ENCLOSURE 4

REVISION TO CALCULATION WCG-ACQ-0275

RWST 6 AND 8 INCH NOZZLE QUALIFICATION

ORIGINAL

QA Record

DNE CALCULATIONS

TITLE RWST 6 AND 8 INCH NOZZLE QUALIFICATION			PLANT/UNIT WBN/UNIT 1
PREPARING ORGANIZATION Bechtel Job 20652	KEY NOUNS (Consult RIMS DESCRIPTORS LIST) EQUIPMENT QUALIFICATION, NOZZLE/SHELL STRESSES		
BRANCH/PROJECT IDENTIFIERS WCG-ACQ-0275	Each time these calculations are issued, preparers must ensure that the original (RO) RIMS accession number is filled in.		
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These calculations contain unverified assumption(s)	Yes ☐ No ☒	Yes ☐ No ☒	Yes ☐ No ☒	Yes ☐ No ☐

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Safety-related? Yes ☒ No ☐

Statement of Problem

QUALIFY THE NOZZLE/SHELL JUNCTURE DUE TO NOZZLE EXTERNAL LOADS ON THE TANK.

CONTRACT: 820613

Abstract A FINITE ELEMENT ANALYSIS IS PERFORMED TO QUALIFY THE EQUIPMENT (REFUELING WATER STORAGE TANK) DUE TO NOZZLE LOADS ON THE TANK. THIS ANALYSIS INCLUDES 8"φ OVER FLOW & 6"φ CONTAINMENT SPRAY TEST LINE NOZZLES.

AN UPDATED EVALUATION OF BOTH NOZZLES USING BIJLAARD TECHNIQUES IS SHOWN IN APPENDIX D. R2

TOTAL NO. of PAGES including cover sheet = ~~437~~ ~~435~~ 505/R2

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Title: RWST 6 AND 8 INCH NOZZLE QUALIFICATION

REVISION LOG

WCG-ACQ-0275

Revision No.	DESCRIPTION OF REVISION	Date Approved
2	This calculation is revised to consider the impact of the 6" nozzle on the qualification of the 8" nozzle. The calculation is performed in appendix D of this calculation and performs the evaluation using a Bijlaard analysis. The evaluation of the 8" nozzle was previously performed in WCG-ACQ-0291 which will be voided upon issue of the revision to this calculation. The calculation also considers, using a Bijlaard analysis the impact of the 8" nozzle, on the qualification of the 6" nozzle. This revision is performed using loads from piping analysis calculation N3-72-01A revision 2 for the 8" nozzle. The critical loads (i.e. axial loadings and bending moments) were generally less severe than those from the R0 version used in the finite element analysis of this calculation. The external loadings from N3-72-09A R13 used for the Bijlaard analysis were the same as that used in the finite element analysis. It is concluded that the loads used in the finite element analysis were generally in agreement with loads used in the Bijlaard analysis and the finite element portion of this analysis is retained for information. It is expected that any further revision of the nozzle loads will be addressed by by Bijlaard analysis if the calculations are not too conservative. The Bijlaard analysis considered a hydrodynamic pressure stress of 11,704 psi compared to the pressure stress of 5846 psi used in revision 1 of this calculation. The finite element analysis of revision 1 determined a faulted condition stress near the 6 inch nozzle of membrane 2596 psi and membrane + bending 21845 psi. Adjusted for a pressure of 11,704 psi results in membrane 14300 psi and membrane + bending = 33545 psi. The revision 2 Bijlaard analysis calculated these same stresses to be membrane 13747 psi and membrane + bending = 31691 psi. The stresses are very closely in agreement. DMW 7/7/92 It is expected that further revisions to this calculation will be performed using the Bijlaard analysis of appendix D because of the simplicity of its use. Pages added: iA, iB, ii, D1 THROUGH D68 Pages deleted: NONE Pages changes: COVER SHEET, 1, 5, 6, 7	7-10-92

APPENDIX D: BIJLAARD ANALYSIS OF 8" (AND 6") NOZZLE

THIS SHEET ADDED BY REV 2

PURPOSE

The purpose of this appendix is to present a Bijlaard analysis demonstrating the qualification of the 8" overflow nozzle and the 6" inch containment spray nozzle on the Refueling Water Storage Tank. This analysis will consider the interaction effect of each of the two nozzles.

This appendix incorporates and updates information previously contained in calculation WCG-ACQ-0291 which provided qualification of the 8 inch nozzle for the RWST tank. This previous evaluation (WCG-ACQ-0291) did not specifically address the interaction of the 6" nozzle with the 8" nozzle and this was identified during an NRC audit of calculations as documented in reference D5 (attachment D1). WCG-ACQ-0291 will be voided and the information is updated and clarified herein.

This Bijlaard approach very conservatively considers the interaction effect and further updates this calculation (e.g. WCG-ACQ-0275 R2 considers piping analysis N3-72-09A revision 2 loadings). The R0 critical loadings (axial and bending) used in the appendix A finite element analysis are generally more severe (i.e. R0 axial load is similar and R0 resultant bending is larger) than the R2 loadings (see appendix B and appendix D, attachment D2. Because of this conservatism and because of sufficient margins between calculated stresses and allowables shown in the finite element analysis there is no effect on the final conclusions of the finite element analysis of appendix A. The ANSYS portion of this analysis will remain intact for information purposes.

Differences do exist between the results of the finite element analysis and the Bijlaard analysis. It is possible that a finite element analysis could have some results greater that the Bijlaard analysis, even if identical loads were used, due to the finite element analysis conservatively modeling the tank connection as a flat plate.

ASSUMPTIONS

There are no unverified assumptions in this Bijlaard analysis.

REFERENCES

D1. Watts Bar Unit 1, piping stress calculation N3-72-01A, rev. 13, (6" nozzle). (see attachment D2)

D2. Watts Bar Unit 1, piping stress calculation N3-72-09A, rev. 2, B18 920609 754). (8 inch over flow line, outside the tank). See attachment D2.

D3. Pittsburg-Des Moines "Design of Two Refueling Water Storage Tanks" dated 1/3/77 with last revision dated 8/30/77. Contract 820613, MEB 830921 928).

D4. Pitsburg-Des Moines stress report providing additional information for the reference D3 "Design of Two Refueling Water Storage Tanks" received on 8/14/80. Contract 820613. B07 890915 067. Portions of this report providing loadings are contained in attachment D2.

D5 Letter from NRC's P.S. Tam to TVA's M. Medford dated May 26 1992 (perinent portions are contained in attachment D1 of this appendix).

D6. Welding Research Council Bulletin 107 "Local Stresses in Spherical and Cylindrical Shells due to External Loadings" dated April 1972 (third revised printing of August 1965 WRC 107).

D7. WBN Report CEB-81-41, "Watts Bar Nuclear Plant, Seismic Analysis of Refueling Water Storage Tank" B26 910424 077.

D8. WB-DC-40-31.6, R4 "Seismically Qualifying Tanks and Reservoirs and Their Supports" (T29 920521 939).

D9. PDM drawings 50039 D2, D9, E9, contract 820613. Pertinent portions of these drawings are reproduced in attachment D3 of this appendix.

CALCULATIONS/EVALUATIONS

The nozzle loadings will be evaluated to the stress levels identified in Design Criteria WB-DC-40-31.6 (ref. D8).

The allowable stresses are:

	Design/ Normal	Upset	Emergency	Faulted
Pm	1.0Sh	1.1Sh	1.5Sh	2.0Sh
(Pm or Pl) + Pb	1.5Sh	1.65Sh	1.8Sh	2.4Sh

When evaluating the results of the Bijlaard analysis
Pm is taken as Pm + Pl(membrane);
and (Pm or Pl) + Pb is conservatively taken as Pm + Pl(membrane + bending).

Per FSAR section 9.2.7 the design and operating pressures are atmospheric with a design temperature of 200°F. The maximum operating temperature of 145°F is conservative per discussions between the systems engineer (Steve Robertson) and the preparer of this calculation (D. M. Wilson) on 6/15/92. The allowable stress "Sh" is taken as 18350 psi. Therefore:

Normal Condition
Pm + Pl(membrane) < 1.0Sh = 18350 psi
Pm + Pl(membrane + bending) < 1.5Sh = 27525 psi
Upset Condition
Pm + Pl(membrane) < 1.1Sh = 20185 psi
Pm + Pl(membrane + bending) + Pb < 1.65Sh = 30278 psi
Faulted Condition
Pm + Pl(membrane) < 2.0Sh = 36700 psi
Pm + Pl(membrane + bending) < 2.4Sh = 44040 psi

The pressure load is considered as a primary general membrane stress Pm and the gross bending stress due to seismic loading will also be considered as a primary general membrane stress.

Allowable nozzle loads were obtained for the original PDM analyses (ref. D3 and D4). These approved values were investigated by PDM using a Bijlaard analysis and approved in the reference D3 calculation. Reference D4 provided an evaluation of the piping internal to the tank and provided actual loads for the piping inside. The PDM allowables were determined to be good for the external piping and are listed below for information.

ALLOWABLE LOADS FROM EXTERNAL PIPING
(Ref. D3, page 6.2)

	AXIAL	SHEAR		BENDING		TORSION
	Px axial (lb)	Py, long. (lb)	Pz circ.	Mby, circ (in-lb)	Mbz long	Mtx torsion (in-lb)
6" nozzle						
NORMAL,allow	1480	1050	1050	11270	11270	31875
UPSET,allow	2105	1395	1395	15025	15025	42500
EMERGENCY,allow	2737	1745	1745	18700	18700	53125
FAULTED,allow	2737	1745	1745	18700	18700	53125
8" NOZZLE,						
NORMAL,allow	1575	1575	1575	22285	22285	63040
UPSET,allow	2100	2100	2100	29710	29710	84050
EMERGENCY,allow	2625	2625	2625	37140	37140	105065
FAULTED,allow	2625	2625	2625	37140	37140	105065

Actual external loadings listed below were obtained from piping analysis N3-72-01A R13 (ref. D1) for the 6" nozzle and N3-72-09A R2 (ref. D2) for the 8" nozzle.

The actual loadings from N3-72-09A R2 (8" overflow nozzle) considers the piping from outside the tank. For this loading revision the submitted values are below the allowable values for all conditions. Further evaluation of these loadings will, however, be performed in this calculation. Loadings were determined at the shell nozzle juncture.

The actual loadings from N3-72-01A R13 (6" containment spray nozzle) considered the piping from outside the tank. From a review of the isometric and discussions with a piping analyst (J. Valazquez), it was confirmed that the loadings were applied at the safe end of the nozzle with a 6" length. The actual bending moments are conservatively converted into bending moments at the nozzle/pad junction by multiplying the shear force at the node point by the distance from the node point to the nozzle/pad interface (6").

Adjusted Mby = Mby + (6)Pz
Adjusted Mbz = Mbz + (6)Py

In the table below, the adjusted moments are shown and the moments at the safe end are shown in parentheses for the 6 inch nozzle. The individual load components which exceed the vendor allowables are underlined for clarity.

ACTUAL EXTERNAL NOZZLE LOADS
(see pages D54 and D55 of this calculation)

	AXIAL	SHEAR		BENDING		TORSION
	Px axial (lb)	Py, long. (lb)	Pz circ.	Mby, circ (in-lb)	Mbz long	Mtx torsion (in-lb)
6" nozzle				(24276)	(23148)	
NORMAL,actual	1116	784	222	25608	27852	40188
NORMAL,allow	1480	1050	1050	11270	11270	31875
				(32700)	(46824)	
UPSET,actual	2013	1696	1015	38790	57000	73620
UPSET,allow	2105	1395	1395	15025	15025	42500
				(44124)	(78564)	
FAULTED,actual	3243	2668	1820	55044	94572	108252
FAULTED,allow	2737	1745	1745	18700	18700	53125
8" NOZZLE,						
NORMAL,actual	253	1220	4	37	16903	511
NORMAL,allow	1575	1575	1575	22285	22285	63040
UPSET,actual	530	1594	274	6625	24816	3940
UPSET,allow	2100	2100	2100	29710	29710	84050
FAULTED,actual	767	1914	499	12049	31556	6625
FAULTED,allow	2625	2625	2625	37140	37140	105065

The actual external loads from the 6" nozzle exceeded vendor allowables for several of the loading conditions. The actual loads from the 8" nozzle were within allowable limits for the revision 2 loads.

The internal loads will be conservatively combined with the external loads disregarding signs and the loads for performing the Bijlaard analysis are developed.

The internal loadings are obtained from the PDM analysis (ref. D4) and are tabulated below. Note that for the 8" internal nozzles vertical and axial loads are essentially carried by the lower support and the transverse loads are carried by the nozzle.

ACTUAL INTERNAL NOZZLE LOADS
(see pages D60 and D63 of this calculation)

	AXIAL	SHEAR		BENDING		TORSION
	Px axial (lb)	Py, long. (lb)	Pz circ.	Mby, circ (in-lb)	Mbz long	Mtx torsion (in-lb)
6" nozzle						
NORMAL,actual	0	200	0	0	4725	0
UPSET,actual	0	250	130	3075	5910	0
FAULTED,actual	0	300	260	6150	7090	0
8" NOZZLE,						
NORMAL,actual	0	0	0	0	0	0
UPSET,actual	0	0	40	840	0	0
FAULTED,actual	0	0	80	1680	0	0

These internal loads are relatively small when compared to the external loads. The external loads are summarized again below for clarity.

ACTUAL EXTERNAL NOZZLE LOADS

	AXIAL	SHEAR		BENDING		TORSION
	Px axial (lb)	Py, long. (lb)	Pz circ.	Mby, circ (in-lb)	Mbz long	Mtx torsion (in-lb)
6" nozzle						
NORMAL,actual	1116	784	222	25608	27852	40188
UPSET,actual	2013	1696	1015	38790	57000	73620
FAULTED,actual	3243	2668	1820	55044	94572	108252
8" NOZZLE,						
NORMAL,actual	253	1220	4	37	16903	511
UPSET,actual	530	1594	274	6625	24816	3940
FAULTED,actual	767	1914	499	12049	31556	6748

The total nozzle loads to be used for the evaluation of the nozzles will be conservatively taken as the sum of the loads from the external and internal sides. The loadings used in the Bijlaard analysis are summarized immediately below.

ACTUAL EXTERNAL + INTERNAL NOZZLE LOADS

	AXIAL	SHEAR		BENDING		TORSION
	Px axial (lb)	Py, long. (lb)	Pz circ.	Mby, circ (in-lb)	Mbz long	Mtx torsion (in-lb)
6" nozzle						
NORMAL,actual	1116	984	222	25608	32577	40188
UPSET,actual	2013	1946	1145	41865	62910	73620
FAULTED,actual	3243	2986	2080	61194	101662	108252
8" NOZZLE,						
NORMAL,actual	253	1220	4	37	16903	511
UPSET,actual	530	1594	314	7465	24816	3940
FAULTED,actual	767	1914	579	13729	31556	6748

The design pressure of the tank is atmospheric, but both hydrostatic and hydrodynamic pressures are considered in this analysis.

The hydrostatic and hydrodynamic pressures used in this Bijlaard analysis are determined from Report CEB-81-41 (reference D7) and are tabulated below: Using the set B spectra from Table A-1(d) and A-2(d) of CEB-81-41 the hydrostatic and hydrodynamic pressures (p) at elevation 729.9 (at the bottom of the tank are:

Normal conditions, static, = 2.122 k/ft² = 14.70 psi.
Upset conditions, OBE, = 3.265 k/ft² = 22.67 psi
Faulted conditions, SSE, = 4.238 k/ft² = 29.43 psi

The actual thickness of the insert plate at the connection is 1 3/16". References D3 and D4 conservatively used an insert plate thickness of 1.0625" for the PDM analysis and this conservative value will also be used in the Bijlaard analysis presented in this calculation. The outside diameter of the tank is 43.5 feet. The actual wall thickness of the tank near the insert plate is 21/32" and this will be the wall thickness used in this calculation (0.6563"). Reference D3, D4 and D9.

The mean radius of the tank is taken as approximately 261 inches for the purpose of this analysis.

The internal pressure stress due to the hydrostatic and hydrodynamic pressures discussed above is taken as pr/t = 261p/0.6563.

Normal conditions, Pst = 261(14.70)/0.6563 = 5846 psi.
Upset conditions, Pu = 261(22.67)/0.6563 = 9015 psi.
Faulted conditions, Pf = 261(29.43)/0.6563 = 11704 psi.
Note that these pressure stresses in the tank are in the circumferential direction only.

The seismic gross bending stresses are also determined from CEB-81-41, ref. D7, table A-1(c) for the Set B, OBE, and table A-2(c) for the set B SSE.

The moment of inertia of the tank cross section is determined by:

$I = 3.1416(Ro^4 - Ri^4)/4$, The outer radius Ro is taken as 261".
Ri = 260.3437"

$I = 36,520,472\ in^4$

The equivalent membrane stress is found simply by Mc/I
From reference D7 the maximum response moment is 26700 k-ft for the OBE and 47640 k-ft for the SSE.

For the upset condition the seismic bending stress is
26700000(12)261/I = 2290 psi

For the faulted condition the seismic bending stress is
47640000(12)261/I = 4085 psi

The seismic membrane stresses act in the longitudinal direction. There are, of course no seismic stresses during the normal condition.

Bijlaard constants from the reference D3 PDM calculation (pages 6.12 and 6.17) and WRC Bulletin 107 (ref. D6) were used.

The Bijlaard analysis for the normal, upset, and faulted conditions are contained in Figures 1 through 21 as listed below:

Figures 1 through 3 are stresses from the 6" nozzle at the 6" nozzle/insert plate junction. It includes pressure and seismic loadings.

Figures 4 though 6 are stresses form the 8" nozzle at the 8" nozzle/insert plate. It includes pressure and seismic loadings.

Figure 7 through 9 are additional stresses from the 6" nozzle at the junction with the 8" nozzle. This approach assumes a fictitious attachment nozzle of 14-4.3125 = 9.6875" radius to reach the edge of the 8" nozzle. For these additional stresses the seismic and pressure stresses are not considered again.

Figures 10 through 12 are additional stresses from the 8" nozzle at the junction with the 6" nozzle. This approach assumes a fictitous attachment nozzle of 14 - 3.3125 = 10.6875" radius to reach the edge of the 6" nozzle.

Figures 13 through 15 are stresses from the 6" nozzle at the junction of the insert plate and shell. It includes pressure and seismic loading. This approach assumes a fictitious attachment radius of 12".

Figures 16 through 18 are additional stresses from the 8" nozzle at the junction of the insert plate and shell. A fictitious attachment radius of 12" was used. Pressure and seismic loadings were not added for these additional stresses.

Figures 19 through 21 are additional stresses at the shell/insert plate junction from a support on the 8" overflow line located in the vicinity of the two nozzles. The support is located 21" below the centerline of the 8" nozzle. A fictitious attachment radius of 9" was used (ref. D9). Loadings were determined from the PDM analysis (ref. D4).

The results of the Bijlaard analysis at the nozzle/insert plate junctions are tabulated below and compare the maximum principle stresses with the allowable stresses:

STRESSES AT NOZZLE/INSERT PLATE JUNCTION - PSI
(see figures 1 through 12 of this appendix)

	6" @ 6" JUNCTION	8" @ 8" JUNCTION	ADDITION 6" @ 8" JUNCTION	ADDITION 8" @ 6" JUNCTION	TOTAL 8" JUNCTION	TOTAL 6" JUNCTION	ALLOWABLE
NORMAL							
M	6334	6024	535	192	6559	6526	18350
M+B	12031	7875	3008	1033	10883	13064	27525
UPSET							
M	10022	9303	1020	304	10323	10326	20185
M+B	19881	12230	5712	1625	17942	21506	30278
FAULTED							
M	13347	12087	1643	400	13730	13747	36700
M+B	29561	15934	9218	2130	25152	31691	44040

The stress at the junctions of the nozzles and the insert plate are well within allowable limits.

This Bijlaard evaluation will also investigate stresses at the junction of the insert plate and shell. The distance from the center of the nozzle to the edge of the insert plate is 12 inches and this will be taken as the radius of the fictitious attachment radius. The shell vessel thickness T will be taken as 0.6563 inches.

The interaction at the junction of the insert plate and shell will also conservatively consider the 45 degree support on the bottom of the 8" overflow line (ref. D9) in this Bijlaard evaluation. The loads are obtained from the PDM analysis reference D4. The support loads are applied to the shell 21 inches below the centerline of the 8" pipe. The load is carried to the shell through a 10 inch diameter, 1/4" pad. The distance from the center of the pad to the edge of the insert plate is 21 -12 = 9 inches. Therefore a Bijlaard analysis will be performed with a fictitious attachment radius of 9 inches to conservatively evaluate the impact of the support on stresses at the insert plate/shell junction.

The loadings from the support are from reference D4 and are listed below:

SUPPORT LOADS FROM OVERFLOW LINE
(see page D62)

	AXIAL Px axial (lb)	SHEAR Py, long. (lb)	SHEAR Pz circ. (lb)	BENDING Mby, circ (in-lb)	BENDING Mbz long (in-lb)	TORSION Mtx torsion (in-lb)
Overflow support						
NORMAL,actual	2420	2420	0	0	0	0
UPSET,actual	3025	3025	0	0	0	0
FAULTED,actual	3630	3630	0	0	0	0

The maximum principle stress at the junction of the insert plate and shell are tabulated below. Stresses from the 6" nozzle were calculated considering the pressure and seismic stresses and conservatively added the effect of the 8" nozzle and the overflow support without seismic or pressure stress. The sum of these three cases conservatively represents the combined stresses at the insert plate junction. The combined stresses are tabulated below.

INTERACTION OF 6", 8" NOZZLE & OVERFLOW SUPPORT AT INSERT PLATE/SHELL JUNCTION - PSI
(see figures 13 through 21 of this appendix)

	6" @ SHELL JUNCTION	ADDITIONAL IMPACT 8" @ SHELL JUNCTION	ADDITIONAL IMPACT, SUPPORT @ SHELL JUNCTION	TOTAL	ALLOWABLE
NORMAL					
M	6901	453	1018	8372	18350
M+B	11539	2002	4922	18463	27525
UPSET					
M	11014	710	1270	12994	20185
M+B	18607	2847	6181	27635	30278
FAULTED					
M	14933	933	1512	17378	36700
M+B	26274	4090	7386	37750	44040

The stresses in the shell at the shell/insert plate junction are well within allowable limits even though they were combined conservatively by adding the magnitudes of the highest principle stresses.

CONCLUSION

The evaluation conducted above using a Bijlaard analysis demonstrates the acceptability of the latest nozzle loadings on the RWST tank. It includes the evaluation of the effect of adjacent nozzle and shows that when conservatively considering the interactions that the nozzles remain qualified.