instrumentation nozzle and attached Class 2 piping are evaluated to determine the natural frequency of the system (see Appendix B). This frequency is compared against the mechanical excitation frequency of the pump to ensure that the nozzle and piping will not have resonant vibration problems. The natural frequency is then compared to the seismic and BLPB spectra at the RCP to determine the inertial seismic and BLPB loads. These loads are added to the nozzle mechanical loads.

Figure 4-2 shows the layout of the attachment weld, marked up from the replacement plan drawing [3]. The attachment weld is a J-groove weld with additional fillet weld buildup. However, only the groove weld depth is considered in the structural qualification of the weld. Each of the stresses discussed above will be combined to calculate the overall stress intensity in the weld. See Section 5.0 for details.

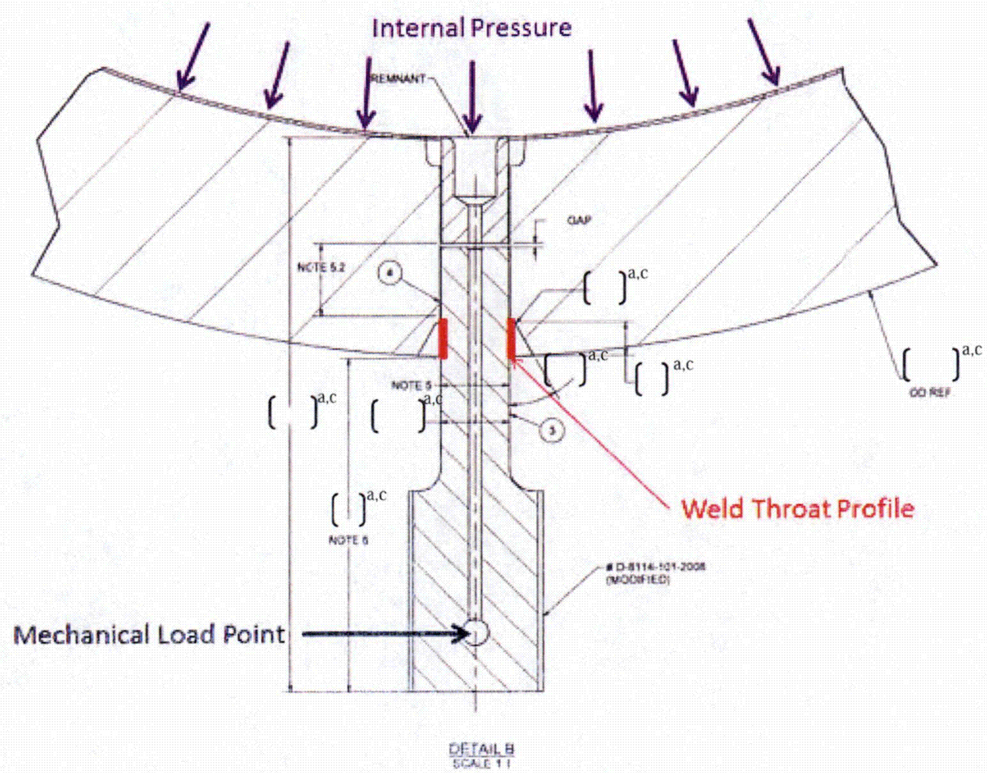


Figure 4-2: Attachment Weld Layout

In addition to the structural qualification of the attachment weld, it is also shown to meet design-by rules per the applicable section of [6]. See Section 4.5 of this document for details.

4.4 Discussion of Significant Assumptions

There are no significant assumptions in this calculation note.

4.5 Acceptance Criteria

The ASME Code applicable to the qualification of the replacement instrumentation nozzle and attachment weld is the 1974 Edition with no Addenda. Reference [7] reconciles the use of the newly procured replacement material for evaluation to the 1974 Edition. Reference [7] also addresses the differences between the 1974 Code year and the 1995 Edition with 1997 Addenda, which was used for the PLANT X evaluation [1].

4.5.1 Instrumentation Nozzle Qualification

The acceptance criteria for the instrumentation nozzle listed in [1] are applicable to this calculation note. Per the reconciliation in [7], all allowable stresses are equivalent between the 1974 Code year (used for Palo Verde Unit 3) and the 1995 with 1997 Addenda Code year (used for PLANT X). Therefore, the allowable stress criteria used in PLANT X are applicable to this calculation note.

4.5.2 Attachment Weld Qualification

4.5.2.1 Structural Analysis

The acceptance criteria for the attachment weld are twofold. First, the maximum stress intensity calculated as described in Section 4.3.2 is compared to the primary stress allowable per NB-3221.1. To conservatively evaluate the weld material, the limiting S_m value between the RCP suction safe end and the replacement nozzle is used. The applicable S_m values for the two materials are summarized in Table 4-1. The minimum S_m value used for qualification of the weld stress intensity is 17.0 ksi.

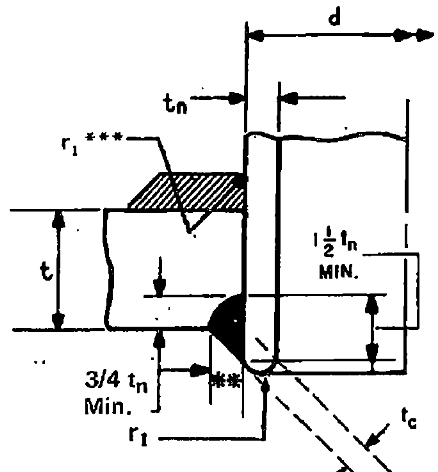
Table 4-1: Weld Qualification Material Properties per [6]

Part	Material	S_m (ksi) at [ ]^{a,c} °F
RCP Suction Safe End	SA-508 Class 1[29]	17.0
RCP Instrumentation Nozzle	SB-166 (Alloy 690) [4]	23.3

4.5.2.2 Design-by Rules Analysis

Attachment Weld

The second acceptance criterion for the instrumentation nozzle attachment weld is qualification of the design-by rules for the attachment weld sizing. Per Section NB-3351.4, this is a Category D weld meeting the requirements of Section NB-4244(d) for attachment of nozzles using partial penetration welds. Therefore, Figure NB-4244(d)-1, applies to this type of attachment weld. Section (c) of Figure NB-4244(d)-1 is the most applicable to this design, as shown here in Figure 4-3.



(c)*

**THE ¾ t_n MIN. DIMENSION APPLIES TO THE FILLET LEG AND THE J GROOVE DEPTH
*** IF WELD DEPOSIT REINFORCEMENT IS NOT USED, r_1 SHALL APPLY TO BASE MATERIAL INSTEAD OF WELD BUILD UP.

FIG. NB-4244(d)-1 PARTIAL PENETRATION NOZZLE, BRANCH, AND PIPING CONNECTIONS

Figure 4-3: Attachment Weld Design Requirements [6]

The requirement for the size of the weld is that the groove depth be at least $3/4t_n$, where t_n is the nozzle body thickness. Per [4], t_n is equal to [ ]^{a,c} inches [ ]^{a,c}. The minimum required depth is then 3/4 x [ ]^{a,c} inches = [ ]^{a,c} inches. The design weld depth of 1/2 inch shown on [3] is greater than the required [ ]^{a,c} inches. The $3/4t_n$ requirement also applies to the width of the fillet weld leg, as shown above. The fillet weld length calculated from [3] is [ ]^{a,c} inches (considering the [ ]^{a,c} angle and the [ ]^{a,c}-inch radius). This also meets the $3/4t_n$ requirement.

Figure NB-4244(d)-1, (c) also requires that the total weld size of the groove depth plus fillet leg height be a minimum of $1.5t_n$. The full weld size shown on [3] is 3/4 inches, which is greater than the required [ ]^{a,c} inches ([ ]^{a,c} inches = [ ]^{a,c} inches).

Socket Weld

The Class 2 socket weld connecting the instrumentation nozzle to the downstream piping is qualified by designing the socket weld according to Section NC-3661.2 of [6]. Because the weld is sized according to design-by rules, it is qualified within the qualification of the existing Class 2 piping.

Section NC-3661.2 of [6] references Figure NC-4427-1, which calls for a fillet weld leg size of 1.09 times the piping thickness. However, Arizona Public Service (APS) has requested that the socket weld be designed in accordance with [18] using a 2:1 ratio. Using this ratio, the minimum fillet weld leg is 1.09 times the piping thickness on the shorter leg and 2.18 times the thickness along the pipe axis. This layout is shown in Figure 4-4.

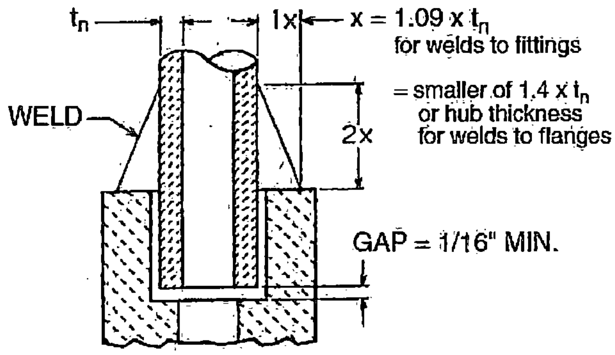


Figure 4-4: Socket Weld Design Criteria

The attached Class 2 piping is [ ]^{a,c} (see Appendix B). Therefore, the thickness of the pipe is [ ]^{a,c} inches. The minimum fillet leg sizes are [ ]^{a,c} inches and [ ]^{a,c} inches. The fillet sizing of 0.25 inches and 0.50 inches shown in [5] exceed this requirement.

Section NC-3661.2 of [6] cites the ANSI Standard B16.11 [23]. However, the dimensional information in B16.11 is not a requirement, as discussed in Section 1.2 of [23]. All dimensions related to the design of the fitting (bore depth, diameter, etc.) have been designed on the replacement instrumentation nozzle to match the original design [24].

4.6 Input

4.6.1 Seismic and BLPB Response Spectra

The applicable RCP OBE spectra are included on pages C-107 through C-109 of [13]. The safe shutdown earthquake (SSE) spectra are included on pages C-281 through C-283 of [13].

The BLPB spectra for this analysis have been developed, as discussed in Appendix A.

4.6.2 Nozzle Mechanical Loads

The nozzle mechanical loads were supplied by APS for evaluation of the replacement pressure instrumentation nozzle, as shown in [14]. These loads are in the plant global coordinate system, where X is south, Y is vertical up, and Z is west. The nozzle mechanical loads are summarized in Table 4-2. The nozzle mechanical loads must be converted to the coordinate system of the instrumentation nozzle for evaluation. Per [17], the nozzle is in the horizontal plane, with its longitudinal axis offset 38.67° from the global x-axis.

Table 4-2: Nozzle Mechanical Loads [14]

Global Load [14]	Normal (lbs, ft-lbs)	Faulted (lbs, ft-lbs)
Fx		
Fy		
Fz		
Mx		
My		
Mz		

a,c

4.6.3 RCP Safe End Applied Loads

The RCP safe end applied loads are listed in the Palo Verde piping specification [9]. The pipe section of interest is the P-13 connection steam generator 2 to pump 2A. The piping loads are taken from the loads for P-4 at point B according to the sign convention shown on Figure 8, Sheet 8 of [9] for P-13. These loads are summarized in Table 4-3.

Table 4-3: RCP Safe End Applied Loads [9](1)

Direction	Piping NO1(2)	Piping NO2(2)	Piping NO3(2)	Piping NO4(2)	Piping NO5(2)
Fx (kips)					
Fy (kips)					
Fz (kips)					
Mx (ft-kips)					
My (ft-kips)					
Mz (ft-kips)					

a,c

Note:

(1) [

]a,c

(2) Load cases piping N01 through N05 represent various normal operating load conditions combining the effects of deadweight, thermal (with and without friction during heatup), cooldown, and full power conditions as defined in [9].

4.6.4 Pressure and Thermal Transients

The Palo Verde Unit 3 pressure and thermal transients for the RCP are listed in the generic System 80 specification [12]. The RCP specification [8] points to reference [11], which states that the original spectra are applicable for all three units at Palo Verde. The original spectra for the RCP are documented in the generic System 80 specification [12].

The Palo Verde Unit 3 pressure and thermal transient are taken from [12].

The design pressure for Palo Verde Unit 3 is [ ]^{a,c} psi [12].

4.6.5 Geometry

The following drawings are used as input to this calculation note:

- [4] – replacement nozzle geometry and material
- [3] – replacement nozzle attachment weld layout
- [5] – RCP suction safe end sizing

The replacement instrumentation nozzle for Palo Verde Unit 3 is identical to the PLANT X [1] nozzle, except that it is slightly shorter to account for the remnant piece of the original nozzle.

4.6.6 Material Properties

Table 4-4 summarizes the material properties for the replacement half-nozzle and RCP safe end. These properties are taken from the applicable ASME Code year [6], at an operating temperature of [ ]^{a,c} °F .

Table 4-4: Half-nozzle Replacement Material Strength Properties(2)

Material	S_m (ksi)	S_u (ksi)
SB-166 Alloy 690	23.3	70.0(1)
SA-508 Class 1	17.0	N/A – not needed

Note:

(1) Material data for S_u was in development in the 1974 ASME Code year. The S_m value between the 1974 Code year and the PLANT X analysis (to a later Code year) is the same. Therefore, the S_u value of 70 ksi from the PLANT X analysis [1] is used herein. There is sufficient margin in the stress calculations to justify this value of S_u.

(2) The strength of the attachment weld is based on the minimum of the material strengths for the RCP safe end and the replacement instrumentation nozzle. This is a conservative approach for the strength of the weld.

5.0 Evaluations, Analysis, Detailed Calculations, and Results

5.1 Comparison of Palo Verde Unit 3 Transients to PLANT X Analysis Transients

Computer run 1 shows a detailed comparison of each required Palo Verde Unit 3 transient condition. An overall qualitative assessment of the transients, as compared to the applicable PLANT X [1] transients, is included herein. The purpose of this comparison is to show that the secondary stress and fatigue evaluations performed for the instrumentation nozzle in [1] are applicable to the Palo Verde Unit 3 instrumentation nozzle transient evaluation.

Fatigue and primary plus secondary stresses are affected by the following:

1. thermal transients
2. pressure transients
3. number of cycles

1. Thermal Transients

The safe end of the instrumentation nozzle is insulated and the water inside the nozzle opening is trapped. Therefore, heat from the RCP water will be transferred from the inside surface of the RCP suction safe end to the attachment weld region by conduction.

During normal operating conditions, the maximum reactor coolant temperature variations (excluding heatup and cooldown) are no greater than [ ]^{a,c} °F [12]. Thus, it is expected that temperature variations on the weld region and outer nozzle area for normal conditions are negligibly small and that the corresponding stress variations are small. The Palo Verde Unit 3 heatup and cooldown transients are similar to the PLANT X heatup and cooldown transients, as shown in computer run 1.

The Palo Verde Unit 3 upset transients [ ]^{a,c} are generally enveloped by two PLANT X upset transients [ ]^{a,c}. The effect of these upset transients on the weld region will be small.

An ASME Section III evaluation only requires a primary stress evaluation for faulted conditions. Therefore, the faulted transient, [ ]^{a,c}, is not evaluated. Only the primary stresses due to pressure and faulted mechanical loads are evaluated.

2. Pressure Transients

The maximum pressure variation during the Palo Verde Unit 3 normal transients is [ ]^{a,c} psi and the maximum pressure variation for the Palo Verde Unit 3 upset transients is [ ]^{a,c} psi. For PLANT X, the maximum pressure variation is for the upset transient of decrease in heat removal by the secondary

system, [ ]a,c psi. The difference between the two plants during upset transients is [ ]a,c psi. Therefore, the stresses due to this difference are expected to be negligible.

3. Number of Cycles

The evaluations in this calculation note are only applicable for 18 months of operation for the Palo Verde Unit 3 instrumentation nozzle. Based on that short duration, the number of cycles for the Palo Verde Unit 3 instrumentation nozzle is much less than that evaluated for the PLANT X instrumentation nozzle for full operating life (60 years).

Conclusion

Based on the three justifications above, it is concluded that the fatigue usage factor and the primary plus secondary stress on the J-groove weld and instrumentation nozzle calculated in PLANT X [1] are applicable to the Palo Verde Unit 3 instrumentation nozzle and new attachment weld for 18 months. [

]a,c

5.2 Vibration Assessment

Section 4.3 of [10] states that the reactor coolant system (RCS) may experience vibratory excitation with frequencies of:

- [ ]a,c CPS – lower range
- [ ]a,c CPS – middle range
- [ ]a,c CPS – upper range

The replacement instrumentation nozzle has relocated the attachment weld; therefore, the natural frequency of the nozzle and attached Class 2 piping are evaluated to ensure that neither are within the excitation ranges. This evaluation is performed in Appendix B.

The results of Appendix B are summarized in Table 5-1 for the two-way restraint condition. The cases run in Appendix B for various valve rotations were run to conservatively address all cases. However the only case which is directly applicable to the actual valve orientation is labeled "Two-way Restraint."

Table 5-1: Class 2 Piping and Instrumentation Nozzle Modal Frequency

Configuration	Mode Frequency				
	1st (Hz)	2nd (Hz)	3rd (Hz)	4th (Hz)	5th (Hz)
Two-way Restraint	[				]a,c

Note: Value in blue is the natural frequency of the replacement instrumentation nozzle.

The first mode is the natural frequency of the piping. This minimum piping frequency of [ ]a,c Hz and the instrumentation nozzle frequency of [ ]a,c Hz are outside of the restricted ranges, which is acceptable to avoid a resonant vibration issue. All other frequencies are well outside of the restricted ranges.

The frequency highlighted in blue is the natural frequency of the replacement instrumentation nozzle, [ ]a,c Hz. [ ]a,c Hz is conservatively used in comparing to the applicable seismic and pipe break spectra for the worst case acceleration of the nozzle. This frequency, [ ]a,c Hz, is used to determine the nozzle inertial loads due to OBE, SSE, and BLPB events. Per [25], the damping ratios to be used for a seismic analysis of small bore piping are 1% for OBE and 2% for SSE. 2% damping is also used for the BLPB response spectra. The response spectra documented in [20] and Appendix A were used to calculate the inertial loads summarized in Table 5-2. See computer run 2 for calculation of the instrumentation nozzle weight and the center of gravity.

Table 5-2: Seismic and Pipe Break Inertial Loads – Global Coordinate System(1)

Load Case	Acceleration (g's)			Force (lbs)		
	X	Y	Z	X	Y	Z
OBE						
SSE						
BLPB						

a,c

Note:

(1) These loads are in the global coordinate system and must be rotated to the nozzle coordinates, as discussed in Section 4.6.2.

5.3 Instrumentation Nozzle Qualification

The closed-form solution for the stress intensities of the PLANT X instrumentation nozzle is shown in Table 6-6 of [1]. This closed-form solution will also be used for the Palo Verde Unit 3 nozzle. The mechanical loads summarized in Table 4-2 for the Palo Verde Unit 3 instrumentation nozzle are used in the formulas for the external load criteria to evaluate stress intensities in the replacement instrumentation nozzle. Table 5-3 summarizes the nozzle mechanical loads used to evaluate the PLANT X load criteria.

Table 5-3: Adjusted Nozzle Mechanical Loads for Palo Verde Unit 3

Nozzle Load	Normal (lbs, in-lbs)	Faulted (lbs, in-lbs)
Total Fa(1) (Axial)		
Fv (Total Shear)		
T (Torsion)		
Mb (Total Bending)		

a,c

Note:

(1) See Section 5.4.2 for explanation of total axial load.

The PLANT X load criteria evaluations for the Palo Verde Unit 3 applied loads are summarized in Table 5-4. The formulas in Table 5-4 are taken from Table 6-6 of [1]. This table was developed to calculate load criteria for the nozzle such that it meets all applicable ASME Code criteria based on the various nozzle loadings.

Table 5-4: Instrumentation Nozzle Load Criteria Evaluation

Stress Intensity (ksi)			Loading Condition	Criteria (ksi)[(1)]
	[ ]a,c			
P_m=		= 6.96	Design	P_m < [ ]a,c = 17.64
		= 16.18	Level D	P_m < [ ]a,c = 38.2
$P_L + P_b$=		= 8.97	Design	$P_L + P_b$ < [ ]a,c = 26.96
		= 19.71	Level D	$P_L + P_b$ < [ ]a,c = 57.8
$P_L + P_b$=	This row is applicable to the original weld region only; therefore, it is not applicable to the replacement nozzle.			

Note:

(1) S_m, P, and S_u are the same for the Palo Verde Unit 3 and PLANT X evaluations. Therefore, the criteria values have not changed.

The stresses calculated in Table 5-4 are well below the allowable stress values. As described in Section 4.3.2, the impact of seismic and BLPB inertial loads is included in the applied loads. The evaluation of thermal and pressure transients is bounded by the PLANT X analysis [1], as discussed in Section 5.1. [ ]a,c Therefore, the instrumentation nozzle meets all ASME Code requirements, and no further evaluation is necessary.

5.4 Attachment Weld Qualification

5.4.1 Nozzle Opening Reinforcement Requirements

ASME Section NB-3330 requires reinforcement around any opening. The reinforcement requirement is related to the nozzle hole diameter. Since the existing base metal will be exposed to primary water, the base metal might corrode over time. The reinforcement areas for three different hole sizes are calculated to determine allowable hole diameters. As shown in Table 5-5, the minimum reinforcement area for each hole size is greater than the required area of reinforcement.

Table 5-5: Nozzle Opening Reinforcement Calculations

a,c

Since the hole size is much smaller than suction safe end size, the effect of the opening angle on the area calculation is negligibly small.

5.4.2 Primary Stress

The following evaluation considers the applicable loading on the attachment weld to calculate the primary stress intensity. The loads for normal and faulted conditions are evaluated separately, against the applicable Section III ASME Code allowable stresses. This evaluation includes the effects of mechanical loads on the instrumentation nozzle, inertial loads due to seismic and BLPB, pressure loads from the RCP safe and, and mechanical loads from the RCS piping on the RCP safe end.

Table 5-6 summarizes the nozzle input loads. These loads are the sum of applied piping loads from Class 2 piping, as well as seismic and pipe break inertial loads. To conservatively evaluate the OBE condition, OBE inertial loads are added to the normal condition piping loads. The summed applied loads are converted to the coordinate system of the nozzle (where F_a is the nozzle axial direction, F_v is the square root of the sum of squares of the two nozzle shear directions, T is torsion, and M_b is the square root of the sum of squares of the two nozzle bending moments).

Table 5-6: Attachment Weld Input Loads

Total Input Load	Local Combined Coordinates		
	Normal	Faulted	Units
F_a		a,c	lbf
F_v			lbf
T			in-lbf
M_b			in-lbf

The weld size used in the following evaluations is [ ]a,c inches. This size is used instead of the full weld size of 0.5 inches [3] to account for potential corrosion in the RCP safe end base material. See Section 5.4.1 for details regarding this evaluation. The case chosen for evaluation is the middle case, in which the nozzle hole radius is set to [ ]a,c inches. The resulting weld depth with an increased hole radius of [ ]a,c inches is [ ]a,c inches of weld.

Figure 5-1 shows the dimensions that are used in the structural evaluation. Computer runs 3 and 4 include the full MathCAD input.

a,c

Figure 5-1: Instrumentation Nozzle Dimensions

Normal Stress Evaluation:

[ ]a,c

a,c

a,c

Faulted Stress Evaluation:

a,c

a,c

a,c

5.4.3 Secondary Stress and Fatigue Evaluation

The evaluation of secondary stresses and fatigue usage in the instrumentation nozzle in [1] considered thermal and pressure transients, as discussed in Section 5.1. The only major difference between the Plant X attachment weld and the Palo Verde Unit 3 attachment weld is that the Palo Verde Unit 3 attachment weld is on the outer surface of the RCP safe end; the Plant X weld is on the inside surface. See Figure 4-1. Thermal and pressure transients are less severe on the outer surface of the RCP.

As discussed in Section 5.1, the results of the primary plus secondary stress and fatigue usage calculations in [1] are applicable to the evaluation of the Palo Verde Unit 3 instrumentation nozzle and attachment weld for 18 months.

The total cumulative usage factor on the outer surface of the RCP for the PLANT X analysis is [ ]^{a,c}. This evaluation is based on the full life of PLANT X. The Palo Verde Unit 3 replacement nozzle need only be qualified for a single fuel cycle of 18 months. Therefore, the fatigue usage factors for the PLANT X analysis are bounding of the Palo Verde Unit 3 instrumentation nozzle. No further evaluation of the attachment weld is required.

6.0 Listing of Computer Codes Used and Runs Made in Calculation

Table 6-1: Summary of Computer Codes Used in Calculation

Code No.	Code Name	Code Ver.	Configuration Control Reference	Basis (or reference) that supports use of code in current calculation
1	Microsoft Excel®	N/A	N/A	Microsoft Excel is general purpose software for spreadsheet applications. Microsoft Excel is not verified and validated for use in safety- or non-safety-related applications; therefore, all calculations performed by Microsoft Excel are verified per the requirements of WEC 3.2.6 and WEC 3.3.3, as well as Level III Procedures ES 3.2.1.
2	MathCAD®	N/A	N/A	MathCAD is general purpose software for mathematical applications. MathCAD is not verified and validated for use in safety- or non-safety-related applications; therefore, all calculations performed by MathCAD are verified per the requirements of WEC 3.2.6 and WEC 3.3.3, as well as Level III Procedures ES 3.2.1.
3	ANSYS®	12.1	[22]	ANSYS is a general purpose finite element code that is suitable for the analyses contained in this calculation. The analyses include a heat transfer and stress analysis to determine loads at various points within the system. ANSYS is a commercially available, general-purpose computer code, verified and controlled in the Westinghouse computer system.
4	PIPESTRESS®	3.7.0	[26]	General purpose code developed for use with piping for nuclear application. The program has a built-in function that computes resultant loads.
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				

Calculation Note Number	Revision	Page
CN-MRCDA-15-13-NP	0	34

a,c

Table 6-2: Electronically Attached File Listing

a,c

a,c

Table 6-3: Computer Code Checklist
(Completed By Author)

No.	Self Review Topic	Yes	No	N/A
1	Are macros, scripts, calculational worksheets, or single-application programs used in the analysis?	X		
2	Have the requirements in WEC 3.6.1 and WEC 3.6.6, if applicable, for the documentation and qualification of the macros, scripts, calculational worksheets, or single-application computer programs been met?			X
3	Has the range of use for the macros, scripts, calculational worksheets, or single-application programs been verified and documented in the calculation note?	X		
4	Have all macros, scripts, calculational worksheets, or single-application program limitations been identified and documented within the calculation note?	X		
5	In the case of finite element analysis models, scripts and macros: Are there any commands or element type limitations identified that apply to this analysis?		X	
6	In the case of finite element analysis models, scripts and macros: Have macros (e.g., ANSYS APDL) used in the analysis, been documented in accordance with WEC 3.6.1 and WEC 3.6.6?		X	

Appendix A: BLPB Response Spectra

This appendix describes the generation of BLPB response spectra for the RCP. [

]a,c

A.1 Inputs

The acceleration time-history data are from [21]. [

]a,c

a,c

A.2 Method of Evaluation

[

]a,c

A.3 Results

The enveloped response spectra are generated for all damping values. These results are electronically attached in computer run 5. The 2% BLPB enveloped response spectra are shown in Figure A-1 through Figure A-3.

a,c

Figure A-1: BLPB Enveloped Response Spectra, Top of RCP Motor, X-direction

a,c

Figure A-2: BLPB Enveloped Response Spectra, Top of RCP Motor, Y-direction

a,c

Figure A-3: BLPB Enveloped Response Spectra, Top of RCP Motor, Z-direction

Appendix B: Evaluation of Instrumentation Piping Frequencies

The purpose of this appendix is to calculate the frequencies of the instrumentation nozzle with the attached pipe.

B.1 Method Discussion

The instrumentation nozzle and piping PIPESTRESS model [26] is developed based on the geometric and material information presented in [3, 4, 14, 16, and 17]. The applicable ASME Code years are [27] for the piping and [28] for the instrumentation nozzle.

B.1.1 Input

Major geometric input of the piping model is taken from [3, 4, 16, and 17]. Per [4], the material of the instrumentation nozzle is SB-166 Inconel 690. The material of the piping is SA-312 TP304 per [14]. The material properties used in this analysis are listed in Table B-1. The section properties of the model are shown in Table B-2.

Table B-1: Material Properties

Modulus (10^6 psi)	70°F	200°F	300°F	400°F	500°F	600°F	650°F
SB-166 Inconel 690	30.3	29.5	29.1	28.8	28.3	28.1	27.85
SA-312 TP304	28.3	27.7	27.1	26.6	26.1	25.4	24.8

Table B-2: Sectional Properties

Cross-section	Outside Diameter (in)	Thickness (in)	Mass Density (lbs/ft)		Description
1				a,c	Instrumentation Nozzle
2					Instrumentation Nozzle with Larger Outside Diameter
3					Piping without Insulation
4					Piping with Insulation

B.1.2 Model Development

The PIPESTRESS model is developed based on [3, 4, 14, 16, and 17] and is shown in Figure B-1. [

]^{a,c}

a,c

Figure B-1: Instrumentation Nozzle and Piping Model

B.2 Modal Analysis

A modal analysis is performed for the instrumentation nozzle with the piping. The frequencies for three different configurations (two-way restraint configuration, two-way restraint with 45° valve stem rotation configuration, and -45° valve stem rotation configuration) are listed in Table B-3. The first significant modes for the piping are highlighted in yellow. The first significant modes for the nozzle are highlighted in blue.

Table B-3: Natural Frequency Data

Configuration	Mode				
	1st (Hz)	2nd (Hz)	3rd (Hz)	4th (Hz)	5th (Hz)
Two-way Restraint					[redacted]
Two-way Restraint with Valve Stem 45° Rotation					[redacted]
Two-way Restraint with Valve Stem -45° Rotation					[redacted]

a,c

a,c

Figure B-2: Instrumentation Nozzle and Piping

a,c

Figure B-3: Valve with Tubing

Appendix C: Reference Information

C.1 Reference [24]

a,c

C.2 Reference [30]

a,c

a,c

a,c

Checklist A: Proprietary Class Statement Checklist

Directions (this section is to be completed by authors): Authors are to determine the appropriate proprietary classification of their document. Start with the Westinghouse Proprietary Class 1 category and review for applicability, proceeding to Westinghouse Proprietary Class 2 – Non-Releasable and finally to Westinghouse Proprietary Class 2 – Releasable. The proprietary classification is established when the first criterion is satisfied.

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Checklist B: Calculation Note Methodology Checklist

(Completed By Author)

No.	Self Review Topic	Yes	No	N/A
1	Was the latest version of the calculation note template used?	X		
2	Is all information in the cover page header block provided appropriately?	X		
3	Are all the pages sequentially numbered, and are the calculation note number, revision number, and appropriate proprietary classification listed on each page? Are the page numbers in the Table of Contents provided and correct?	X		
4	Does this calculation note fulfill the customer requirements?	X		
5	Is the Summary of Results and Conclusions provided in Section 2.0 consistent with the purpose stated in Section 1.0 and calculations contained in Section 5.0?	X		
6	Is sufficient information provided for all References in Section 3.0 to facilitate their retrieval (e.g., from EDMS, SAP, CAPs, NRC's ADAMS system, open literature, etc.), or has a copy been provided in Appendix A?	X		
7	Are Section 4.2 and the open items box on the calculation note cover sheet consistent and, are all open items documented in Section 4.2 tracked in an open items database and include an estimated scheduled date for closure?	X		
8	Are all computer outputs documented in Table 6-2 and consistent with Table 6-1?	X		
9	Are all computer codes used under Configuration Control and released for use?	X		
10	Are the computer codes used applicable for modeling the physical and/or computational problem contained in this calculation note?	X		
11	Have the latest and/or most appropriate versions of all computer codes been used?	X		
12	Have all open computer code errors identified in Software Error Reports been addressed?	X		
13	Are the units of measure clearly identified?	X		
14	Are approved design control practices (e.g., Level 3 procedures, guidebooks, etc.) followed without exception?	X		
15	Are all hand-annotated changes to the calculation note initialed and dated by author and verifier? Has a single line been drawn through any changes with the original information remaining legible?			X
16	Was a Pre-Job Brief held prior to beginning the analysis?	X		
17	Was a Self Check performed prior to submitting the analysis for Peer Checks and/or final verification?	X		
18	Was a Peer Check performed to review inputs documented in Section 4.6 prior to performing analyses?	X		
19	Was a Peer Check performed to review results before documenting them in Section 5.0?	X		
20	If required, have computer files been transferred to archive storage? Provide page number for list of files if not included in Table 6-2. Page	X		
21	If applicable, have the results of any previous assessments on the analysis of record been incorporated in this calculation note?			X
22	If this calculation note requires a change to a safety analysis database (e.g., SAIK), has the change been submitted such that the database will be updated?			X
23	If this calculation note used FEA methods, were the guidelines discussed in WCAP-16904-P used?	X		
24	Has an editorial review been performed on this calculation note?	X		
25	Are all trademark symbols and the trademark attribution statement correctly identified in the calculation note?	X		

If 'NO' to any of the above, provide page number of justification or provide additional explanation here or on subsequent pages.

Checklist C: Verification Method Checklist

[Completed By Verifier(s)]

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1	Independent review of document. (Briefly explain method of review below or attach.)	SEL, GZH, AEW, ESS
2	Verification performed by alternative calculations as indicated below.[(1)]	
	a. Comparison to a sufficient number of simplified calculations which give persuasive support to the original analysis.	
	b. Comparison to an analysis by an alternate verified method.	
	c. Comparison to a similar verified design or calculation.	
	d. Comparison to test results.	
	e. Comparison to measured and documented plant data for a comparable design.	
	f. Comparison to published data and correlations confirmed by experience in the industry.	
3	Completed Group-Specific Verification Checklist. (Optional, attach if used.)	
4	Other (Describe)	

(1) For independent verification accomplished by comparisons with results of one or more alternate calculations or processes, the comparison should be referenced, shown below, or attached to the checklist.

Verification: The verifier's signature (or Electronic Approval) on the cover sheet indicates that all comments or necessary corrections identified during the review of this document have been incorporated as required and that this document has been verified using the method(s) described above. For multiple verifiers, appropriate methods are indicated by initials. If necessary, technical comments and responses (if required) have been made on the "Additional Verifier's Comments" page.

Additional Details of Verifier's Review

The 3-pass methodology has been used throughout.

Checklist D: 3-Pass Verification Methodology Checklist

[Completed by Verifier(s)]

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	First Pass			
1	Were the general theme, scope of document, and scope of review clear?	X		
	Second Pass			
2	Do the references appear to be documented correctly? Is there enough information present to ensure the referenced document is retrievable?	X		
3	Do the acceptance criteria seem appropriate?	X		
4	Does the technical content of the calculation note make sense from a qualitative standpoint and are appropriate methods used?	X		
	Third Pass			
5	Do the results and conclusions meet the acceptance criteria? Do the results and conclusions make sense and support the purpose of the calculation note?	X		
6	Has the technical content of the document been verified in adequate detail? Examples of technical content include inputs, models, techniques, output, hand calculations, results, tables, plots, units of measure, etc.	X		
7	Does the calculation note provide sufficient detail in a concise manner? Note that sufficient detail is enough information such that a qualified person could understand the analysis and replicate the results without consultation with the author.	X		
8	Is the calculation note acceptable with respect to spelling, punctuation, and grammar?	X		
9	Are the references accurate? Do the references to other documents point to the latest revision? If not, are the reasons documented? Are the references retrievable?	X		
10	Are computer code names spelled correctly? If applicable, are numerals included in the official code name as appropriate?	X		
11	Has the calculation note been read word-for-word, cover-to-cover?	X		
12	Have all differences between the documented and the verifier-calculated results been resolved, justified if applicable, and documented?	X		

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No.	Verifier's Comments	Author's Response (If Required)
	Revision 0-A	
	None	None Required
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	As per mark-up	All comments have been addressed