ENCLOSURE 3

SUMMARY REPORT - PRIMARY PLANT MAKE UP STORAGE TANK UPGRADE

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PRIMARY PLANT MAKE UP STORAGE TANK UPGRADE

SAN ONOFRE NUCLEAR GENERATING STATION

UNITS 2 AND 3

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EXECUTIVE SUMMARY

In 1983, SCE implemented seismically qualified mobile fire tankers to provide the capability to supply make-up water to the Component Cooling Water (CCW) surge tank. This arrangement, however, proved to be very labor intensive to align and operate. Furthermore, several refills may be required for the tankers to perform their function for the entire required period of time.

To eliminate the reliance on the mobile tankers for CCW make-up, the Primary Plant Make-up Storage (PPMS) tanks were considered. It was necessary to upgrade these tanks from their original Quality Class III Seismic Category II design, to Quality Class II, Seismic Category I, and to reconcile the original construction standards to ASME Code, Section III, Subsection ND Code technical requirements (Class 3 tank with the exception of N-stamp and data reports). As a result, the tanks were reanalyzed in accordance with ASME Code, Section III, Subsection ND and Generic Implementation Procedure (GIP). To satisfy the new requirements, several modification to the tanks were implemented. The modifications included reinforcing the bottom section of the tank shell by three continuous rings, adding 36 stringers, 34 additional anchor bolts, and reinforcing the main manhole and three nozzle connections.

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1. INTRODUCTION

The existing Component Cooling Water (CCW) system at Southern California Edison's San Onofre Nuclear Generating Station (SONGS) Units 2 and 3 consists of two redundant trains (critical loops), and one non-critical loop which can be aligned to either one of the critical loops. The make-up water to the CCW surge tank is supplied by the seismically-qualified mobile fire tankers to ensure adequate water supply for a 7-day period. This arrangement, however, is very labor intensive to operate, and the mobile tankers may require several refills to perform their function for the desired 7-day time period.

To eliminate the reliance of the CCW system on the fire tankers for the make-up water, the primary plant make-up water system will be integrated into the CCW system to provide the necessary supply of make-up water. The make-up system will be modified to supply water to the CCW critical loops following loss of normal make-up from the nuclear service water system. It will provide the necessary water inventory to compensate for the maximum allowable leak from both CCW critical loops for a period of seven days.

The make-up system of each unit includes a 300,000 gallon Primary Plant Make-Up Storage (PPMS) tank, T-056 for Unit 2 and T-055 for Unit 3. These tanks were originally designed to the American Petroleum Institute (API)-620 Standard, 5th. Edition, and constructed and tested to API-650 Standard, 5th. Edition, and were classified Quality Class III Seismic Category II components. Both tanks have been upgraded to Quality Class II, Seismic Category I, and reconciled to the requirements of the American Society of Mechanical Engineers (ASME) Code, Section III, Class 3 with the exception of N-stamp and data reports. The ASME 1989 Code with no addenda was used in the reconciliation.

This report provides descriptions of the tank modifications, a summary of the results of the analyses, and the ASME Code reconciliation performed to upgrade the PPMS tanks. Additionally, the report provides a summary of the design input. Additional supporting documents are provided in Appendix A. Response to NRC questions and concerns is included in Appendix B.

2. SUMMARY OF RESULTS AND CONCLUSIONS

1. A Code reconciliation summary is presented in Table 2.1, the summary demonstrates technical compliance of all items except the following:

   (a) Not all the Certified Material Test Reports (CMTR's) for the tank material were retrieved, with 9 heat numbers for both tanks missing from a total of 35 heat numbers. A non-destructive examination (NDE) was performed at 16 locations in addition to 2 reference locations in each tank. Results showed that the material properties to be equivalent to the materials specified in the tank drawings. The available CMTR's and the NDE demonstrated that this requirement is met.

   (b) Weld defects beyond the Code allowable were uncovered by the additional 60 radiographs for Unit 2 and 61 radiographs for Unit 3. The defect numbers and sizes from the radiographs were used as basis for a statistical analysis to calculate with 95% confidence level the expected defect size anywhere in the tank seam welds. The statistical analysis result is then used in a fracture mechanics analysis to demonstrate the tank structural integrity. The analyses performed on both tanks using two separate sets of data concluded the tanks will sustain Design Basis Earthquake (DBE) loads. The analysis considered a through-wall crack size of 5 inches, with a factor of safety of 3.1. If such crack develops, the resulting amount of leak from the tank will be negligible compared to the capacity of the tank, and will not impact the function of the tank as the source of make-up water to the CCW system.

   (c) The existing shell to bottom weld is a double fillet weld in accordance with API 650, Section 3. ASME Subsection ND-4746.2 requires a full penetration weld. The calculation showed that the existing weld meets ASME Code allowable stress. Additionally, the reinforcements added to the bottom of the tank shell, in the form of 3 continuous rings, 68 additional gusset plates and 36 vertical stringers, which decrease the loading of the fillet welds, were not credited in the fillet weld calculation.

   (d) The tank shell manhole did not meet the ASME Code requirement for a reinforcement area. Reinforcing pads were installed on the manhole. Additionally, reinforcing pads were added to 3 nozzles to reduce local stresses in the tank shell.

2. As a result of the seismic upgrade evaluation the following modifications were implemented:

   - Bottom plate extended by a continuous ring.
   - Bottom section of the tank shell was reinforced by two continuous rings and 36 stringers.
   - Additional 34 anchor bolts.
   - Reinforcement pads for the main manhole and three connecting nozzles.
   - Tank drain pipe and valve were replaced.
   - Tank overflow pipe was replaced.

3. The seismic analysis was based on Generic Implementation Procedure (GIP), Reference 5, which addressed both modes of general buckling of the tank shell. To address buckling at higher elevations above the reinforced section of the tank shell Code Case N-284 methodology was utilized. The methodology developed by M.A. Haroun (Reference 28) was used to generate the forcing function on the roof due to sloshing of water against the roof during an earthquake.

   Based on the seismic evaluation results, it is concluded that the stresses in the modified tanks will remain within the values of the Code allowable stresses during a DBE seismic event. The structural integrity of the modified tanks will be maintained during such event.

4. PPMS tank anchorage and concrete were evaluated for DBE and OBE loads, and were found acceptable. The evaluation included bolt loads, shear-tension interaction, shear cone in concrete, bearing stress, bolt spacing and edge distance.

In summary, the modified tanks were reconciled to the technical requirements of ASME III, Subsection ND, and are equivalent to ASME III Class 3. The new modifications satisfy Seismic Category I criteria, ASME Code technical requirements, and additional requirements, i.e., GIP and Code Case N-284. The additional radiographs guarantee appropriate representation of weld defects. Results of the fracture mechanics analysis demonstrated adequate safety margins.

Table 2.1 Code Reconciliation Matrix

ITEM	ASME III SEC. ND	AS BUILT	RECONCILIATION
PLATE MATERIAL	ND-2121	SA-240, 304 [DRAWINGS S023-407-3-61, 62,63, 64]	TECHNICAL REQUIREMENTS MET
CMTRS	ND-2130	CMTRS ARE UNAVAILABLE FOR 9 HEAT NUMBERS IN BOTH TANKS. TOTAL HEAT #S ARE 35	NDE PERFORMED @ 16 LOCATIONS PLUS 2 REF LOCATIONS EACH TANK [RCE-93-013, RCE-93-014] TO VERIFY MATERIAL PROPERTIES: UT, HARDNESS, CHEMICAL REQUIREMENTS MET
BOLT CHAIR		-	REPLACED. TWO RING DESIGN SA-36, PLUS 36, 6 FOOT STRINGERS RUNNING TO UPPER RING. [DCP-6742] REQUIREMENTS MET
FLANGE BOLTING	ND-2128	SA-193, GR B7	REPLACED, REQUIREMENTS MET
WELDING	ND-2400, SPECIFIES ASME SEC. IX	API 650, SEC. 7, SPECIFIES ASME SEC. IX	EQUIVALENT, REQUIREMENTS MET
WELD EXAMINATION	ND-5300	API 650, SEC 6,	SEE DETAIL COMPARISON S/A-1415-1, PAGE 9. IDENTIFIED DEFECTS FROM THE GRAPHS WERE USED AS BASIS FOR STATISTICAL AND LINEAR FRACTURE MECHANICS EVALUATIONS USING SEC XI GUIDELINES. REQUIREMENTS SATISFIED
	ND-5420, MINIMUM EXTENT OF SPOT RADIOGRAPHIC EXAMINATION	API 650, PARAGRAPH 6.1.3	ADDITIONAL 60 RADIOGRAPHS U2, AND 61 U3. REQUIREMENTS EXCEEDED
DESIGN	ND-3811.2 => ND-3100, - GIP - CODE CASE-284 ND-3352 JOINT EFF 85%	-API 620,	NEW ANALYSIS PERFORMED TO ADDRESS THIS SECTION REQUIREMENTS. RESULTS: - INCREASED # OF BOLTS BY 36 -TANK BOTTOM EDGE EXTENSION - NEW BOLT CHAIR - UPPER RING AND 36 STRINGERS -NOZZLE REINFORCEMENT [CALCULATION M-DSC-280 FOR UNIT-2] [CALCULATION M-DSC-269 FOR UNIT-3] REQUIREMENTS MET
	ND-3821.3 LOADING=> ND-3111	-API 620	LOADS CONSIDERED: PRESSURE WEIGHT SSE INCLUDED FLUID RESPONSE (SLOSHING) NOZZLE LOADS REQUIREMENTS MET
	ND-3112.4 ALLOWABLE STRESSES	-API 620	REANALYZED TO ASME SEC III REQUIREMENTS MET
OPENINGS	ND-3332, 3335	-	REINFORCEMENT AND LOCAL STRESSES CHECK ADDED REINFORCING PADS FOR SHELL MANHOLE AND THREE NOZZLES REQUIREMENTS MET

Table 2.1 Code Reconciliation Matrix - cont.

BOTTOM PLATE	ND-3831 (a), BOTTOM PLATE MIN. THICKNESS OF 1/4"	API 650, PARAGRAPH 3.2.1, 1/4"	EQUIVALENT, REQUIREMENTS MET
FOUNDATION DESIGN	ND-3831 (c), TYPE OF FOUNDATION, REFERS TO API 650, APPENDIX B	API 650, APPENDIX B	EQUIVALENT, # OF BOLTS INCREASED FROM 36 TO 70 REQUIREMENTS MET
SHELL	ND-3842, SHELL PLATE MIN. THICKNESS OF 3/16"	API 650, PARAGRAPH 3.3.3, 3/16"	EQUIVALENT, REQUIREMENTS MET
ROOF	ND-3852, GENERAL ROOF DESIGN	PARAGRAPH 3.5	EQUIVALENT, REQUIREMENTS MET
FABRICATION	ND-4000	API 650, SECTIONS 5 &6	RECONCILED, REQUIREMENTS MET
	ND-4224, OVALNESS TOLERANCE MAX DEVIATION 4.8"	NO REQUIREMENTS	ACTUAL DIAMETRAL DEVIATIONS WERE VERIFIED AND FOUND ACCEPTABLE. U2 MAX 2.64", U3 MAX 2.4" [M-DSC-280--U2] [M-DSC-269--U3] REQUIREMENTS MET
	ND-4232, ALIGNMENT, 1/4t VERTICAL AND HORIZONTAL	API 650, PARAGRAPH 5.2.3	COMPARABLE, THE API REQUIREMENTS ARE MORE STRINGENT THAN THE ASME CODE FOR THE LOWER SHELL COURSES, WHERE THICKNESS OF THE PLATE IS > 1/4" REQUIREMENTS MET
	ND-4246.2, BOTTOM TO SIDEWALL: FLAT BOTTOMS SHALL BE ATTACHED TO SIDEWALLS BY FULL PENETRATION WELDS.	API 650, SECT. 3, ALLOWS DOUBLE FILLET	QUALIFIED BY STRESS ANALYSIS PER ND-3852.6 (d) (1) [M-DSC-280--U2] [M-DSC-269--U3] REQUIREMENTS MET
TESTING	ND-6500, FILL WITH WATER	API 650, FILL WITH WATER	EQUIVALENT, TANK RETESTED AFTER MODIFICATION, REQUIREMENTS MET
OVER PRESSURE PROTECTION	ND-7000, NONE REQUIRED, VENT CAPACITY IS ADEQUATE TO KEEP TANK AT ATMOSPHERIC PRESSURE	NO REQUIREMENTS	VENTING REQUIREMENTS ARE MET REQUIREMENTS MET
ISI			SURVEILLANCE, MAINTENANCE, REPAIR AND REPLACEMENT PER ASME SECT. XI REQUIREMENTS MET

OTHER ND REQUIREMENTS WERE VERIFIED VERSUS API AND FOUND EQUIVALENT. THEREFORE, REQUIREMENTS ARE MET: ND-3861,3862,3863,4246.1,4246.3,4246.4,4246.5,4246.6,4246.7,4300,5282.

3. DESIGN ASSUMPTIONS

1. The weight of nozzles, the ladder, and reinforcing stringers is assumed negligible compared to the weight of the tank and its water content.

2. Seismic structural interaction was not considered in the analysis. The interaction effects have been included in the development of seismic spectra used in the seismic analysis of the tanks.

3. The existing anchor bolts and the additional anchor bolts share the applied loads according to the ratio of their bolt areas.

4. Flexibility analysis was performed on the piping lines attached to the PPMS tanks using decoupled models of these lines to reduce the complexity of the models. The decoupling is technically acceptable based on the following considerations:

   - Since the sizes of the piping attached to the tank are very small (4″ or less) compared to the size of the tank, the interaction between the piping and the tank shell should be confined to the region of the shell surrounding the nozzle connection.

   - The nozzles are well separated from each other. Therefore, no interaction between the different nozzles is expected.

5. The ratio t_{eff}/R (effective wall thickness/tank radius) was calculated at 0.00091, which falls below the 0.001 to 0.01 applicable range, in the Generic Implementation Procedure (GIP), for the tank parameters. However, it is conservative to use the GIP curves assuming $t_{eff}/R=0.001$ based on trend of these curves.

Additional design assumptions can be found in Reference 33 (evaluation of PPMS tank anchorage).

4. TANK DESCRIPTION AND DESIGN INPUT

4.1 Tank General Data and Description

The Primary Plant Make-Up Storage Tanks (PPMS) at San Onofre Nuclear Generating Station (SONGS) were manufactured by Brown-Minneapolis Tank and Fabricating Company. The following is original general design data of the PPMS tanks:

- Tag number : T-056 for SONGS Unit-2,
  T-055 for SONGS Unit-3

- Main dimensions

  Figure 4.1 shows the following main dimensions of the PPMS tank:

Diameter	: 40 ft inside diameter
Height	: 34 ft high
Wall thickness	: 5/16″, 1/4″ and 3/16″ depending on elevation above the bottom of the tank (see Figure 4.1)
Roof radius	: 48 ft
Roof thickness	: 1/4″
Bottom thickness	: 1/4″

- Design pressure : atmospheric

- Capacity : 300,000 gallons

- Material : type 304 stainless steel plates. Material Spec number: SA240, Grade 304

- Anchor bolts chairs : the tanks are anchored to the foundation by 36 equally-spaced anchor bolts. The anchor bolt chair material is A-36 in the original design. Modified chair material is SA-36.

- Code of Design and Analysis

  The tanks were constructed to API-650, 5th. Edition, including Supplement number 1. Analysis was performed per API-620, including Supplement number 1.

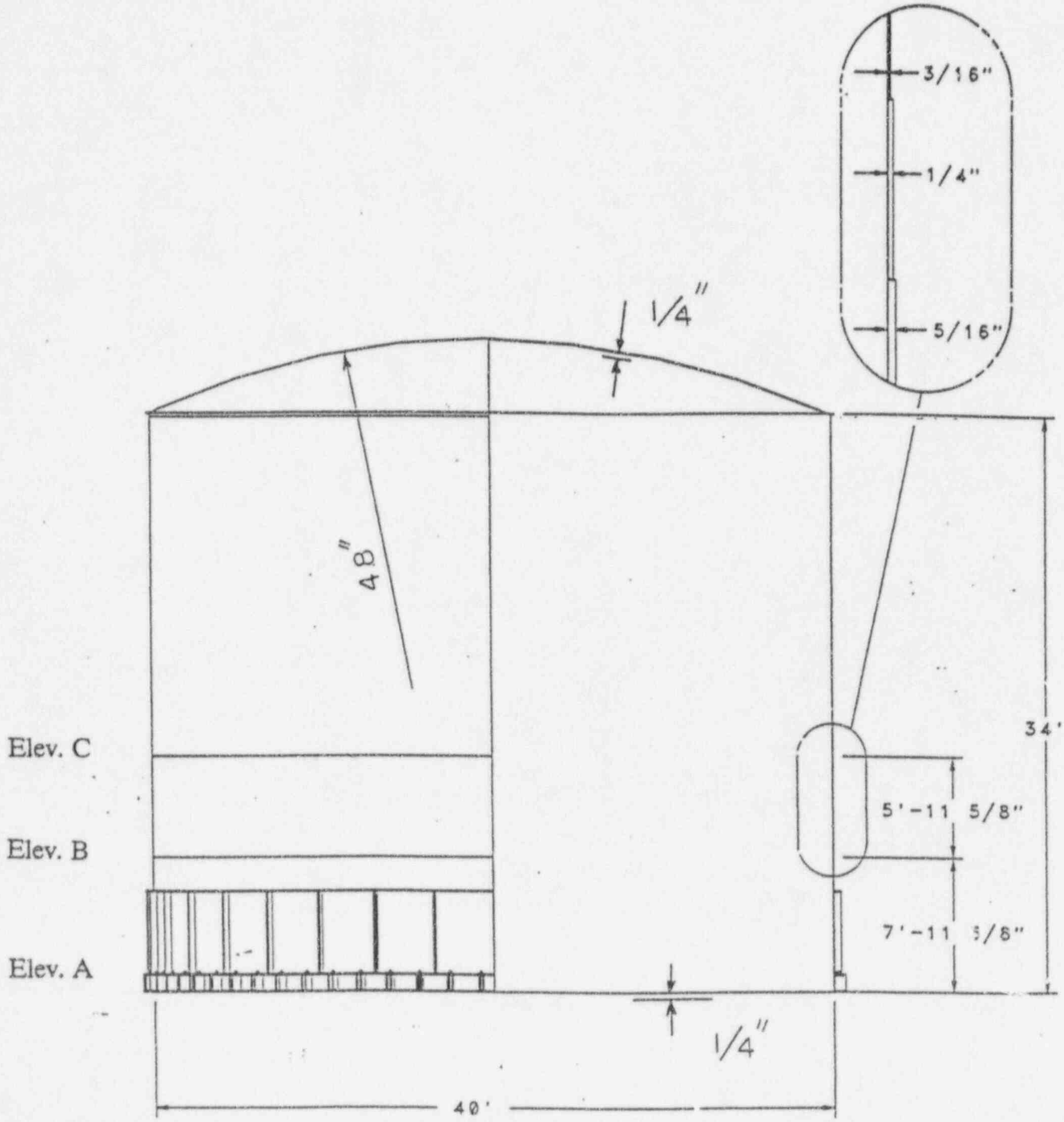


Figure 4.1 Main Dimensions of the PPMS tank

4.2 Material Properties

Tank Plates Material: Stainless Steel, SA 240-304 (Reference 25)

The following material properties of SA 240-304, at 120°F[(1)], were used in the analysis (Reference 2):

> Young's modulus (E) = 28.0 x 10^6 psi (Reference 2)
>
> Yield strength (S_y) = 29,000 psi (Reference 2)
>
> Allowable stress intensity (S_m) = 20,000 psi (Reference 2)

Anchor bolt chair material: SA-36 (Reference 24)

> Yield stress (f_y) @ 110°F = 3[illegible]68 ksi (Reference 2)
>
> Allowable stress (S) @ 110°F = 1.[illegible]6 ksi (Reference 2)

Note (1): The actual design temperature, per FCN F-7519M for P&ID number 40133, is 104°F. Therefore, the use of 120°F as the reference temperature for material properties is conservative.

4.3 Anchor Bolt Assemblies

Figure 4.2 shows the main dimensions of a typical anchor bolt assembly. Two different bolt sizes exist in the tank after modification:

1. 1½″ ASTM A307 bolts (36 original anchor bolts),
2. 2″ ASTM A615 bolts (34 new anchor bolts).

Also, a ring was welded to the outside edge of the bottom plate as shown in Figure 4.2. Holes for anchor bolts were drilled in the ring (1⅝″ for the original bolts, and 2⅛″ for the new bolts).

4.4 Reinforcing Bars

Per Reference 4, the concrete base is reinforced by #18 size reinforcing bars (rebars). These rebars are 2.257″ in diameter and are separated by 16″ center-to-center distance.

4.5 Nozzle and Piping Data

The nozzle loads evaluated are given in data sheets, attached in Southern California Edison Calculation No. M-DSC-280, Appendix D, which were extracted from various calculations as noted in the nozzle load data sheets.

The following piping is attached to the PPMS tank:

4″ Sch. 40S SA-312 TP304 @ elev. 31′-0″	(PPMS Suction)
4″ Sch. 80 SA-312 TP304 @ elev. 9′-9 13/16″	(Overflow)
3″ Sch. 40S SA-312 TP304 @ elev. 11′-0″	(CCW Suction)
3″ Sch. 80 SA-312 TP304 @ elev. 8′-5″	(Drain)
2½″ Sch. 40S SA-312 TP304 @ elev. 31′-0″	(PPMS Fill Inlet)
2″ Sch. 80S SA-312 TP304 @ elev. 31′-0″	(PPMS Recirculation)
1″ Sch. 80S SA-312 TP304 @ elev. 16′-0″	(CCW mini-flow)

4.6 Response Spectra

The following SONGS 2 & 3 response spectra were used in the seismic evaluation and are included in Appendix A.

(a) DBE Horizontal Response Spectra, 20689, Revision 0.

(b) DBE Vertical Response Spectra, 20690, Revision 0.

(c) OBE Horizontal Response Spectra, 20713, Revision 0.

(d) OBE Vertical Response Spectra, 20714, Revision 0.

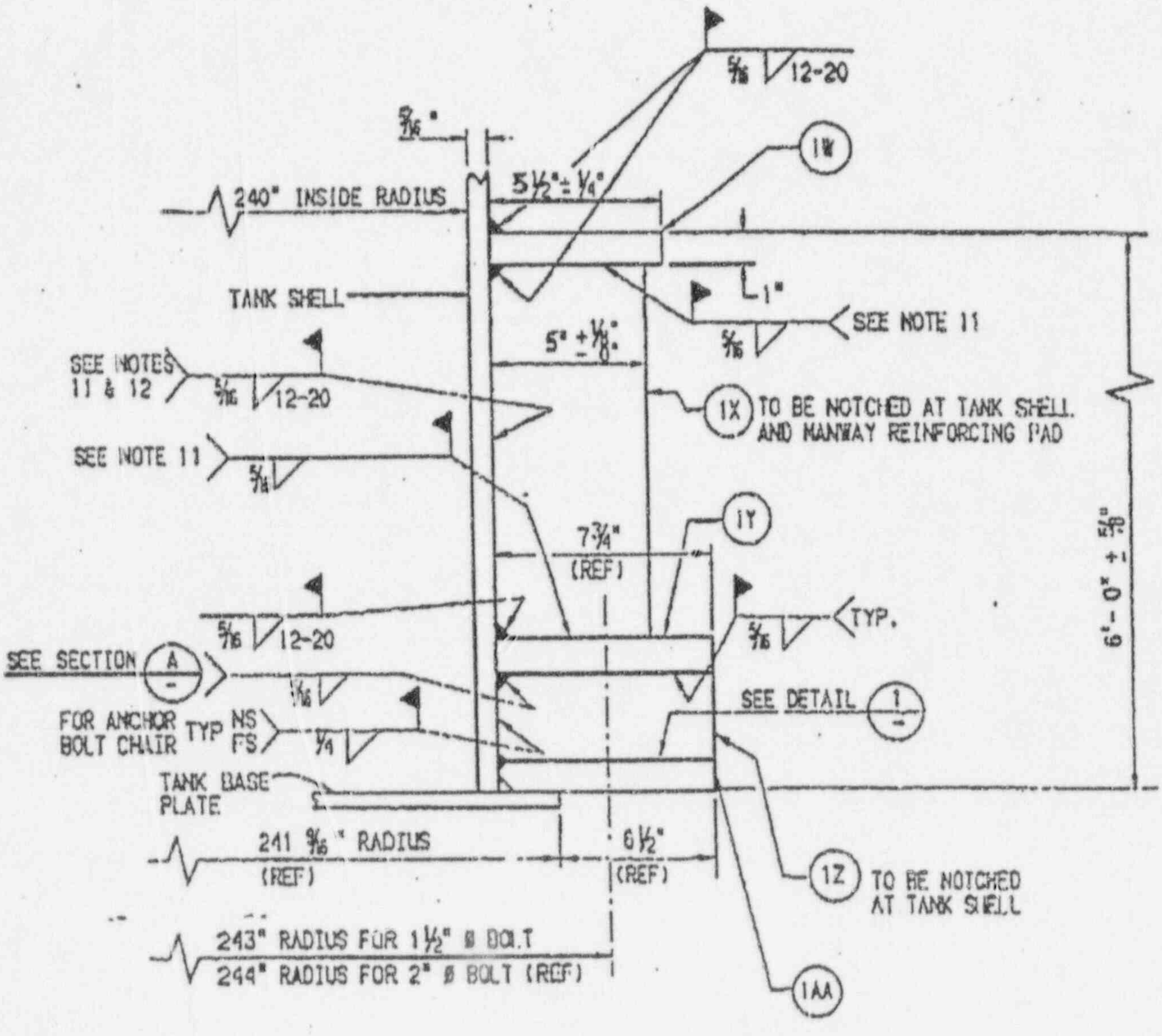


Figure 4.2 Modified Anchor Bolt Assembly

5. METHODOLOGY AND SIGNIFICANT RESULTS

The tank upgrade design report was prepared by Structural Integrity Associates, Inc. of San Jose, California. This report is included, in its entirety, in SCE Calculations No. M-DSC-280 for Unit-2 and M-DSC-269 for Unit-3. The methodology of the seismic analysis is based on "Generic Implementation Procedure (GIP) for Seismic Verification of Nuclear Plant Equipment," Reference 5; ASME Code Case 284, Reference 29; and according to ASME Boiler and Pressure Vessel Code Section III, Reference 2. The PPMS tank design methodology is summarized in Section 5.1 of this report, which includes the following subsections:

- Section 5.1.1 includes the tank design per GIP procedure (Reference 5). This section also includes the roof evaluation for sloshing loads, and qualification of the tank to ASME Code design rules.

- Section 5.1.2 includes the application of ASME Code Case N-284 (Reference 29) analysis methodology. The additional analysis per Code Case N-284 deals with the reinforced modified tank since the GIP procedure does not cover the effect of the tank reinforcing stiffeners (stringers). Code Case N-284 was also used to evaluate the tank shell at different elevations since the GIP procedure addresses only the bottom elevation.

Additional analyses included :

1. Tank shell stresses,
2. Bolt stresses,
3. Nozzle stiffness,
4. Tank shell local stress at nozzle connections, and
6. Out-of-roundness check.

The methodologies used in these analyses are summarized in sections 5.2 through 5.8 of this report.

Since the tank shell welding did not meet the ASME Code requirements, additional radiographic examination was performed to provide a statistical sample for characterizing the tank welding defects. The statistical analysis was followed by a fracture mechanics analysis based on worst case defect to demonstrate acceptability of the welds with high degree of reliability. A summary of the methodologies used is provided in Section 5.9 of this report; details can be found in SCE Calculations M-DSC-280 and M-DEC-269, Appendices E and F.

A summary of the PPMS tank anchorage evaluation is provided in Section 5.10.

5.1 Modified PPMS Tank Seismic Evaluation

5.1.1 Analysis Per GIP (Reference 5)

The methodology outlined in this section is based on Chapters 4, 5 and 7 and Appendix C of GIP (Reference 5). The analysis includes the following evaluations of :

- Tank shell buckling
- Anchor bolts and their embedments
- Bolt chair

The seismic evaluation of the tank is performed using the step-by-step procedure of the GIP. There are 22 steps, these steps and the results summary are given below :

Step 1 Input data

R	Nominal radius of the tank, = 240″
H'	Height of tank shell, = 408″
t_{min}	Minimum shell thickness at the top of the tank, = 0.1875″
t_s	Minimum thickness of the tank shell in the lowest 10% of the tank shell, = 0.3125″
t_{se}	Adjusted tank shell thickness to account for the added stringers, = 0.4764″
σ_y	Yield strength of the tank shell material, = 29,000 psi
h_c	Height of anchor bolt chair, = 12.75″
E_s	Young's modulus of the tank shell material, = 28.03E6 psi
γ_f	Weight density of fluid in tank, = 0.0361 lb_f/in^3
H	Maximum height of fluid in the tank, = 384″
h_f	Height of freeboard above fluid surface, = 34.15″
N	Number of anchor bolts = 36
d	Diameter of existing anchor bolt, = 1.5″
h_b	Effective length of bolt from anchor plate to chair top, = 40.75″
E_b	Young's modulus of anchor bolt material, = 29.28E6 psi
V_s	Average shear wave velocity of soil, (the tanks are located inside the building on a thick foundation. Therefore, V_s will not be considered further).

Step 2 Calculate the following ratios and values:

$H/R = 1.6$

$t_{se}/R = 0.002$

$t_{av} = (\Sigma\, t_i\, h_i)/H', \quad i=1,n$

$= 0.2488''$

where : n = total number of sections of the tank shell with different thicknesses,

t_i, h_i = the thickness and height of the <u>ith</u> section of the tank shell.

$t_{ef} = (t_{av} + t_{min})/2 = 0.2182''$

$t_{ef}/R = 0.00091''$

$A_b = \pi d^2/4 = 1.7671 \text{ inch}^2$

$t' = [(N A_b)/(2 \pi R)](E_b/E_s) = 0.109''$

$c' = (t'/t_s)(h_c/h_b) = 0.1091''$

$W = \pi R^2 H \gamma_f = 2{,}508{,}481$ lb.

<u>Step 3</u> Find fluid-structure modal frequency, F_f Hz

Enter Table 7-3 (GIP, Section 7, Page 7-35) with: R, t_{ef}, and H/R from Steps 1 and 2, and read,

$F_f = 7.58$ Hz

$F_f(s,f) = 7.58*(28.03/30)^{0.5} = 7.33$ Hz (stainless steel tank adjustment)

<u>Step 4</u> Find spectral acceleration (Sa_f)

Determine the maximum spectral acceleration (Sa_f), for 4% damping, and over a range of F_f +/- 20%.

From the spectra read,

$Sa_f = 1.15$ g (Design Basis Earthquake)
$Sa_f = 0.75$ g (Operating Basis Earthquake)

<u>Step 5</u> Base shear load (Q)

Calculate shear load coefficient, Q', using Figure 7-3 of GIP (Reference 5) corresponding to H/R and t_{ef}/R, both from Step 2. Calculate base shear load, Q

$Q' = 0.71$

$Q = Q' \, W \, Sa_f = 2{,}048{,}175$ lb.

<u>Step 6</u> Base overturning moment (M)

Calculate base overturning moment coefficient M' using Figure 7-4 of GIP (Reference 5) corresponding to H/R from Step 2. Calculate overturning moment, M

$M' = 0.345$

$M = M' \, W \, H \, Sa_f = 3.82 \times 10^8$ in-lb

The seismic capacity of the tank shell and anchorage to resist the overturning moment (M) calculated in Step 6 above is evaluated below. The overturning moment is resisted by compression in the tank wall, and tension in the anchor bolts. Thus, the overturning moment capacity is controlled by shell buckling on the compression side, and anchor bolt capacity on the tension side.

<u>Step 7</u> Bolt tensile capacity

In this step, the anchor bolt tensile load capacity (P_u lb) is calculated per Section 4 and Appendix C of Reference 5. This bolt capacity is based on "ductile failure" in the bolt rather than the concrete. The allowable bolt stress (F_b) is given by:

$P_u = 76{,}368$ lb (combined tensile strength of existing and new bolts)

$V_{all} = 38{,}259$ psi (combined shear strength of existing and new bolts)

$F_b = P_u/A_b = 33{,}941$ psi

Next step is to determine the anchorage connection capacity to resist the bolt tensile load capacity (P_u) calculated above.

<u>Step 8</u> Top plate

The top plate transfers the anchor bolt load to the vertical stiffeners and the tank wall (see Figure 4.2). The maximum bending stress in the top plate is given by:

$$\sigma = \frac{(0.375g - 0.22d)\,P_u}{f\ c^2}$$

σ = 39,100 psi > f_y (=35,680 psi for A-36 at 110°F)

The top plate is adequate if $\sigma < f_y$. If this condition is not met, calculate the load reduction factor f_y/σ. This reduction factor is applied to F_b to calculate reduced allowable bolt stress (F_r) as follows:

$F_r = F_b\ (f_y/\sigma)$ psi

F_r = 30,562 psi

The reduced bolt stress allowable should be used to calculate the tank overturning moment capacity.

Step 9 Tank shell stress

The anchor bolt loads are transferred to the tank shell as a combination of direct vertical load and bending moment. The maximum bending stress in the tank shell is:

$$\sigma = \frac{P_u e}{t_s^2}\left[\frac{1.32\ Z}{\dfrac{1.43\ a\ h^2}{R\ t_s^2} + (4\ a\ h^2)^{0.333}} + \frac{0.031}{\sqrt{R\ t_s}}\right]$$

where

$$Z = \frac{1.0}{\dfrac{0.177\ a\ t_b}{\sqrt{R\ t_s}}\left(\dfrac{t_b}{t_s}\right)^2 + 1.0}$$

Z = 0.936

σ = 50,452 psi > f_y (=29,000 psi)

The tank shell is adequate if $f_y > \sigma$. If this condition is not met, calculate the load reduction factor f_y/σ. This reduction factor is applied to F_b to calculate reduced allowable bolt stress (F_r) as follows:

$F_r = F_b\ (f_y/\sigma)$

F_r = 19,509 psi

The reduced bolt stress allowable was used to calculate the tank overturning moment capacity.

Step 10 Vertical stiffener plates

Vertical stiffener plates are considered adequate for shear stress, buckling, and compressive stress if the following three guidelines are satisfied:

$$\bullet \ \frac{k}{j} < \frac{95}{\sqrt{\frac{f_y}{1000}}}$$

k/j = 4.5 < 15.90

$$\bullet \ j > 0.04(h - c) \text{ and } j > 0.5 \text{ inch}$$

$j = 0.75'' > 0.465''$

$$\bullet \ \frac{P_u}{2\,k\,j} < 21{,}000 \text{ psi}$$

$P_u/2kj$ = 15,085 psi < 21,000 psi [O.K.]

where the dimensions k and j are the stiffener width and thickness, respectively.

Step 11 Chair-to-tank wall weld

The load per linear inch of weld is given by:

$$W_w = P_u\sqrt{\left(\frac{1}{a + 2h}\right)^2 + \left(\frac{e}{a\,h + 0.667\,h^2}\right)^2} \leq \frac{30{,}600\,t_w}{\sqrt{2}}$$

W_w = 1,807 lb/in

$30,600\ t_w/\sqrt{2} = 5,409$ lb/in $> W_w$ [O.K.]

where allowable weld strength is 30,600 psi per GIP, $t_w = 0.25''$.

Step 12 Fluid pressure for elephant foot buckling

The fluid pressure coefficient for elephant foot buckling (P_e') is determined by entering Figure 7-7 of GIP with Sa_f from Step 4 and H/R from Step 2. Then the fluid pressure at the base of the tank (P_e) is given by:

$P_e = P_e' \gamma_f R = 24.26$ psi

Step 13 Elephant-foot buckling stress capacity factor

Determine the elephant-foot buckling stress capacity factor using the following formula:

$$\sigma_{pe} = \frac{0.6E_s}{(R/t_{se})}\left[1-\left(\frac{P_eR}{\sigma_y t_{se}}\right)^2\right]\left[1-\frac{1}{1.12+S_1^{1.5}}\right]\left[\frac{S_1+\sigma_y/36,000}{S_1+1}\right]$$

where

$S_1 = R/(400\ t_{se}) = 1.26$

P_e = elephant-foot buckling stress capacity factor from Step 12, = 24.26 psi.

E_s = elastic modulus of elasticity of tank shell material from Step 1, = 28.03E6 psi.

R = nominal radius of tank from Step 1, 240″.

t_{se} = minimum thickness of tank shell in the lowest 10% of the shell height (H′), from Step 1, adjusted to account for stringers
= 0.4764″

σ_{pe} = 15,191 psi

Step 14 Fluid pressure for diamond-shape buckling

The fluid pressure coefficient for diamond-shape buckling (P_d') is determined by entering Figure 7-9 with Sa_f from Step 4 and H/R from Step 2. Then the fluid pressure at the base of the tank (P_d) is given by:

$P_d' = 2.063$

$P_d = P_d' \gamma_f R = 17.87$ psi

Step 15 Diamond-shape buckling stress capacity factor

Determine the diamond-shape buckling stress capacity factor using the following formula:

$$\sigma_{pd} = (0.6\gamma + \Delta\gamma) \frac{E_s}{R/t_{se}}$$

where

$$\gamma = 1 - 0.73(1 - e^{-\phi}) = 0.449$$

$$\phi = \frac{1}{16}\sqrt{\frac{R}{t_{se}}} = 1.40$$

where : $\Delta\gamma$ = increase factor for internal pressure from Figure 7-11, = 0.12.

$\sigma_{pd} = 21{,}680$ psi

Step 16 Allowable buckling stress

The allowable buckling stress (σ_c) is calculated as 72% of the lower value of σ_{pe} or σ_{pd}, i.e.,

$\sigma_c = 0.72\,[\min.(\sigma_{pe}, \sigma_{pd})] = 10{,}938$ psi

Step 17 Overturning moment capacity

The base overturning moment coefficient for ductile failure (M'_{cap}) is determined from GIP, Figure 7-12 with c' from Step 2, σ_c (psi) from Step 16, F_b (psi) being the smaller of F_b from

Step 7 or F_r from either Step 8 or Step 9. Finally, obtain h_c and h_b from Step 1.

$$M'_{cap} = 0.13$$

$$M_{cap} = (M'_{cap})(2F_b)(R^2t_s)(h_b/h_c)$$

$$M_{CAP} = 4.45x10^8 \text{ in-lb}$$

Step 18

Compare the overturning moment capacity of the tank (M_{cap}) from Step 17 with the overturning moment (M) from Step 6. The tank is considered adequate if

$$M_{cap} \geq M$$

M_{cap} (=4.45x10^8 in-lb) > M (=3.82x10^8 in-lb) [O.K.]

Step 19 Base shear load capacity

Compute the base shear load capacity as follows:

$$Q_{cap} = 0.55\ (1 - 0.21\ Sa_f)\ W + 70^* V_{all}/2$$

$$Q_{cap} = 2.38x10^6 \text{ lb}$$

Using Sa_f from Step 4, W from Step 2 and V_{all} from step 7.

Step 20

Compare the base shear load capacity of the tank (Q_{cap}) from Step 19 with the base shear load (Q) from Step 5. The tank is considered adequate if

$$Q_{cap} \geq Q$$

Q_{cap} (=2.38x10^6 in-lb) > Q (=2.048x10^8 in-lb) [O.K.]

Step 21 Slosh height

The slosh height is given by the following equation:

$$h_s = 0.837\ R\ Sa_s$$

where Sa_s is the spectral acceleration (1/2% damping) of the ground at the sloshing mode (F_s), which is calculated as follows:

$$F_s = \frac{1}{2\pi}\sqrt{\frac{1.84G}{R}\tanh(1.84\frac{H}{R})} \quad Hz$$

where : G = acceleration of gravity (=386.4 in/sec^2)
F_s = 0.2732 Hz, Sloshing period = 3.66 seconds

$h_s = 0.837 \, R \, S_{as} = 301.32''$

Step 22 Available freeboard

Compare the available freeboard (h_f) from Step 1 within the slosh height (h_s) calculated in Step 21. The tank is adequate if $h_f \geq h_s$,

$h_s = 301.32'' > h_f = 34.15''$

Water will slosh against the roof. An evaluation is performed below.

Roof Qualification for Sloshing

Since the guideline of Step 22 above was not satisfied, the hydraulic forces acting on the roof due to sloshing were calculated as follows:

- The vertical force exerted by the sloshing water would be the sloshing mass times the maximum vertical acceleration (0.77g for DBE per Section 4.6).

  $FV_{DBE} = 0.29*2{,}508{,}481*0.77 = 560{,}144$ lb.

- Conservatively, calculate the horizontal sloshing water volume as the entire volume under the roof and above the cylindrical shell. The sloshing water mass is then calculated by multiplying by the density of water. The horizontal force would be the sloshing mass times the maximum horizontal acceleration (1.15g for DBE).

  $FH_{DBE} = 0.0361*4{,}814{,}637*1.15 = 199{,}880$ lb.

- Calculate the total sloshing load on the roof as the square root of the sum of the squares of the horizontal and vertical sloshing.

  $F_{DBE} = 594{,}738$ lb.

- The equivalent pressure due to the sloshing water is the total force divided by πR^2 (3.29 psi) and the additional membrane stress caused by the pressure is simply $F/2\pi Rt$, where t is the roof thickness ($t = 0.25''$).

  Thus, the additional membrane stress due to sloshing water is 7,580 psi which are much smaller than the Code allowable value of 35,680 psi for DBE per ASME ND-3821.5.

- The stresses at the tank-to-roof weld is $F/2\pi Rt_{throat}$, where F is the total force on the roof due to sloshing, and $t_{throat} = 0.1326''$.

σ_{weld} (DBE) = 2.97 ksi which is much smaller than the Code allowable value of 35.68 ksi. [O.K.]

5.1.2 ASME Code Case N-284

The GIP methodology described in Section 5.1.1 is based on calculating the overturning moment and base shear at the bottom of the tank, where both quantities reach their maximum values. The methodology of a paper, by M. A. Haroun published in 1983 (Reference 27), was used to calculate the moment and shear loads at various levels of the tank. These moment and shear loads were used to qualify the tank shell per ASME Code Case N-284 at the following levels:

- Elevation A: at the bottom of the tank.
- Elevation B: at the top of the first tier (see Figure 4.1).
- Elevation C: at the top of the second tier (see Figure 4.1).

ASME Code Case N-284 provides an alternative methodology for determining the allowable compressive stress in the tank shell. This methodology is defined for both unstiffened and stringer stiffened cylindrical shells.

Result:

Elevation A: σ_ϕ = 28,528 psi < $\sigma_{\phi\text{-all}}$ (=64,235 psi) [O.K.]

Elevation B: σ_ϕ = 28,108 psi < $\sigma_{\phi\text{-all}}$ (=38,620 psi) [O.K.]

Elevation C: σ_ϕ = 13,445 psi < $\sigma_{\phi\text{-all}}$ (=33,404 psi) [O.K.]

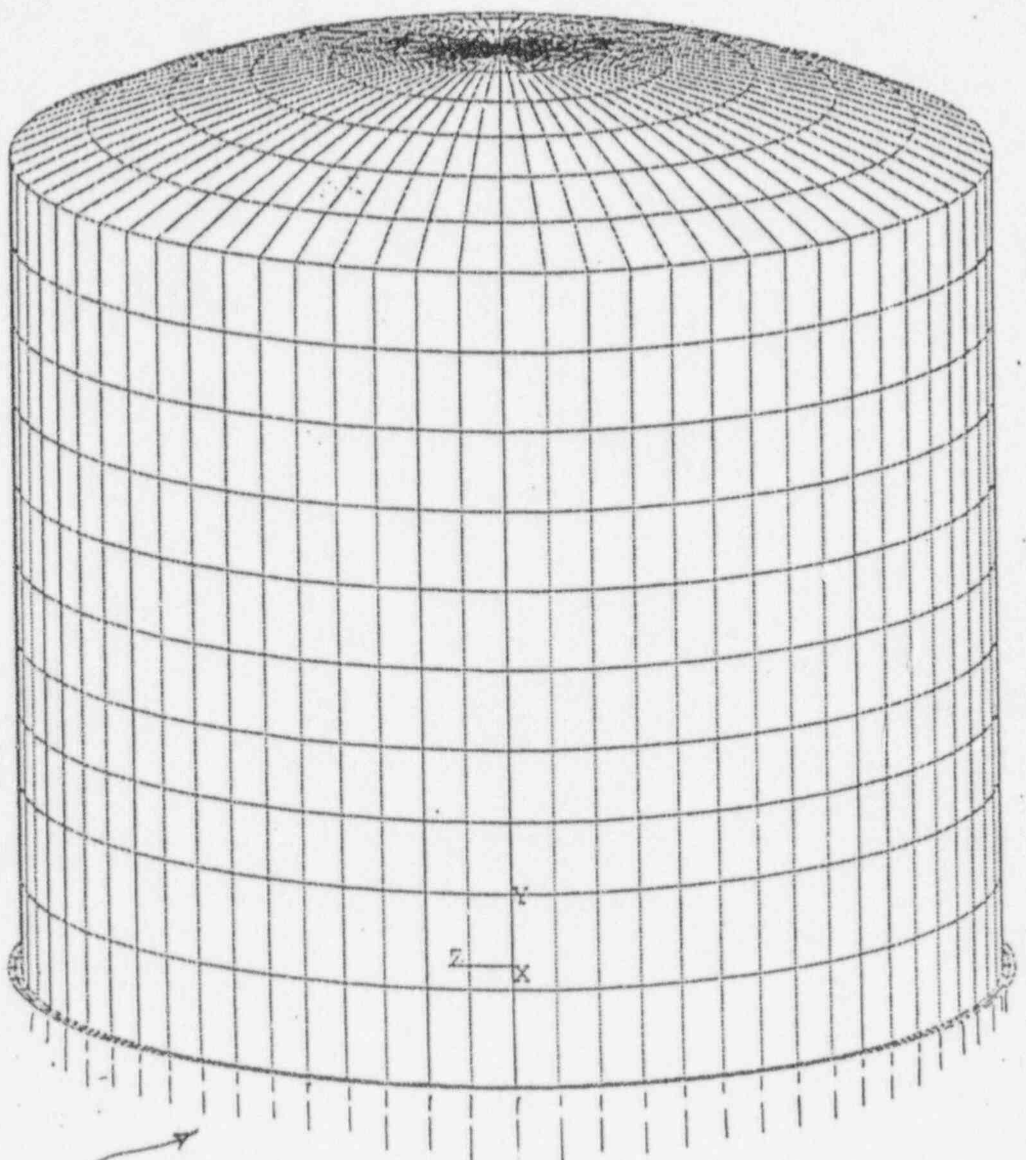
where σ_ϕ is the axial compressive stress, at the indicated level, in the tank shell, and $\sigma_{\phi\text{-all}}$ is the corresponding calculated allowable stress.

5.2 Angular Distribution of Shear Load in the Anchor Bolts

To determine the maximum shear stress in the tank anchor bolts, to evaluate the anchor bolt chair bottom ring,a sinusoidal shear force distribution was assumed. A finite element analysis was performed to verify this assumption. A tank model was generated using the finite element program ANSYS. The model is made up of ANSYS element type STIF63, which is an elastic quadrilateral shell element (Reference 3). This element type has six degrees of freedom at each corner node: translations in the x, y and z directions, and rotations about the x, y and z axes. The element has stress stiffening and large deflection capabilities. It is also capable of modeling plates on elastic foundations. This feature was utilized to model the bottom plates.

Figure 5.1 shows a computer plot of the finite element model used in the analysis. The model dimensions and material properties are based on the tank data summarized in Section 4. Figure 5.1 also shows the locations of the centerlines of anchor bolts at the bottom of the tank, and the displacement boundary condition. The model is loaded in the horizontal direction by a uniformly distributed 10^6 lb force representing horizontal seismic loads. The shear forces in the bolts were calculated as a function of angular bolt location, as shown in Figure 5.2. The figure shows that maximum bolt shear loads act on the bolt at the 90° location.

Figure 5.2 shows the normalized shear force in anchor bolts plotted versus the angle (θ). The figure also shows a plot of a true sinusoidal distribution. Results shown in the figure clearly indicate the validity of the sinusoidal distribution assumption.



Model is constrained at bolt locations

Figure 5.1 Finite Element Model of the PPMS Tank

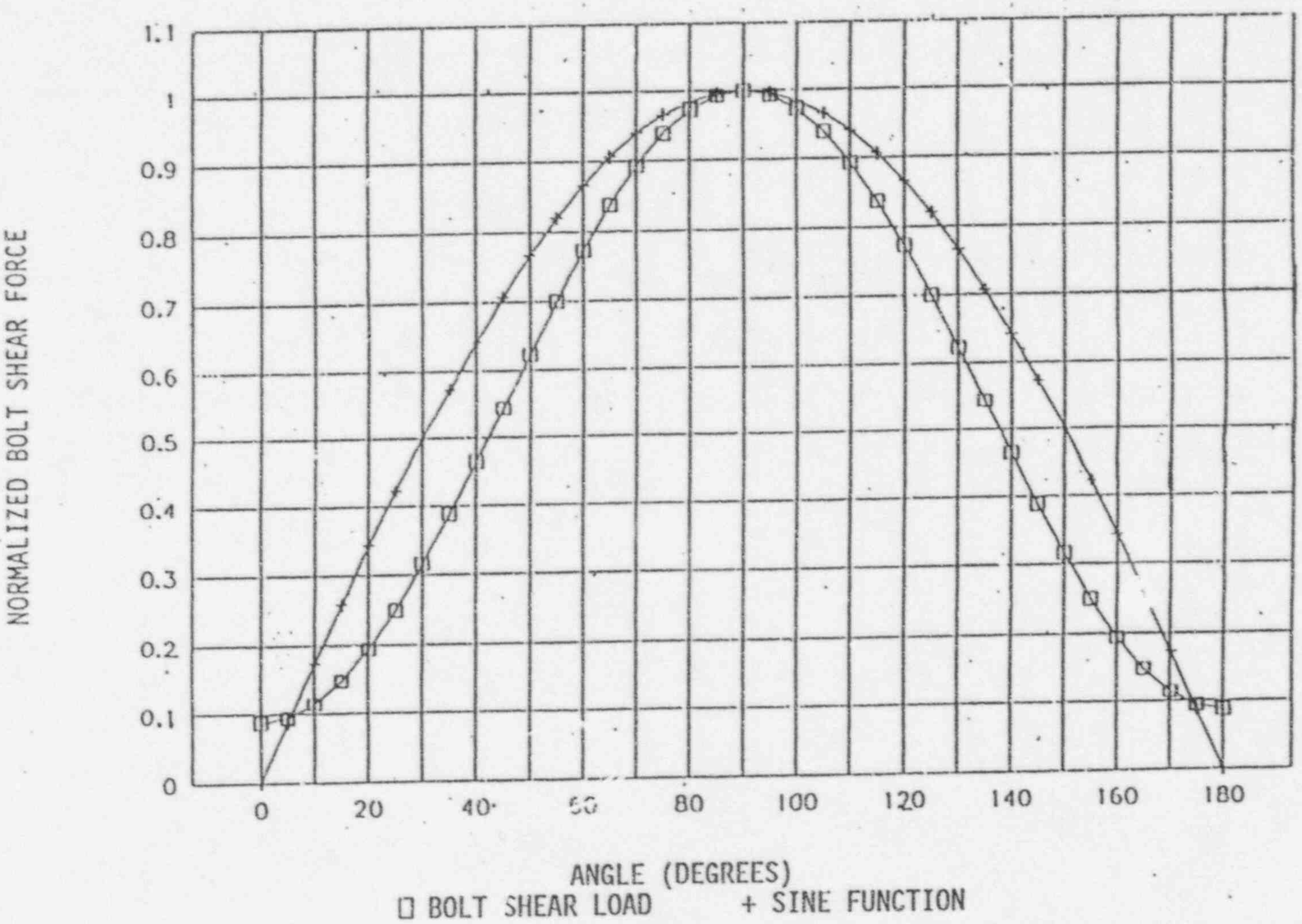
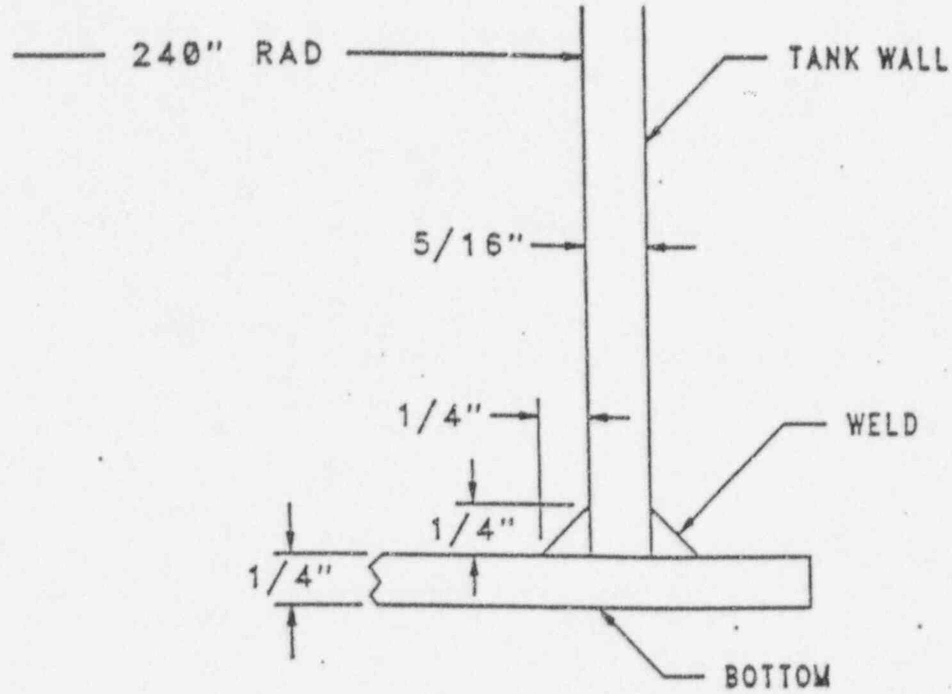


Figure 5.2 Normalized Bolt Shear Force Distribution

5.3 Shell-to-Bottom Fillet Weld Evaluation



The tank shell is welded to the bottom by a double 1/4″ fillet weld in accordance with API-650, Section 3, while ND-4746.2 calls for a full penetration weld. To address this deviation, the weld was evaluated for both shear and moment loads using ND-3852.6 shear allowable. The analysis results show that the existing fillet weld meets the ASME Code allowable stresses under DBE loading.

Result:	Maximum shear in weld	= 5.76 ksi < 13.6 ksi	[O.K.]
	Maximum normal stress in weld	= 9.48 ksi < 13.6[1] ksi	[O.K.]
	Maximum shear in base metal	= 4.07 ksi < 13.0 ksi	[O.K.]

Note (1): the shear allowable was conservatively used for the normal stress.

5.4 Shear Evaluation of Anchor Bolt Chair Bottom Plate

Finally, methodology of Reference 7 was used to evaluate the added bottom ring. This ring is added for better constructibility of the modified anchor bolt chairs. This evaluation is based on the sinusoidal bolt shear force assumption described in Section 5.2 of this report. The methodology of References 7 and 8 can be summarized as follows:

(a) Tearout Failure

A tearout stress check is performed to calculate the required plate thickness, t, to preclude the tearout failure type, shown in Figure 5.3(a). The allowable shear stress is conservatively taken equal to 13 ksi per Reference 2 (Subsection ND-3852.6).

Result: t (required) = 0.65″ < t (actual) = 0.75″ [O.K.]

(b) Pure Tension Rupture

This failure mode is illustrated in Figure 5.3(b). The average tensile stress, σ_{ave}, in the plate should not exceed the allowable stress of the plate material (S=12.6 ksi per Reference 2). The use of this allowable is conservative since it is being used to evaluate Level D loading.

Result: σ_{ave} = 6,784 psi < S (=12,600 psi) [O.K.]

(c) Failure by Crushing

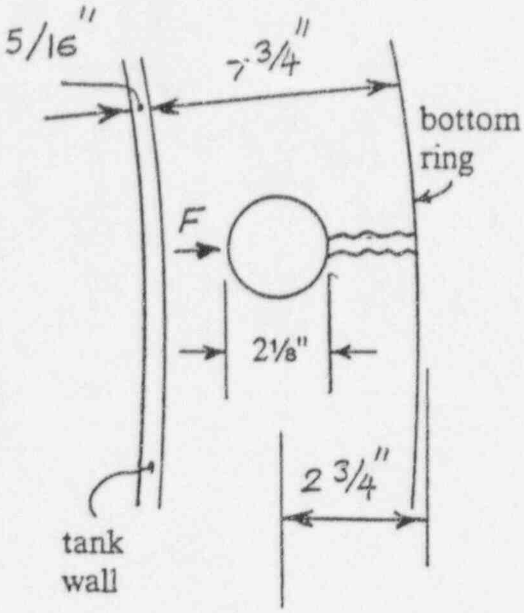
This failure mode is illustrated in Figure 5.3(c). The stress acting on the projected area should not exceed the yield stress (f_y).

Result: σ_{ave} = 25,440 psi < f_y (=36,000 psi) [O.K.]

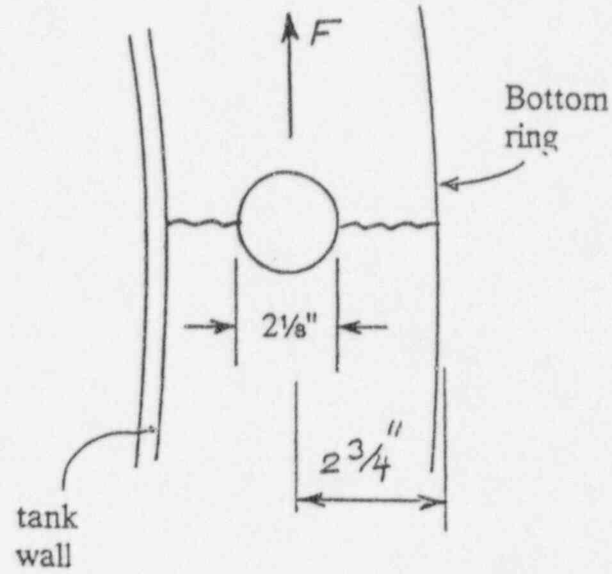
5.5 Nozzle Stiffness Evaluation

Nozzle stiffness values, to be used in the piping analysis, are approximated using the methodology and formulas in WRC Bulletin 297 (Reference 14).

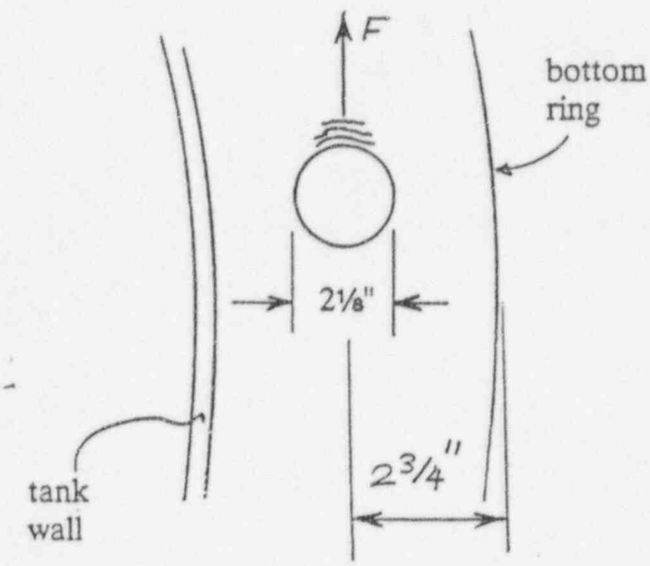
Due to the narrow range of parameters given in the bulletin, interpolations and estimations were used as appropriate. The magnitude of nozzle stiffness obtained by this process gives realistic translational and rotational end reactions at the nozzle-shell connections, and therefore provides a reasonable basis for piping design analysis.



(a) Tearout Failure



(b) Tensile Failure



(c) Failure by Crushing

Figure 5.3 Bottom Ring Failure Modes

5.6 Local Stress Check for External Loads at Nozzle-to-Tank Connections

Several nozzles are attached to the PPMS tanks at SONGS Units 2 and 3. Local stresses evaluation of the tank shell was performed using the computer program ME101LS (Reference 12). The evaluation is based on Bijlaard stress analysis for cylinders. Details can be found in SCE calculations M-DSC-280 and M-DSC-269. The evaluation is stress intensity based using the same approach for detailed analysis of localized effects for Class 1 components,

Primary stress intensity allowable = 1.5 S_m
Primary + secondary stress allowable = 3.0 S_m

where the stress intensity allowable (S_m) = 20 ksi. Note that local yielding in the vicinity of nozzles is allowed by the ASME Code. Results of the local stress evaluation are summarized in Table 5.1 below.

Table 5.1 Local Stress Check Results Summary

Nozzle Description	Size	Primary Mem+ Bending Stress (ksi)	Primary + Secondary Stress (ksi)
CCW Suction	3″	18.9	48.5
CCW Miniflow	1″	15.2	40.2
PPMST Fill Inlet	2½″	13.4	48.5
PPMS Recirculation	2″	10.5	40.4
PPMS Suction	4″	14.0	53.8
Overflow	4″	20.4	48.3

No evaluation was performed on the nozzle of the 3″ drain line at the bottom of the tank and the nozzles of the two 2″ instrument taps, which were judged acceptable based on load comparison with other nozzles.

5.7 Shell Manway (Main Manway)

Each PPMS tank is equipped with a 24″ shell manway and a 24″ roof manway. The shell manway was reinforced by a 1/4″ thick, 37″ outside diameter, 25″ inside diameter split pad. Details can be found in Appendix A, Section 10.4 of SCE calculations M-DSC-280 and M-DSC-269.

5.8 Out-of-Roundness Requirements

Surveys were conducted on the Unit-2 PPMS tank, T-056, to measure the diameter at different angles. These measurements were taken at the following elevations: 7 ft, 11 ft and 26 above the bottom and 6 ft below the top of the tank. Results of the survey are documented in Reference 27(a).

Similarly, surveys were conducted on the Unit-3 PPMS tank, T-055, to measure the diameter at different angles. These measurements were taken at two elevations: 7 ft above the bottom and 6 ft below the top of the tank. Results of the survey are documented in Reference 27(b), and a copy is attached in SCE Calculation No. M-DSC-269, Appendix D.

Per ASME, ND-4224, the out-of-roundness requirement is checked as follows:

1. Step 1

   Calculate $D_{ave}/100$, where D_{ave} is the average diameter of the tank in inches. Maximum allowable out-of-roundness per ASME Code $\leq 0.1\ D_{ave}$ (average tank shell diameter) not to exceed 12″.

2. Step 2

   Based on field measurements, calculate the maximum diametral out-of-roundness for each tank.

Both SONGS Unit-2 and Unit-3 PPMS tanks were tested for out-of-roundness at two different elevations. Results are summarized below.

Allowable out-of-roundness on diameter	= 4.80″ per ND-4224	
Unit-2 maximum out-of-roundness	= 2.64″	[O.K.]
Unit-3 maximum out-of-roundness	= 2.40″	[O.K.]

5.9 Statistical Analysis of Examination Data and Fracture Mechanics Evaluation

Existing radiographic examination results revealed unacceptable weld defects beyond the ASME Code, Paragraph ND-5000. Undercut, Incomplete Fusion, Slag Inclusion, Inadequate Penetration, Root Concavity/Convexity, Porosity and occasionally Cracks were observed. A statistical approach, combined with a fracture mechanics evaluation was adopted by SCE to demonstrate acceptability of the tank shell welds with high reliability. Acceptance by analytical evaluation is allowed by the ASME Code for flaws not meeting acceptance criteria (see Section XI, Article IWA-3000). This analytical evaluation approach can be described briefly as follows :

- Statistical analysis based on re-examination of the tank by spot radiography. A large number of spots was specified to ensure adequate statistical base to provide at least 95% confidence level that 95% of the defects do not exceed a given size.

- Fracture mechanics evaluation using a bounding defect size to demonstrate that a considerable factor of safety exists.

A description of these analyses is given below.

5.9.1 Statistical Analysis of Radiographic Examination Data

The purpose of the statistical analysis is to calculate the 95th percentile bounding defect length with 95% probability that any flaw size is bounded by the calculated bounding flaw length with 95% confidence level. A sample size of 60 radiographs from Unit 2 and 61 radiographs from Unit 3 were chosen to represent at least 3.5% of the total length of weld seams or at least 5% of the total length of the weld seams in the bottom three shell courses, which are considered critical from a stress point of view. Figure 5.4 shows the spots selected for radiographic examination of Unit-2 PPMS tank (T056). These spots include vertical seams, horizontal seams and intersections, and cover all the welders involved in the tank construction. Examination of the spot radiography testing results showed 283 welding flaws ranging in size from 1/32″ to 4⅞″; these results are plotted in Figure 5.5.

Result: T056

mean value of flaw size = 0.364″,
standard deviation = 0.547″

Similarly, Figure 5.6 shows the spots selected for radiographic examination of Unit-3 PPMS tank (T055). These include vertical seams, horizontal seams and intersections, and cover all the welders involved in the tank construction. Examination of the spot radiography testing results showed 126 welding flaws ranging in size from 1/16″ to 4½″; these results are plotted in Figure 5.7.

Result: T055

mean value of flaw size = 0.472″,
standard deviation = 0.714″

The next step of the statistical analysis is to apply the theory of order statistics for non-parametric testing as follows (References 31 and 32):

- Establish the minimum sample size for 95% confidence that 95% of the population is bounded by a given defect length. Based on the methodology of Reference 30, this population size is 93, which is less than the available 283 population size produced by tank examination for the Unit-2 tank, and 126 for the Unit-3 tank.

- Arrange the flaw population in ascending order based on size:

  $$a_1 \le a_2 \le \ldots \le a_s \le \ldots \le a_n$$

  where a_i is the size of the ith flaw (i=1,...,n & n=283 is the total number of samples for Unit-2 and 126 for Unit-3). The value of a_s represents the desired bounding flaw size.

- According to Reference (32), the upper bound flaw size, which has a 95% confidence that it bounds 95% of the population, is given by:

  $$s = np + w_\alpha\sqrt{np(1-p)}$$

  where

  p = specified probability
  = 0.95

  w_α = one-tailed 95th percentile of the Gaussian distribution
  = 1.645″

Result: T056

The value of s was calculated at 275, and the corresponding flaw size is 1.625″. Therefore, it is concluded that 95% of the flaws are bounded by the value 1.625″ with a 95% confidence level.

T055

The value of s was calculated at 124, and the corresponding flaw size is 3.5″. Therefore, it is concluded that 95% of the flaws are bounded by the value 3.5″ with a 95% confidence level.

This bounding defect size described briefly above was used as basis for the subsequent fracture mechanics evaluation described in Section 5.7.2 of this report. Details of the analysis can be found in Appendix E, of SCE Calculation No. M-DSC-280 for Unit-2 and M-DSC-269 for Unit-3.

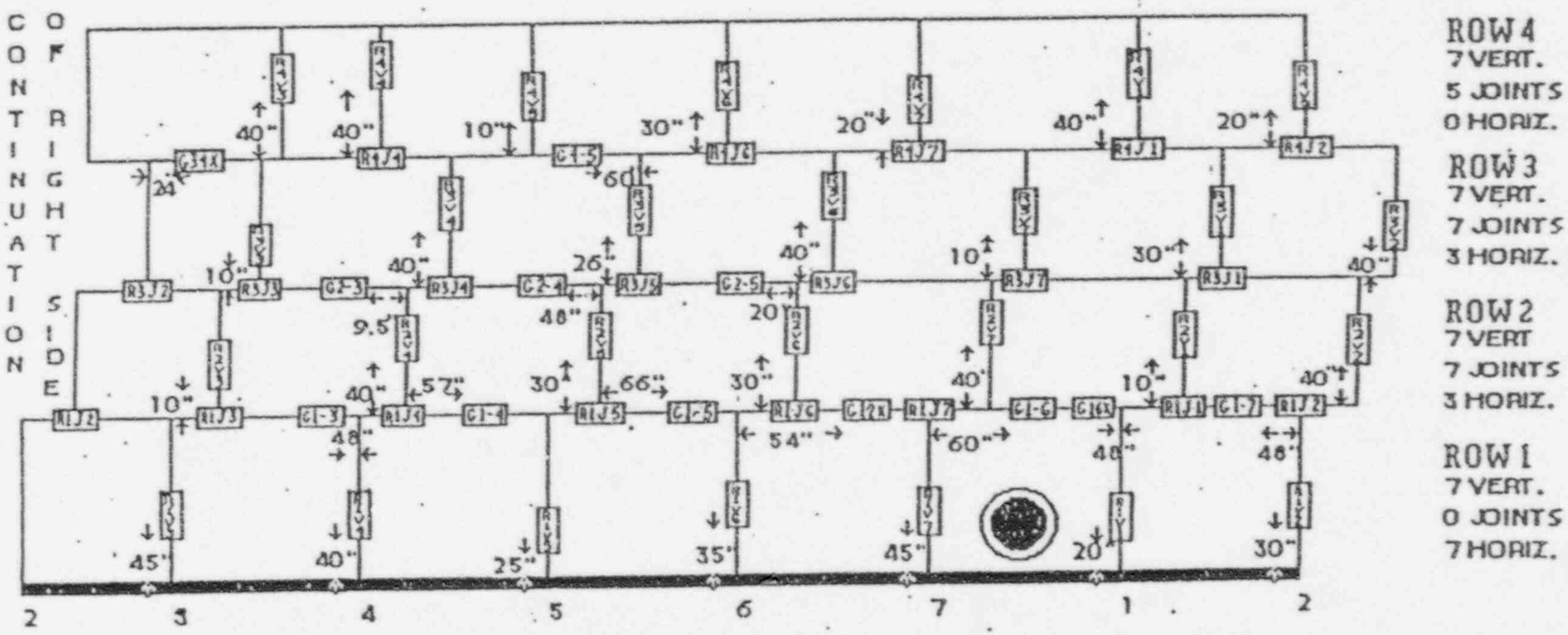


Figure 5.4 Radiographic Examination Map for Unit-2 PPMS Tank (T056)
(Includes Four Bottom Courses)

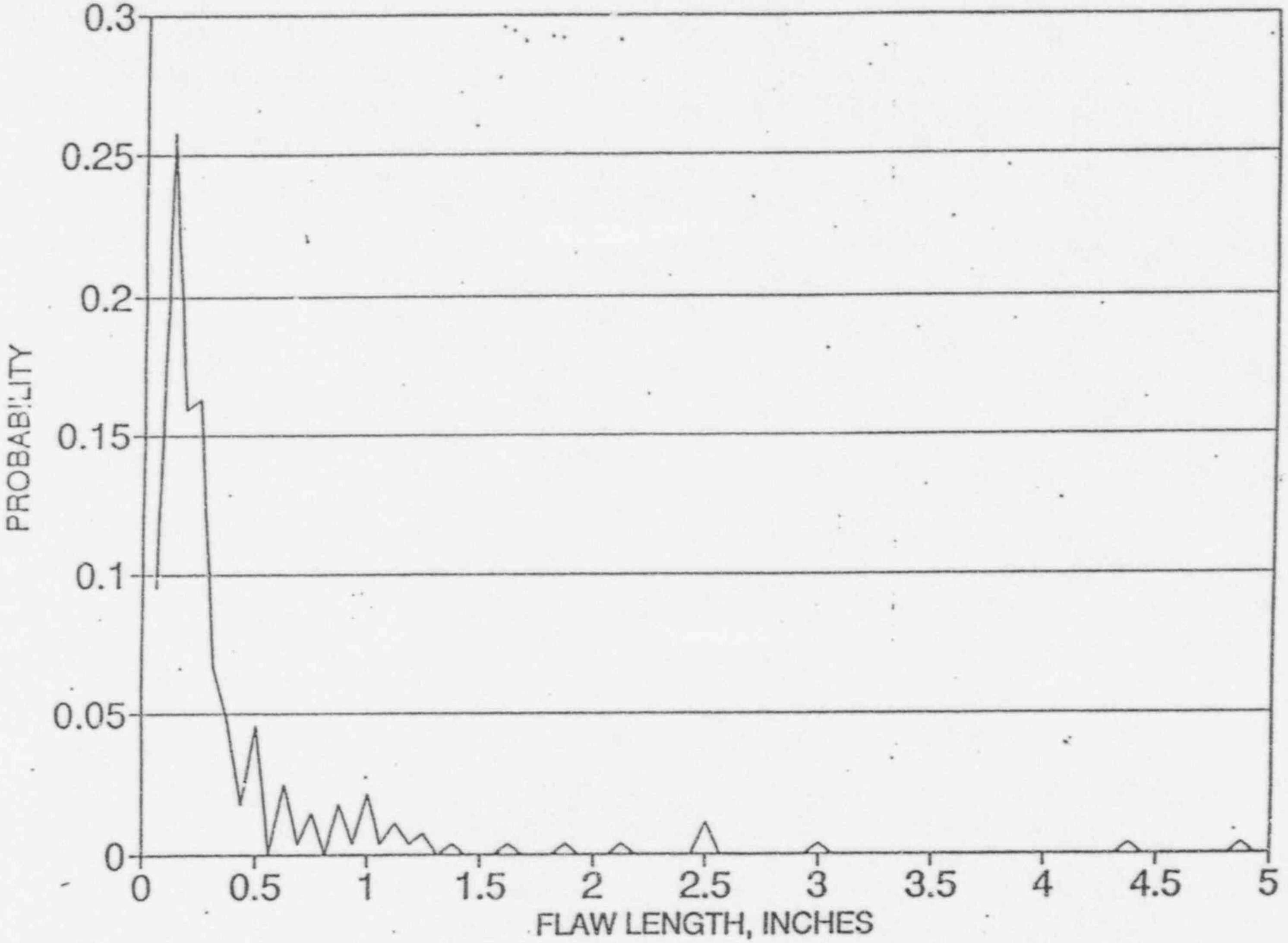


Figure 5.5 Weld Defect Size Population Distribution for Unit-2 PPMS Tank (T056)

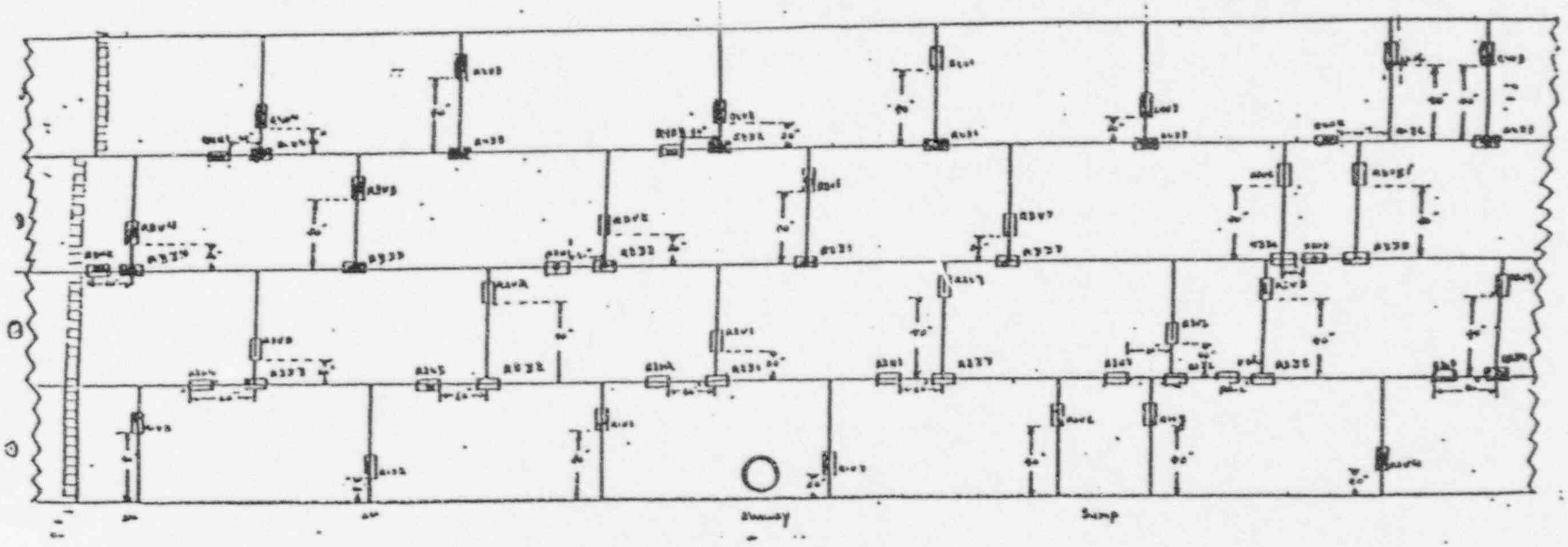


Figure 5.6 Radiographic Examination Map for Unit-3 PPMS Tank (T055)
(Includes Four Bottom Courses)

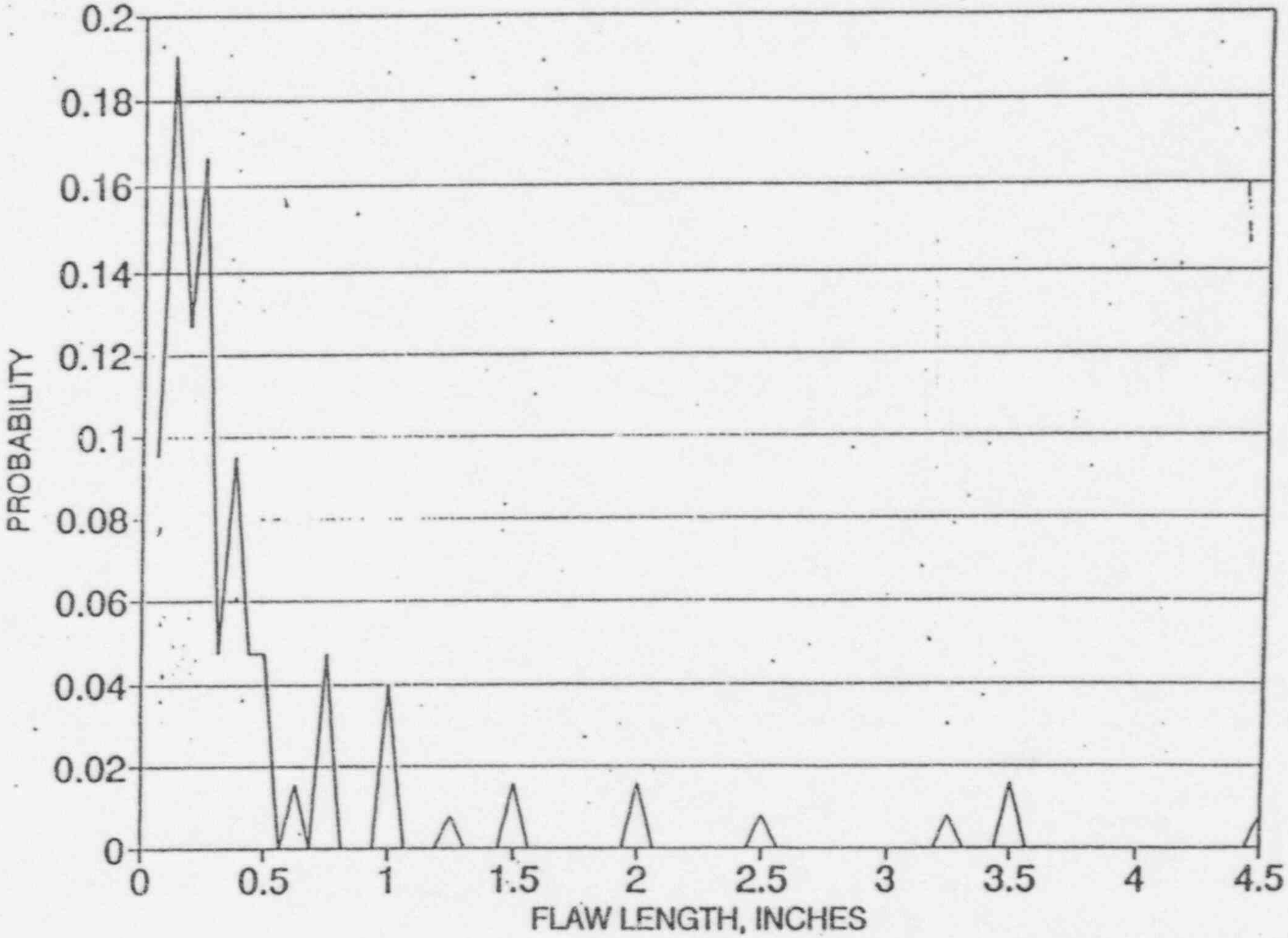


Figure 5.7 Weld Defect Size Population Distribution for Unit-3 PPMS Tank (T055)

5.9.2 Fracture Mechanics Evaluation

Based on the results of the radiographic examination and the statistical analysis of the examination data, fracture mechanics evaluation of the tank welding defects was performed. The fracture mechanics analysis can be described briefly as follows:

- Calculation of the stress components in the tank:

  (a) meridional stress in the tank is calculated using the overturning moment from the tank design results (see Section 5.1). The corresponding stress (σ) is then calculated using the simplified familiar formula:

  $$\sigma = \frac{Mr}{I}$$

  σ = 5.3 ksi

  where

  M = the overturning moment,
  r = tank radius (240″),
  I = moment of inertia of the tank cross section.

  (b) hoop stress in the tank is calculated using the three-dimensional finite element model shown in Figure 5.1. Additional hydrostatic pressure, to account for water sloshing during a DBE event, was included. Hoop stress distribution is shown in Figure 5.8; it can be seen that the maximum hoop stress occurs near the bottom of the second tier - a short distance above the reinforcing ring at the top of the tank shell stiffeners.

  Maximum hoop stress = 15.9 ksi controls.

- Conservatively, an infinitely long crack was postulated in the axial direction in the highest stress region of the tank so that it is subjected to the maximum crack opening stress. Figure 5.9 shows the geometry of the postulated crack in the tank shell. The crack depth is taken as half the wall thickness of the tank shell wall.

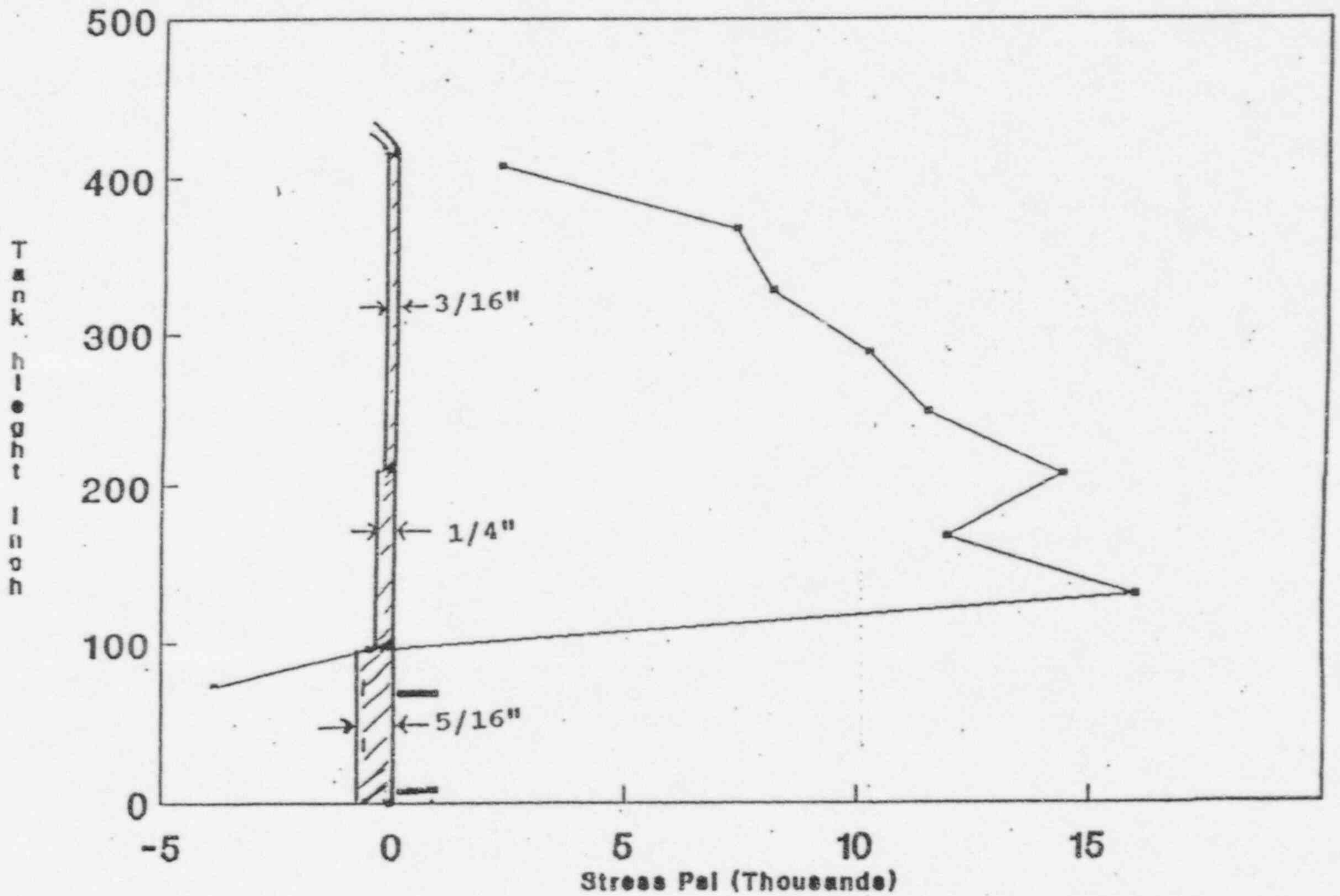


Figure 5.8 Hoop Stress Distribution in the Tank Shell

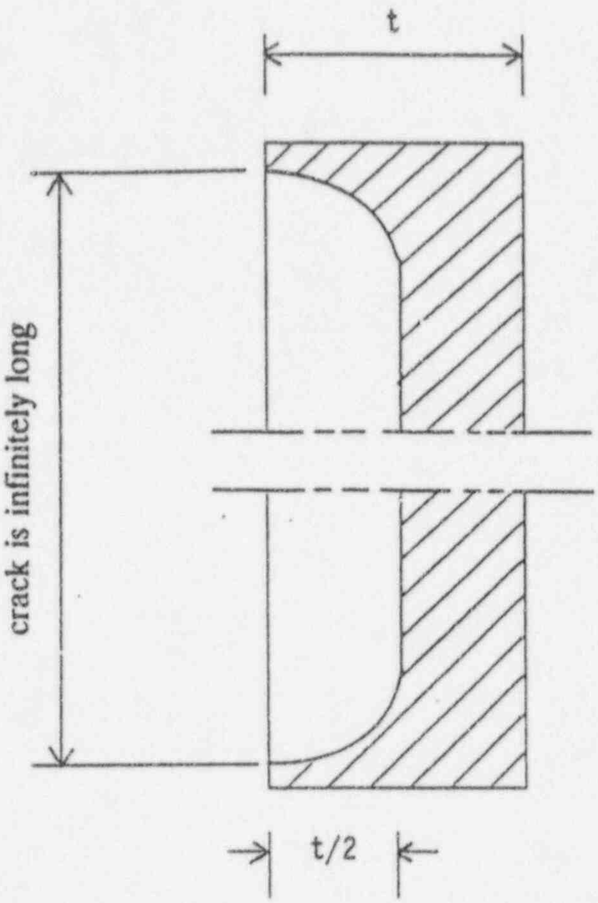


Figure 5.9 Postulated Crack Geometry

For such crack, the stress intensity (K) is given by (Reference 30):

$$K = G_o \sigma \sqrt{\frac{\pi a}{Q}}$$

where

G_o = Free surface correction factor as a function of flaw aspect ratio.

a = Crack depth (taken as half the shell thickness).

σ = Maximum hoop stress (ksi) in the tank. It includes the effect of water sloshing and local stress due to geometrical discontinuities. This stress was calculated using the finite element method.

Q = Flaw shape parameter given by:

$$Q = 1-(G_o\ \sigma/\sigma_{ys})^2/6$$

where σ_{ys} is the material yield strength.

- A second fracture mechanics analysis was also performed assuming a 5″ long through-wall crack, and the stress intensity factor was calculated using the computer program PcCRACK, which is a verified PC-based fracture mechanics evaluation program. Analysis in this case is based on Linear Elastic Fracture Mechanics (LEFM) using standard formulas for through-wall cracks.

- The critical stress intensity factor (K_{IC}) of the tank shell material was calculated as follows:

$$K_{IC} = \sqrt{J_{IC}E}$$

where

J_{IC} = critical J-integral value for the tank shell material (SA 240 -304)
= 990 in-lb/in^2 per Reference 37,

E = Young's modulus of the tank shell material
= 25 ksi

It follows that K_{IC} = 157.32 ksi$\sqrt{\text{inch}}$

The value of K_{IC} calculated above is 16.5% higher than the value of K_{IC} = 135 ksi$\sqrt{\text{inch}}$ given in Generic Letter 90-05 (Reference 36) for austenitic stainless steel.

- Calculate the factor of safety (FS):

$$FS = \frac{K_{IC}}{K}$$

Result:

The following results were obtained for a crack with crack depth equal to half the tank wall thickness:

Stress intensity factor (K_I) = 35.72 ksi$\sqrt{\text{inch}}$ < 157.32 ksi$\sqrt{\text{inch}}$ allowable [O.K.]

Similarly, the following results were obtained for a 5″ through-wall crack in the tank wall:

Stress intensity factor (K_I) = 50.80 ksi$\sqrt{\text{inch}}$ < 157.32 ksi$\sqrt{\text{inch}}$ allowable [O.K.]

The values of K_I calculated above also meet Generic Letter 90-05 stress intensity factor allowable of 135 ksi$\sqrt{\text{inch}}$ with significant margins.

The rate of crack growth, da/dN, is calculated per the 1989 ASME Code, Section XI, Figure A-4300-1. It is assumed that the PPMS tanks will undergo 400 cycles of filling based on the number of shutdowns over a period of 40 years.

Result: Total crack growth = $400(200\times10^{-6})$
= 0.08″

Remaining tank thickness = 0.125-0.08
= 0.045″

5.10 PPMS Tank Anchorage Evaluation

Anchor bolts, concrete shear stresses, shear cone capacity, bolt edge distance, bolt spacing and concrete compression stresses were evaluated in Reference 33. The Radwaste Building basemat was re-evaluated in Reference 34. Anchor bolt loads were calculated based on the tank overturning moment and slosh uplift force obtained from SCE calculations M-DSC-280 and M-DSC-269. The evaluation included both the pre-modification ASTM A307 1½" bolts and the new spin-lock 2" bolts. Shear-tension interaction on the bolts was calculated as follows:

$$(T/T_{all})^2 + (V/V_{all})^2 \leq 1.0$$

where T and V represent tension and shear loads acting on the bolts, respectively. Significant results are summarized below.

Results:

Significant results are given in Table 5.2, for OBE loads, and Table 5.3 for DBE loads.

Table 5.2 OBE Loads Evaluation

	Calculated Tension (kips)	Allowable Tension (kips)	Calculated Shear (kips)	Allowable Shear (kips)	Interaction Design Margin
A-307	29.5	35.3	1.98	17.7	29%
spin-lock	40.5	100	2.72	33	83%

Table 5.3 DBE Loads Evaluation

	Calculated Tension (kips)	Allowable Tension (kips)	Calculated Shear (kips)	Allowable Shear (kips)	Interaction Design Margin
A-307	45.2	56.5	12.11	28.3	18%
spin-lock	62.1	133	16.64	48	66%

6. REFERENCES

1. Field Change Notice (FCN) number F-7520 M, 21 M, and 22 M. These FCN's document the tank modification details.

2. ASME Boiler and Pressure Vessel Code, Section III, Division 1, 1989, no addenda.

3. (a) SCE Calculation M-DSC-280, Revision 1,"SONGS 2 Primary Plant Make-UP Storage Tank Upgrade."
   (b) SCE Calculation M-DSC-269, Revision 0,"SONGS 3 Primary Plant Make-UP Storage Tank Upgrade."

4. Calculation number C-258-9.10, Revision 0,"Primary Plant Make-Up Storage Tank Evaluation."

5. "Generic Implementation Procedure (GIP) for Seismic Verification of Nuclear Plant Equipment," Revision 8, Corrected 2/14/1992, SQUG.

6. ASME Boiler and Pressure Vessel Code, Section II, Division 1, 1989, Material Specifications (Ferrous).

7. Shigley, Joseph E.,"Mechanical Engineering Design," Third Edition, 1977, McGraw-Hill Book Company.

8. (a) API 650, 5th. Edition including Supplement 1.
   (b) API 620, 5th. Edition including Supplement 1.

9. Manual of Steel Construction, Eighth Edition, American Institute of Steel Construction, Inc., 1980.

10. "Design of Welded Structures," Omer W. Blodgett, The James F. Lincoln Arc Welding Foundation, Cleveland, Ohio, March 1982.

11. Design Bases Document S023-TR-EQ, Revision 0,"Environmental Qualification Topical Report."

12. Computer program ME101LS Version M10.

13. Design of Piping Systems, MW Kellogg, Revised 2nd Edition.

14. Welding Research Council Bulletin 297 September 1987,"Local Stresses in Cylindrical Shells Due to External Loadings on Nozzles."

6. REFERENCES - cont.

15. MW Kellogg Company, Design of Piping Systems, Revised 2nd Edition

16. Calculation number M-1203-476-2A, Revision 0.

17. Calculation number M-1203-478-2A, Revision 0.

18. Calculation number S-1415-22, Revision 0.

19. Calculation number 844, Revision 0.

20. Calculation number S-1415-06, Revision 0.

21. Calculation number S-1415-37, Revision 0.

22. Calculation number S-1415-56, Revision 0.

23. Piping Material Specifications 90004 Rev. 53

24. Drawing number S023-407-3-61-2, 40′ dia. x 34′ high Primary Plant Make-Up Storage Tank Shell Plate Layout.

25. Drawing number S023-407-3-62-3, 40′ dia. x 34′ high Primary Plant Make-Up Storage Tank Roof and Bottom Layout.

26. Drawing number S023-407-3-63-4, 40′ dia. x 34′ high Primary Plant Make-Up Storage T056 Nozzle (sheet 1) and T055 Nozzle (sheet 2).

27. (a) Construction Work Order number 92092078000, Out-of-Roundness Test Results.

    (b) Telecopy from G. Vechinski to N. M. El-Akily dated 10/15/1993. Subject: As-Built Inside Tank Radius.

28. Haroun, M. A.,"Vibration Studies and Tests of Liquid Storage Tanks," Earthquake Engineering and Structural Dynamics, Vol. 11, pp 179-206, 1983.

6. REFERENCES - cont.

29. ASME Code Case N-284,"Metal Containment Shell Buckling Design Methods," Reaffirmed July 10, 1989.

30. ASME Section XI working group on flaw evaluation, replacement of stress intensity factor calculation of Article A-3000 of Appendix A, Section XI with stress analysis of cracks handbook by Tada and Paris, Second Edition.

31. Hesson, G. M., Cliff, W. C., and Stevens, D. L.,"A Mathematical Model for Assessing the Uncertainties of Instrumentation Measurements for Power and Flow of PWR Reactors," NUREG/CR-3659, PNL-4973, 1985.

32. Conover, W. J., "Practical Nonparametric Statistics," John Wiley & Sons, Inc.

33. SCE Calculation No. C-258-9.10,"Primary Plant Make-Up Storage Tank Anchor Evaluation."

34. SCE Calculation No. C-258-4.01,"Basemat Design - Reinforcing."

35. Young, W. C.,"Roark's Formulas for Stress and Strain," Sixth Edition, McGraw-Hill Book Company, 1989.

36. Generic Letter 90-05,"Guidance for Performing Temporary Non-Code Repair of ASME Code Class 1, 2, and 3 Piping," June 15, 1990, United States Nuclear Regulatory Commission,

37. Journal of Pressure Vessel Technology, Vol. 108, 1989 Edition.

7. NOMENCLATURE

A = area, in^2

d = outside diameter of nozzle, inch

D_i = inside diameter, inch

D_o = outside diameter, inch

DBE: Design Basis Earthquake (same as SSE)

E = modulus of elasticity, psi

F = force, lb

F_b = allowable bolt stress, psi

F_r = allowable bolt stress after applying a reduction factor, psi

f_y = yield stress, psi

h = height, inch

Hz = Hertz

j = distance between stiffener plates, inch

J_{IC} = critical crack extansion parameter (J-integral), in-lb/in^2

k = stiffener plate width, inch

K_{IC} = critical stress intensity, ksi$\sqrt{\text{inch}}$

L = height of tank, inch

M = overturning moment, in-lb

M_{CAP} = overturning moment capacity, in-lb

OBE: Operating Base Earthquake

7. NOMENCLATURE - cont.

P = radial load, lbs

R = radius, inch

S = allowable stress, psi

S_m = stress intensity allowable

t = wall thickness, inch

w = radial deflection due to P, inch

ν = Poisson's ratio

σ = stress, psi

θ = angle, degrees

τ = shear stress, psi

Note: See also Section 5.1.1, Step 1

APPENDIX A

PPMS TANK DESIGN MODIFICATION DRAWINGS

&

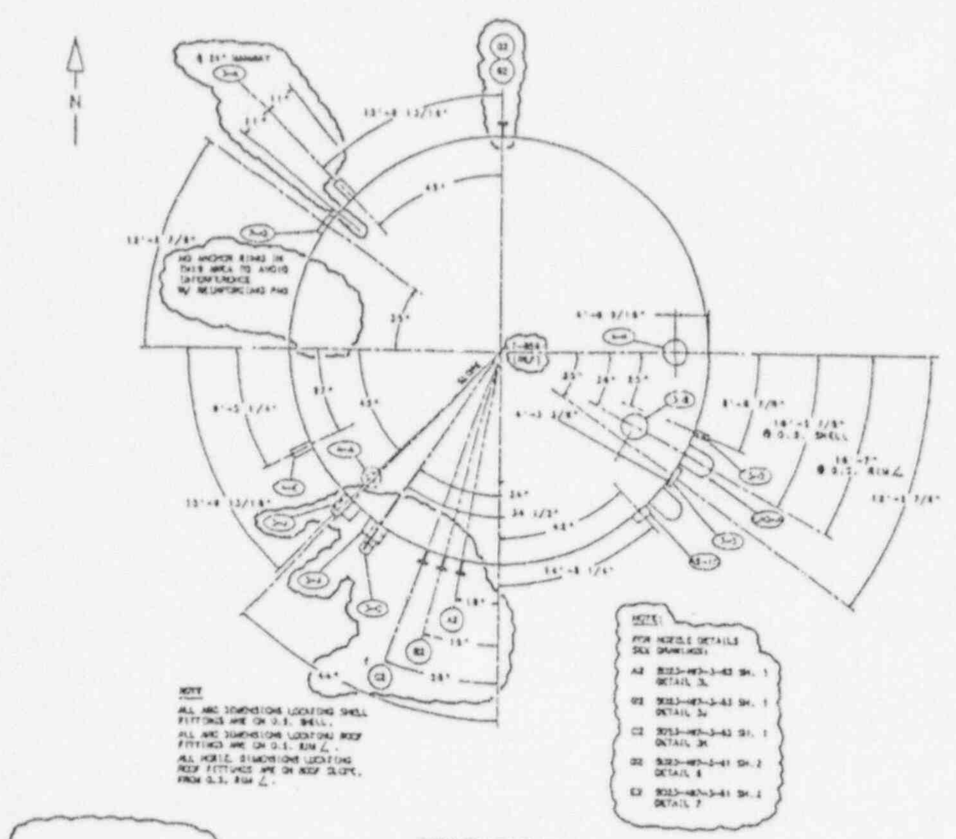
SONGS 2 & 3 RESPONSE SPECTRA

SEE LETTER FROM JOHN R. BLECK TO BECHTEL DATE: 10-17-74

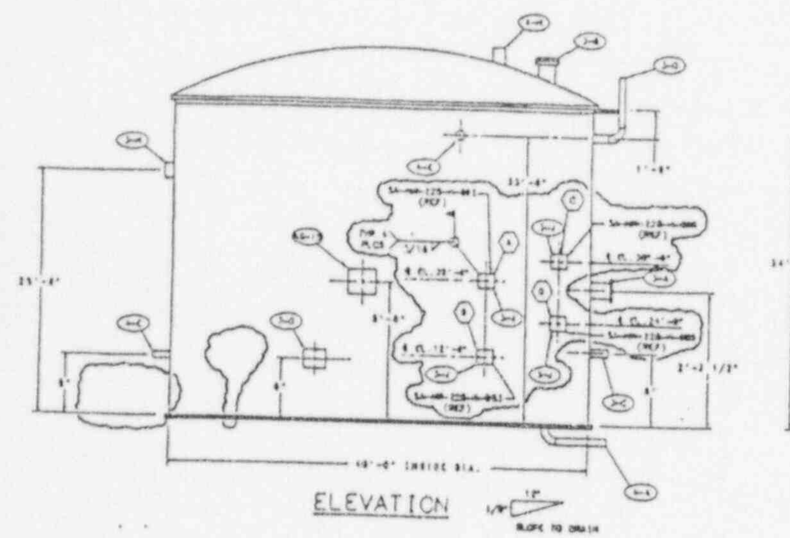
	VESSEL DATA	
DESIGN DATA	DESCRIPTION	PRIMARY PLANT MAKE-UP STOR[illegible]
	NO. REQUIRED	(1)
	CAPACITY	3[illegible] GALLONS (NOMINAL)
	DESIGN PRESSURE	HYDROSTATIC HEAD
	OPERATING PRESSURE	HYDROSTATIC HEAD
	TEST PRESSURE	HYDROSTATIC HEAD
	DESIGN TEMPERATURE	1[illegible]°F
	TEST TEMPERATURE	AMBIENT
	JOINT EFFICIENCY	[illegible]
	CORROSION ALL.	NONE
	CODE & STAMP	DESIGN PER API-620 ALLOWA[illegible]
	CUSTOMER SPECIFICATION	9063-487-3 SCE [illegible]
MATERIAL	SHELL	SA-240-304
	TOP, BOTTOM	SA-240-304
	HEADS	N.A.
	NOZZLE	NECK: SA-312-TP-304 FLANGE: [illegible]
	MANWAY	NECK: SA-240-304 FLANGE: SA[illegible]
	REINFORCING PADS	NONE
	PIPING	SA-312, TP-304
	COUPLINGS	N.A.
	STIFFENER RING	N.A.
	INTERNALS	N.A.
	BOLTING	BOLTS: SA-193 [illegible] NUTS: SA-1[illegible]
	GASKETS	[illegible] RUBBER OR EQUIVA[illegible]
	STRUCTURAL	SA-479-304
	ELECTRODES	E-308, E-308, E-6010 OR EQUIVA[illegible]
	ANCHOR CHAIR	A-36
CONSTRUCTION	STRESS RELIEF	NONE
	LINING	NONE
	INSULATION	NONE
	SURFACE PREPARATION	ALL CARBON STEEL PER SPEC. [illegible]
	CLEANING	BROOM CLEAN AFTER ERECTION
	INTERIOR PAINTING	NONE
	EXTERIOR PAINTING	ALL CARBON STEEL PER SPEC. [illegible]
	LADDER & PLATFORM	[illegible] STD. LADDER IN CONFORMA[illegible]
	CATHODIC PROTECTION	N.A.
	FOUNDATIONS	BY OTHERS
QUALITY ASSURANCE	MILL CERTIFICATION	TOP, BOTTOM & SHELL
	WELDERS	ASME-SEC. IX
	WELDING	API-650
	NON DESTRUCTIVE TEST	SPOT X-RAY PER API-650
	SPECIAL TEST	
	SHELL	HYDROSTATIC TEST BY [illegible]
	BOTTOM	VACUUM BOX PER API-650
	ROOF	VACUUM BOX PER API-650

NOTES:

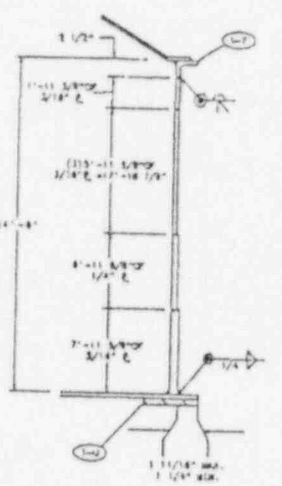
1. ALL FLANGE BOLT HOLES STRADDLE TANK VERTICAL OR RADIAL ℄'S UNLESS OTHERWISE SPECIFIED.
2. ALL WELDING E-308 ELECTRODE UNLESS OTHERWISE SPECIFIED.
3. SHOP TO INDICATE TOP & BOTTOM OF ℄ ON FIRST COURSE THE WORD TOP ON TOP & UOT. ON BOTTOM.

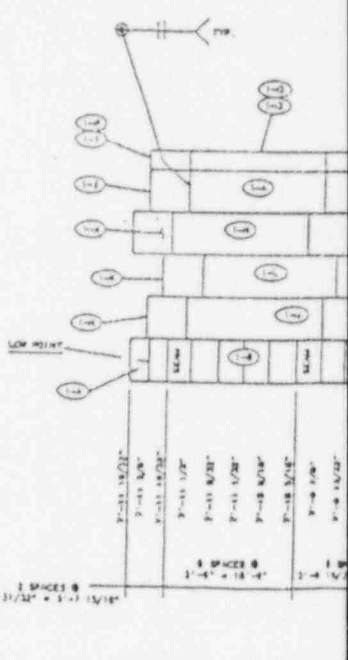


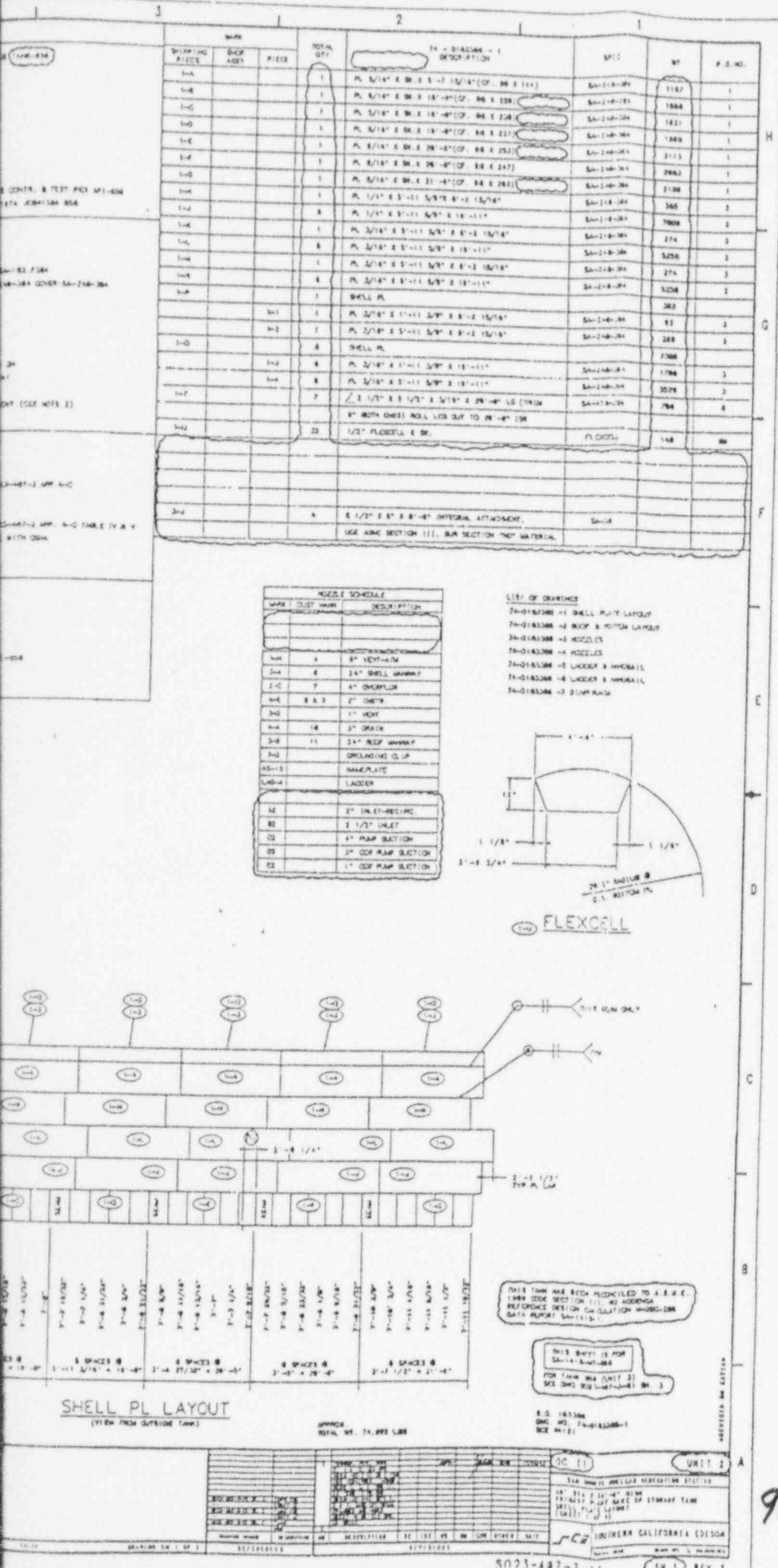
ORIENTATION



ELEVATION





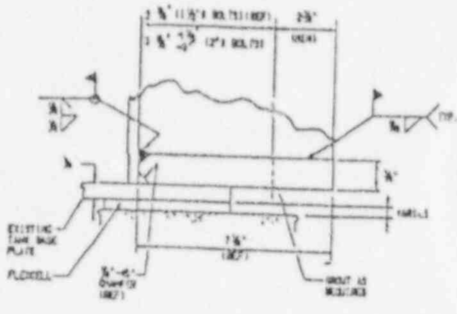


ANSTEC APERTURE CARD

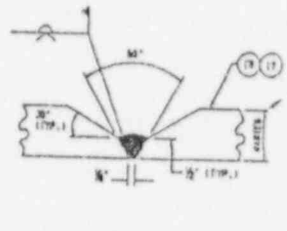
Also Available on Aperture Card

52

9603120065-01

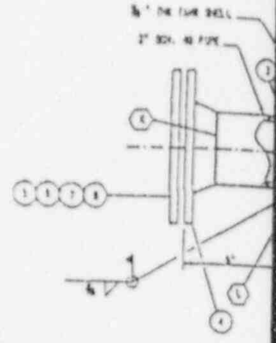


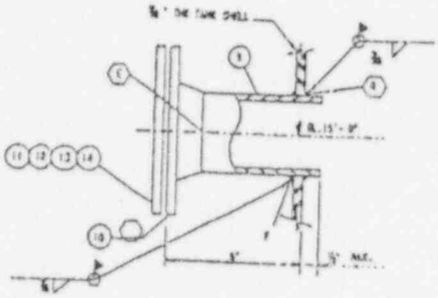
DETAIL 1



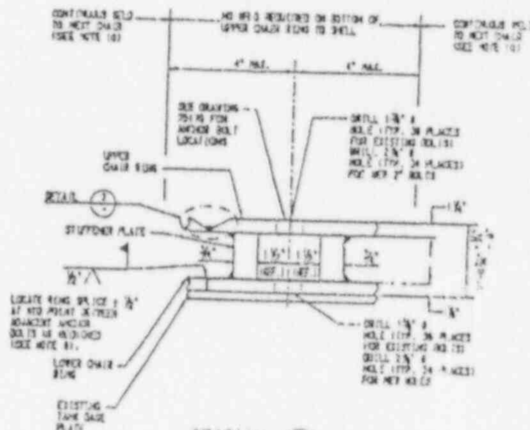
DETAIL 2

LOCATE UPPER AND LOWER CHAIR RING SPLICES AS REQUIRED AT MID POINT ± 1/2" BETWEEN ADJACENT ANCHOR BOLTS.
LOCATE UPPER RING SPLICE AT MIDPOINT BETWEEN STRINGERS.
SEE NOTES 8 & 9.

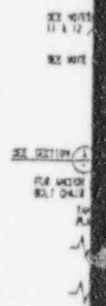




DETAIL 7

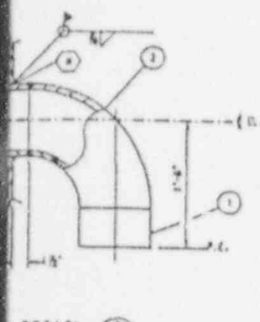


SECTION A

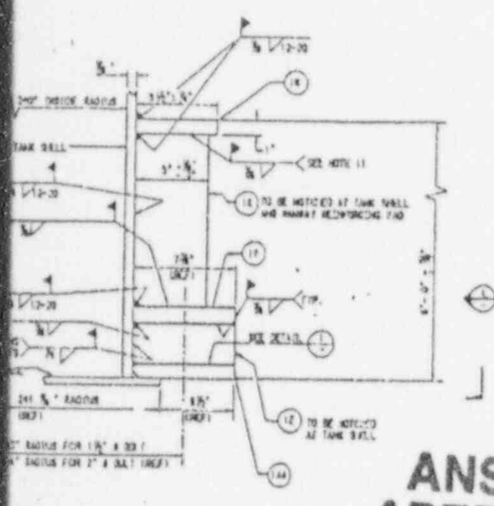


MARK			QTY	DESCRIPTION	SPEC	ST	P.O. NO.
		19	1	UPPER RING 1"X 5½"X 20'-0¾" INSIDE RADIUS FIELD CUT LENGTH AS REQUIRED	SA-36	-	-
		15	38	STRINGERS 1⅜" X 5" X 4'-10" EQUALLY SPACED	SA-36	-	-
		16	1	UPPER CHAIR RING 1¼"X 7¾"X 20'-0¾" INSIDE RADIUS FIELD CUT LENGTH AS REQUIRED	SA-36	-	-
		12	140	STIFFENER PLATE ⅝"X 7⅞"X 1'-1⅞"	SA-36	-	-
		14A	1	LOWER CHAIR RING PLATE [illegible] INSIDE RADIUS FIELD CUT LENGTH AS REQUIRED	SA-36	-	-
		1	11 L/F	3"X PIPE SCH. 40 S.S.	SA-312 TP304		
		2	1	3"X 90° PIPE ELBOW SCH. 40	SA-403 WP304		
		3	11 L/F	2"X PIPE SCH. 40 S.S.	SA-312 TP304		
		4	1	2" 150# R.F.W.N. FLANGE SCH. 40	SA-182 F316		
		5	1	2" 150# BLIND FLANGE	SA-182 F316		
		6	1	2" 150# GASKET [illegible]	ANSI B16.21		
		7	4	⅝"X STUD BOLT (2½" LONG)	SA-193 GR. B7		
		8	8	⅝"X HEX NUT	SA-194 GR. 2H		
		9	11 L/F	1" PIPE SCH. 80	SA-312 TP304		
		10	1	1" 150# R.F.W.N. FLANGE SCH. 80	SA-182 F316		
		11	1	1" 150# BLIND FLANGE	SA-182 F316		
		12	1	1" 150# GASKET [illegible]	ANSI B16.21		
		13	4	½"X STUD BOLT (2½" LONG)	SA-193 GR. B7		
		14	8	½" HEX NUT	SA-194 GR. 2H		

STRESS CALC. M-DSC-290



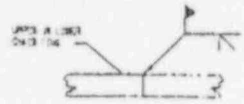
DETAIL 6



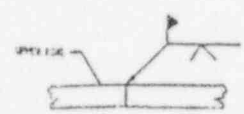
ANCHOR BOLT CHAIR

NOTES:

1. DRILL BOLT HOLES [illegible] COMPLETION OF ANCHOR BOLT INSTALLATION.
2. [illegible] BOLT [illegible] ON DWG [illegible] FOR [illegible] EXISTING LOCATIONS.
3. [illegible] TO MAINTAIN A CLEARANCE OF [illegible] BETWEEN THE ANCHOR BOLT CHAIR UPPER RING AND ALL OBSTRUCTIONS.
4. RING PLATE LENGTHS SHALL BE CUT TO SUIT BY FIELD.
5. STRINGERS ARE TO BE EQUALLY SPACED ± [illegible] IN EITHER DIRECTION TO AVOID [illegible] SPACING MAY BE INCREASED TO ± 2" TO AVOID A WELD [illegible].
6. FOR CLASS [illegible]
PIPE MATERIAL TO BE PER ASME SECTION III, CODE CLASS 3, [illegible] EDITION, NO ADDENDA.
WELDS TO BE PER SECTION [illegible], [illegible] EDITION, NO ADDENDA.
7. DIMENSIONAL TOLERANCE ± [illegible] UNLESS OTHERWISE NOTED.
8. IF UPPER OR LOWER CHAIR RING SPLICES CAN NOT BE [illegible] TOLERANCES, [illegible] SPLICE SHOULD BE INSTALLED [illegible] FULL PENETRATION WELD SHOWN BELOW:



9. FOR UPPER RING SPLICES [illegible] OR LESS OF [illegible] OF A STRINGER, USE A FULL PENETRATION WELD SHOWN BELOW:



10. IF CONTINUOUS WELD IS NOT POSSIBLE DUE TO NOZZLE OBSTRUCTION THEN A GAP UP TO [illegible] LONG IS ALLOWED PROVIDED THAT THE OBSTRUCTED AREA IS WELDED ON THE TOP OF THE UPPER CHAIR RING.
11. TACK [illegible] OPPOSITE SIDE AS REQUIRED. [illegible]
12. FOR STRINGERS AT MANWAY REINFORCING PAD, MAKE A CONT[illegible] WELD ON ONE SIDE TO TANK SHELL, [illegible] WELD TO REINFORCING PAD.

ANSTEC APERTURE CARD

Also Available on Aperture Card

9803120065-02

THIS SHEET IS FOR SA-1415-MT-056 ONLY

FOR TANK 055 SEE DWG SO23-407-3-61 SH. 4

QC II UNIT 2

SAN ONOFRE NUCLEAR GENERATING STATION

40'DIA. X 34'-0" HIGH PRIMARY PLANT MAKE-UP STORAGE TANK SHELL PLATE LAYOUT

SOUTHERN CALIFORNIA EDISON

SO23-407-3-61 SH.2 REV.0

REFERENCES | REVISIONS

• REVISE ON CADD SYSTEM ONLY •

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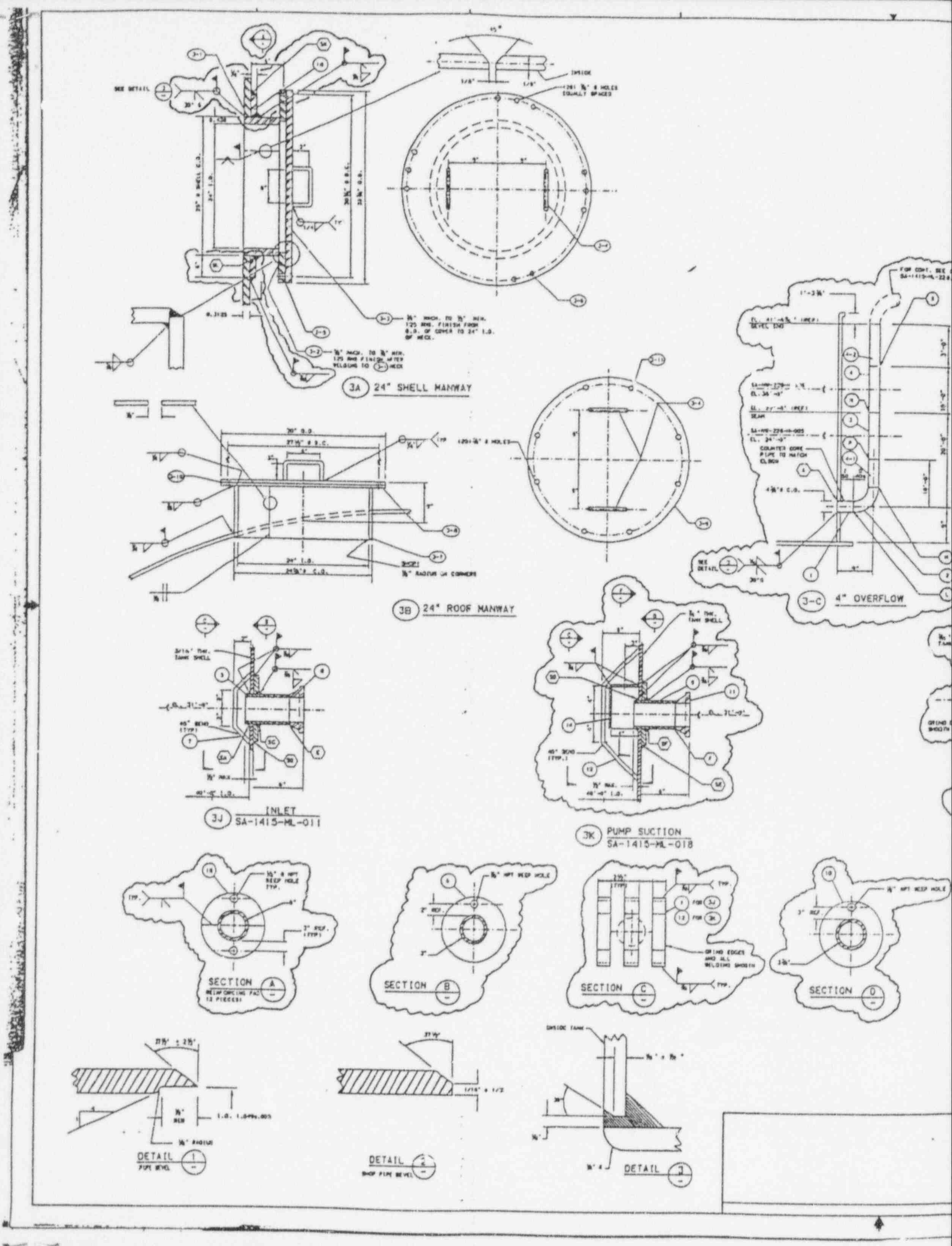
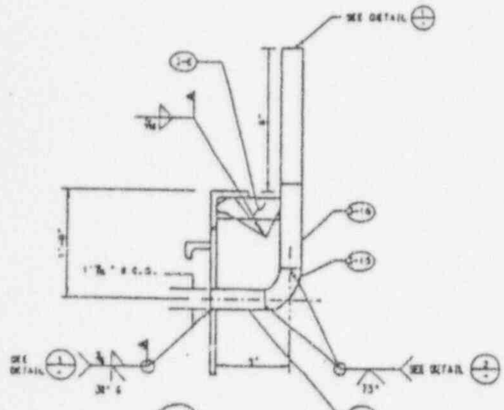
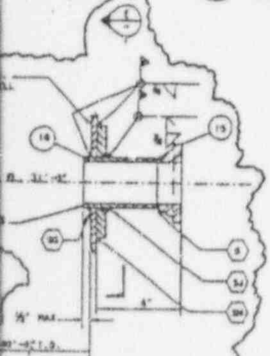

3A 24" SHELL MANWAY
3B 24" ROOF MANWAY
3-C 4" OVERFLOW
3J INLET SA-1415-ML-011
3K PUMP SUCTION SA-1415-ML-018
SECTION A
SECTION B
SECTION C
SECTION D
DETAIL 1
DETAIL 2
DETAIL 3

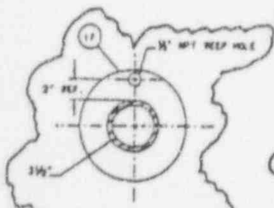
MARK			QTY	DESCRIPTION	SPEC	WT	P.O. NO.
3-A			1	24" SHELL MANWAY		251.5	
		3-1	1	PLATE 5/8" X 17 1/2" X 6'-4 3/4" LG.	SA-240-304	72.6	11
		3-2	1	PLATE 3/4" X 24 3/4" I.D. X 32 3/4" O.D.	SA-240-304	38.5	12
		3-3	1	PLATE 3/4" X 32 3/4" O.D.	SA-479-304	121	13
		3-4	2	BAR 3/4" Ø X 12 3/4" LG. X BK.	SA-479-304	3	16
		3-5	1	GASKET 1/8" THK. X 24" I.D. X 29 3/4" O.D.	RUBBER	1	15
		3-6	28	BOLT 3/4" Ø X 2 1/2" LG. HEX HEAD W/ HEAVY HEX NUT	SA-193-B7 SA-194-2H	15.5	14
	18		2	SPLIT RING REINFORCING PAD 25" I.D. X 37" O.D. 3/8" THK W/ 1/4" Ø WEEP HOLE 20'-0" RADIUS TANK	SA-240-304		
3-B			1	24" ROOF MANWAY		154	
		3-4	2	BAR 3/4" Ø X 12 3/4" LG. X BK.	SA-479-304	3	16
		3-7	1	PLATE 3/8" X 17" X 6'-4 3/4" ROLL TO 24" I.D.	SA-240-304	76	17
		3-8	1	PLATE 3/4" X 24 3/4" I.D. X 30" O.D.	SA-240-304	17	18
		3-9	1	PLATE 3/4" X 29" O.D.	SA-240-304	51	14
		3-10	1	GASKET 1/8" THK. X 24" I.D. X 30" O.D.	RUBBER	1	15
		3-11	20	BOLTS 3/4" Ø X 1 1/2" LG. HEX HEAD W/ HEAVY HEX NUT	SA-193-B7	5	20
3-C			1	4" OVERFLOW			
	1		1	PIPE 4" SCH. 10 X 2 3/4" LG. (COUNTER BORE ONE END TO SCH 40S)	SA-312-TP304		
	2		1	90° ELBOW 4" L.R. SCH. 40S	SA-403-WP304		
	3		1	PIPE 4" SCH. 40S X 10'-0" LG.	SA-312-TP304		
	4		1	PIPE 4" SCH. 40S X 10'-0" LG.	SA-312-TP304		
	4-1		1	PIPE 4" SCH. 40S X 10'-0" LG.	SA-312-TP304		
	4-2		1	PIPE 4" SCH. 40S X 3'-0" LG.	SA-312-TP304		
3-D			1	1" VENT		2.5	
		3-14	1	PIPE 1" SCH. 80 X 3 3/4" LG.	SA-312-304	1	63
		3-15	1	90° ELBOW 1" L.R. SCH. 80	SA-403-304	1	64
		3-16	1	PIPE 1" SCH. 80 X 1'-4 1/2" LG.	SA-312-304	1.5	63
3-E			2	FLAT BAR 1/2" X 3" X 4 3/4" LG.	SA-240-304	1	4
3-J		5	1L/F	PIPE 2 1/2" SCH. 40S (CUT TO SUIT)	SA-376-TP304		
		6	1	RING REINFORCING PAD 1/2" X 5 3/4" O.D.	SA-240-304		
		7	3	PLATE 3/8" X 2 1/2" X 1'-0" (CUT TO SUIT)	SA-240-304		
		8	1	FLANGE 2 1/2" 150# R.F.W.N., SCH. 40S	SA-182-F316		
3-K		9	1L/F	PIPE 4" SCH. 40S	SA-376-TP304		
		10	1	RING REINFORCING PAD 1/2" X 12" O.D.	SA-240-304		
		11	1	FLANGE 4" 150# R.F.W.N., SCH. 40S	SA-182-F316		
		12	3	PLATE 3/8" X 2 1/2" X 3'-0" (CUT TO SUIT)	SA-240-304		
		13	1	PLATE 3/4" X 4" X 16 3/4" LG.	SA-240-304		
		14	1	PLATE 3/8" X 5 3/4" X 4'-6 3/4" (CUT TO SUIT)	SA-240-304		
3-L		15	1	FLANGE 2" 150# R.F.W.N., SCH. 40 BW	SA-182-F316		
		16	1L/F	PIPE 2" SCH. 80S (CUT TO SUIT)	SA-376-TP304		
		17	1	RING REINFORCING PAD 1/2" X 5 3/4" O.D.	SA-240-304		



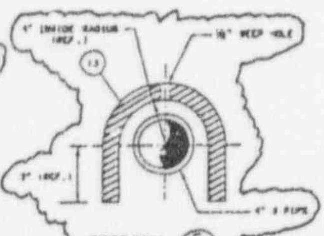
(3-D) 1" VENT



(3L) INLET RECIRC.
SA-1415-ML-023



SECTION (E)



SECTION (F)

◯ = WELD JOINT SYMBOL FOR ASME SECT. III CODE WELDS.
◯ = WELD JOINT SYMBOL FOR ASME SECT. XI CODE WELDS.

ANSTEC
APERTURE
CARD

Also Available on
Aperture Card

NOTES:
1. FOR ALL NOZZLE LOCATIONS SEE DWG. SO23-407-3-61 SH. 1.
2. FOR CLASS "3": PIPE MATERIAL TO BE ASME SECTION III, CODE CLASS 3, 1989 EDITION, NO ADDENDA. WELDS TO BE SECTION IX, 1989 EDITION, NO ADDENDA.
3. DIMENSIONAL TOLERANCES ±1/8".

* REVISE ON CADD SYSTEM ONLY *

54

9603120065-03

THIS TANK HAS BEEN RECONCILED TO A.S.M.E. 1989 CODE SECTION III, NO ADDENDA REFERENCE DESIGN CALCULATION M-DSC-290 DATA REPORT SA-1415-1.

QC II | UNIT 2

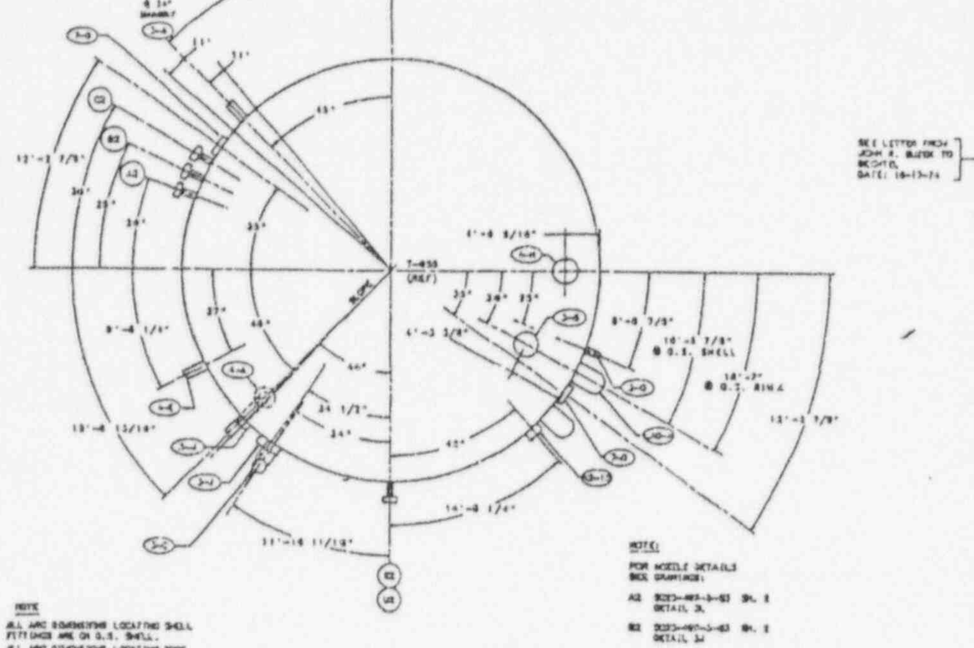
SAN ONOFRE NUCLEAR GENERATING STATION

40' DIA. X 34'-0" HIGH
PRIMARY PLANT MAKE-UP STORAGE TANK (056)
NOZZLE

SOUTHERN CALIFORNIA EDISON

REFERENCES | REVISIONS

SO23-407-3-63 (SH. 1) REV. 4



NOTCH UPPER CHAIN RING IN THIS AREA TO AVOID INTERFERENCE WITH REINFORCING PAD AND MANWAY BOLTING.

SEE LETTER FROM JOHN K. BLEEK TO BECHTEL DATE: 10-13-76

NOTE
ALL ARC DIMENSIONS LOCATING SHELL FITTINGS ARE ON O.S. SHELL.
ALL ARC DIMENSIONS LOCATING ROOF FITTINGS ARE ON O.S. RIM ∠.
ALL HORIZ. DIMENSIONS LOCATING ROOF FITTINGS ARE ON ROOF SLOPE, FROM O.S. RIM ∠.

NOTE:
FOR NOZZLE DETAILS SEE DRAWINGS:

A2 3023-487-3-63 SH. 8 DETAIL 3L
B2 3023-487-3-63 SH. 8 DETAIL 3J
C2 3023-487-3-63 SH. 8 DETAIL 2C
D8 3023-487-3-61 SH. 4 DETAIL 6 ... SH. 1
E2 3023-487-3-61 SH. 4 DETAIL 7 ... SH. 1
2C 3023-487-3-63 4" OVERFLOW
3A 3023-487-3-63 24" SHELL MANWAY

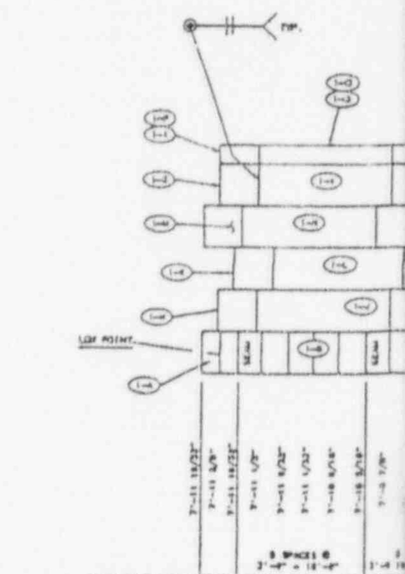
ORIENTATION

	VESSEL DATA	
DESIGN DATA	DESCRIPTION	PRIMARY PLANT MAKE-UP STORA[GE]
	NO. REQUIRED	(1)
	CAPACITY	300,000 GALLONS (NOMINAL)
	DESIGN PRESSURE	HYDROSTATIC HEAD
	OPERATING PRESSURE	HYDROSTATIC HEAD
	TEST PRESSURE	HYDROSTATIC HEAD
	DESIGN TEMPERATURE	100°F
	TEST TEMPERATURE	AMBIENT
	JOINT EFFICIENCY	85
	CORROSION ALL.	NONE
	CODE & STAMP	DESIGN PER API-620 ALLOWA[BLE]
	CUSTOMER SPECIFICATION	3023-487-3 ...
MATERIAL	SHELL	SA-240-304
	TOP, BOTTOM	SA-240-304
	HEADS	N.A.
	NOZZLE	NECK: SA-312-TP-304 FLANGE:
	MANWAY	NECK: SA-240-304 FLANGE: SA-
	REINFORCING PADS	NONE
	PIPING	SA-312, TP-304
	COUPLINGS	N.A.
	STIFFENER RING	N.A.
	INTERNALS	N.A.
	BOLTING	BOLTS: SA-193 B7 NUTS: SA-
	GASKETS	CRANE "CC" RUBBER ...
	STRUCTURAL	SA-479-304
	ELECTRODES	E-308, E-309, E-8018 ...
	ANCHOR CHAIN	A-36
CONSTRUCTION	STRESS RELIEF	NONE
	LINING	NONE
	INSULATION	NONE
	SURFACE PREPARATION	ALL CARBON STEEL PER SPEC.
	CLEANING	BROOM CLEAN AFTER ERECTION
	INTERIOR PAINTING	NONE
	EXTERIOR PAINTING	ALL CARBON STEEL PER SPEC.
	LADDER & PLATFORM	... STD. LADDER IN CONFORMA[NCE]
	CATHODIC PROTECTION	N.A.
	FOUNDATIONS	BY OTHERS
QUALITY ASSURANCE	WELL CERTIFICATION	TOP, BOTTOM & SHELL
	WELDERS	ASME-SEC. IX
	WELDING	API-620
	NON DESTRUCTIVE TEST	SPOT X-RAY PER API-620
	SPECIAL TEST	
	SHELL	HYDROSTATIC TEST BY ... PER
	BOTTOM	VACUUM BOX PER API-620
	ROOF	VACUUM BOX PER API-620

NOTES:

1. ALL FLANGE BOLT HOLES STRADDLE TANK VERTICAL OR RADIAL ℄'S UNLESS OTHERWISE SPECIFIED.
2. ALL WELDING E-308 ELECTRODE UNLESS OTHERWISE SPECIFIED.
3. SHOP TO INDICATE TOP & BOTTOM OF ℄ IN FIRST COURSE THE WORD TOP ON TOP & BOT. ON BOTTOM.

ELEVATION

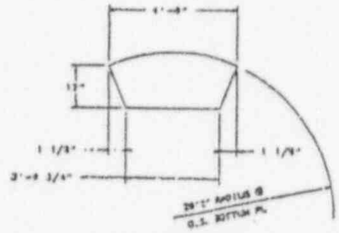


MARK			TOTAL QTY	74 - 0163386 - 1 DESCRIPTION	SPEC	WT	P.O. NO.
SHIPPING PIECE	SHOP ASSY	PIECE					
1-A			1	PL 3/16" X 9K X 3'-7 15/16" (CF. 96 X 144)	SA-240-304	1147	1
1-B			1	PL 3/16" X 9K X 16'-4" (CF. 96 X 127)	SA-240-304	1890	1
1-C			1	PL 3/16" X 9K X 16'-4" (CF. 96 X 129)	SA-240-304	1913	1
1-D			1	PL 3/16" X 9K X 19'-4" (CF. 96 X 243)	SA-240-304	2630	1
1-E			1	PL 3/16" X 9K X 28'-5" (CF. 96 X 140)	SA-240-304	2852	1
1-F			1	PL 3/16" X 9K X 38'-4" (CF. 96 X 247)	SA-240-304	2843	1
1-G			1	PL 3/16" X 9K X 21'-4" (CF. 96 X 263)	SA-240-304	3157	1
1-H			1	PL 1/4" X 3'-11 5/8" X 4'-2 15/16"	SA-240-304	365	2
1-J			6	PL 1/4" X 5'-11 5/8" X 19'-11"	SA-240-304	7860	2
1-K			1	PL 3/16" X 5'-11 5/8" X 6'-2 15/16"	SA-240-304	274	3
1-L			6	PL 3/16" X 5'-11 5/8" X 19'-11"	SA-240-304	5250	3
1-M			1	PL 3/16" X 5'-11 5/8" X 6'-2 15/16"	SA-240-304	274	3
1-N			6	PL 3/16" X 5'-11 5/8" X 19'-11"	SA-240-304	5250	3
1-P			1	SHELL PL		382	
		1-1	1	PL 3/16" X 1'-11 5/8" X 6'-2 15/16"	SA-240-304	83	3
		1-2	1	PL 3/16" X 5'-11 5/8" X 6'-2 15/16"	SA-240-304	300	3
1-Q			6	SHELL PL		7309	
		1-	6	PL 3/16" X 1'-11 5/8" X 19'-11"	SA-240-304	1730	3
		1-	6	PL 3/16" X 5'-11 5/8" X 19'-11"	SA-240-304	5678	3
1-T			7	∠ 3 1/2" X 3 1/2" X 5/16" X 38'-4" LG (TRIM	SA-479-304	788	6
				6" BOTH ENDS) ROLL LEG OUT TO 29'-9" (SR			
1-U			21	1/2" FLEXCELL X 9K.	FLEXCELL	148	99
3-J			4	PL 1/2" X 8" X 4'-8" INTEGRAL ATTACHMENT,	SA-36		
				USE ASME SECTION III, SUB SECTION "NO" MATERIAL			

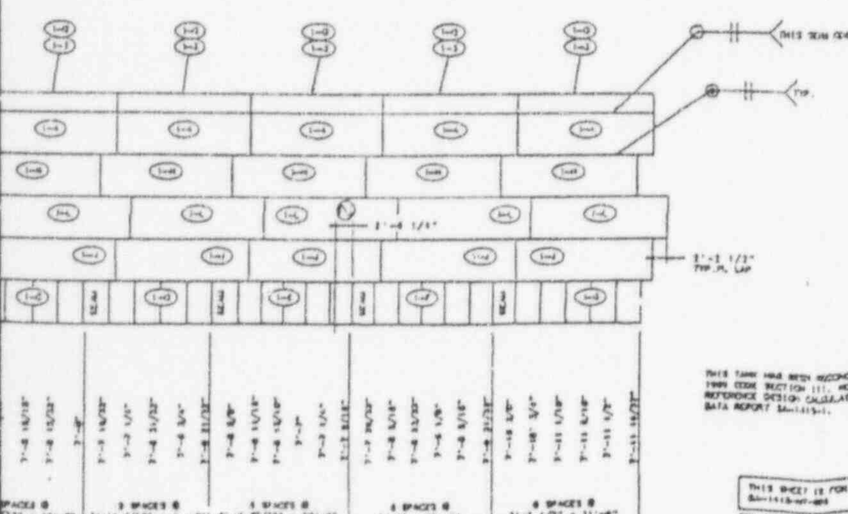
NOZZLE SCHEDULE		
MARK	CUST MARK	DESCRIPTION
6-H	4	8" VENT-ATM
3-A	6	24" SHELL MANWAY
3-C	7	4" OVERFLOW
4-E	8 & 9	3" SHTR.
3-D		1" VENT
3-4	10	3" DRAIN
3-8	11	24" ROOF MANWAY
7-D		GROUNDING CLIP
AB-LS		NAMEPLATE
LAD-4		LADDER
A2		3" INLET-RECIRC.
B2		2 1/2" INLET
C2		4" PUMP SUCTION
D2		3" CCW PUMP SUCTION
E2		1" CCW PUMP SUCTION

LIST OF DRAWINGS

74-0163386 -1 SHELL PLATE LAYOUT
74-0163386 -2 ROOF & BOTTOM LAYOUT
74-0163386 -3 NOZZLES
74-0163386 -4 NOZZLES
74-0163386 -5 LADDER & HANDRAIL
74-0163386 -6 LADDER & HANDRAIL
74-0163386 -7 STAIRWAY



1-U FLEXCELL



SHELL PL LAYOUT
(VIEW FROM OUTSIDE TANK)

APPROX. TOTAL WT. 74,892 LBS

THIS TANK HAS BEEN RECONCILED TO A.S.M.E. 1995 CODE SECTION III, NO ADDENDA. REFERENCE DESIGN CALCULATION M-DBD-108 DATA REPORT SA-1415-1.

THIS SHEET IS FOR SA-1415-07-002

FOR TANK 004 SEE DWG 5023-487-3-61 SH.1

S.O. 184386
DWG. NO. 74-0163386-1
RCE 44121

QC II | UNIT 3

SAN ONOFRE NUCLEAR GENERATING STATION

PRIMARY PLANT MAKE UP STORAGE TANK SHELL PLATE LAYOUT (SHEET 3 OF 7)

SOUTHERN CALIFORNIA EDISON

5023-487-3-61 SH 3 REV 8

ANSTEC APERTURE CARD

Also Available on Aperture Card

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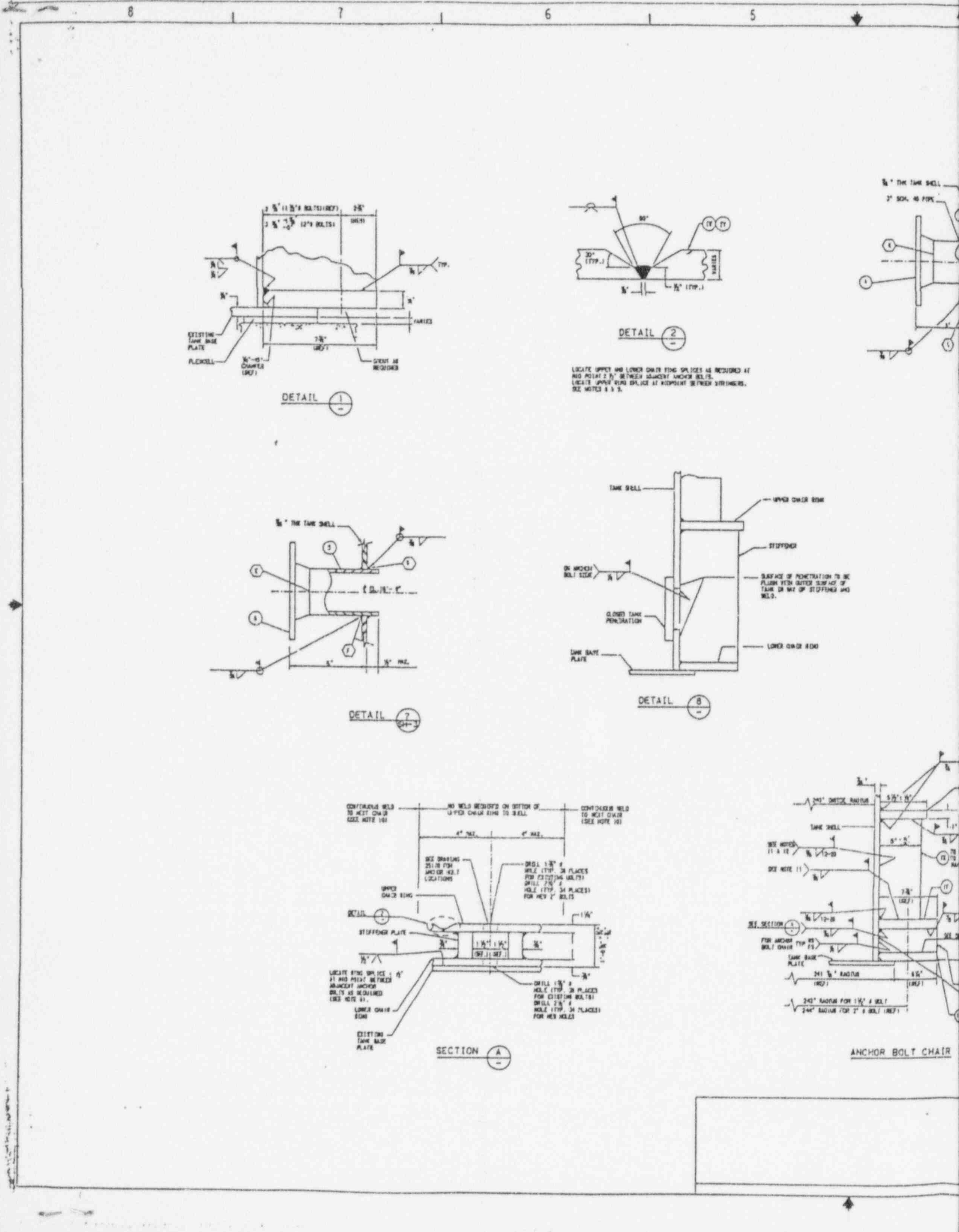
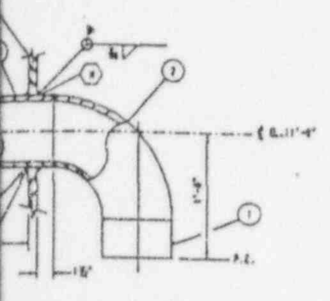
9603120065-04


8
7
6
5
DETAIL 1
EXISTING TANK BASE PLATE
DETAIL 2
DETAIL 7
TANK SHELL
UPPER CHAIR RING
STIFFENER
CLOSED TANK PENETRATION
LOWER CHAIR RING
TANK BASE PLATE
DETAIL 8
UPPER CHAIR RING
STIFFENER PLATE
LOWER CHAIR RING
EXISTING TANK BASE PLATE
SECTION A
TANK SHELL
TANK BASE PLATE
ANCHOR BOLT CHAIR

3 2 1

MARK			QTY	DESCRIPTION	SPEC	WT	P.O. NO.
		14	1	UPPER RING 1" X 3 [illegible]" X 20'-[illegible]" INSIDE RADIUS FIELD CUT LENGTH AS REQUIRED	SA-36	-	-
		15	36	STRINGERS 1 [illegible]" X 5" X 4'-10" EQUALLY SPACED	SA-36	-	-
		17	1	UPPER CHAIR RING 1 [illegible]" X 7 [illegible]" X 20'-[illegible]" INSIDE RADIUS FIELD CUT LENGTH AS REQUIRED	SA-36	-	-
		12	140	STIFFENER PLATE [illegible]" X 7 [illegible]" X 0'-10 [illegible]"	SA-36	-	-
		14A	1	LOWER CHAIR RING PLATE [illegible]" X 7 [illegible]" X 20'-[illegible]" INSIDE RADIUS FIELD CUT LENGTH AS REQUIRED	SA-36	-	-
		1	1L/F	3"Ø PIPE SCH. 40 S.S.	SA-312 TP304		
		2	1	3"Ø 90° PIPE ELBOW SCH. 40	SA-403 WP304		
		3	1L/F	3"Ø PIPE SCH. 40 S.S.	SA-312 TP304		
		4	1	3" 150# R.F.S.O. FLANGE SCH. 40	SA-182 F316		
		5	1L/F	1" PIPE SCH. 80	SA-312 TP304		
		6	1	1" 150# R.F.S.O. FLANGE SCH. 80	SA-182 F316		

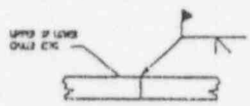
STRESS CALC. M-DSC-263



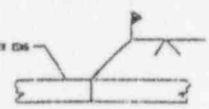
DETAIL 6

NOTES:

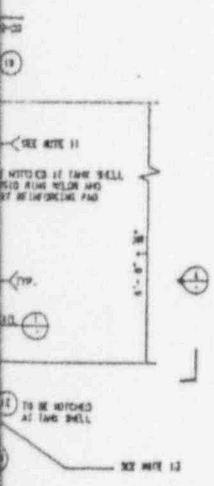
1. DRILL BOLT HOLES IN RINGS @ COMPLETION OF ANCHOR BOLT INSTALLATION.
2. SEE BOLT PATTERN ON DWG [illegible] FOR NEW & EXISTING LOCATIONS.
3. [illegible] TO MAINTAIN A CLEARANCE OF [illegible]" BETWEEN THE ANCHOR BOLT CHAIR UPPER RING AND ALL OBSTRUCTIONS.
4. RING PLATE LENGTHS SHALL BE CUT TO SUIT IN FIELD.
5. STRINGERS ARE TO BE EQUALLY SPACED ± 2 [illegible]" IN EITHER DIRECTION TO AVOID INTERFERENCE.
6. FOR CLASS "3", PIPE MATERIAL TO BE PER ASME SECTION III, CODE CLASS 3, [illegible] EDITION, NO ADDENDA; WELDS TO BE PER SECTION IX, 1989 EDITION, NO ADDENDA.
7. DIMENSIONAL TOLERANCE ± [illegible]" UNLESS OTHERWISE NOTED.
8. IF UPPER OR LOWER CHAIR RING SPLICES CAN NOT BE INSTALLED WITHIN ACCEPTABLE TOLERANCES, THEN SPLICE SHALL BE INSTALLED USING FULL PENETRATION WELD SHOWN BELOW.



9. FOR UPPER RING SPLICES WITHIN [illegible]" OR LESS OF CENTERLINE (℄) OF A STRINGER, USE A FULL PENETRATION WELD SHOWN BELOW.



10. IF CONTINUOUS WELD IS NOT POSSIBLE DUE TO NOZZLE OBSTRUCTION, [illegible] A GAP UP TO [illegible]" LONG IS ALLOWED PROVIDED THAT THE OBSTRUCTED AREA IS [illegible] ON THE TOP OF THE UPPER CHAIR RING.
11. TACK WELD OPPOSITE SIDE AS REQUIRED. [illegible]
12. FOR STRINGERS AT [illegible] REINFORCING PAD, MAKE A CONTINUOUS WELD ON ONE SIDE TO TANK SHELL. DO NOT WELD TO REINFORCING PAD.
13. FOR STIFFENER PLATES THAT INTERFERE WITH [illegible] TANK PENETRATIONS, SEE DETAIL 6.
14. ◯ - WELD JOINT SYMBOL FOR ASME SECTION III CODE WELD.



ANSTEC APERTURE CARD

Also Available on Aperture Card

9603120065-05

THIS SHEET IS FOR SA-1415-MT-053 ONLY

FOR TANK 054 SEE DWG 5023-407-3-61 SH. 2

QC II UNIT 3

SAN ONOFRE NUCLEAR GENERATING STATION

40'DIA. X 34'-0" HIGH PRIMARY PLANT MAKE-UP STORAGE TANK SHELL PLATE LAYOUT

SHEET 4 OF 4

SOUTHERN CALIFORNIA EDISON

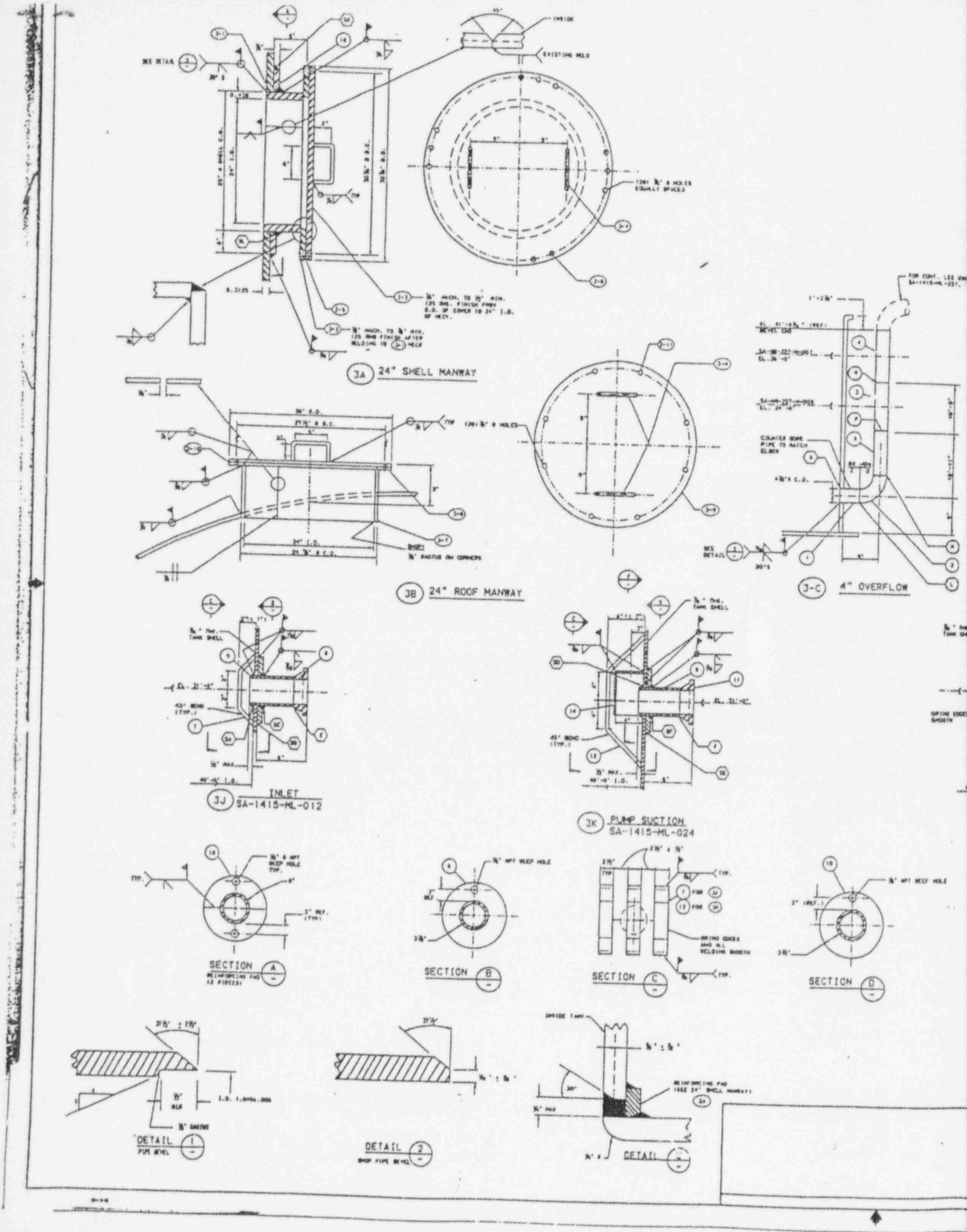
5023-407-3-61 SH.4 REV.0

REFERENCES REVISIONS

* REVISE ON CADD SYSTEM ONLY *

F E D C B A

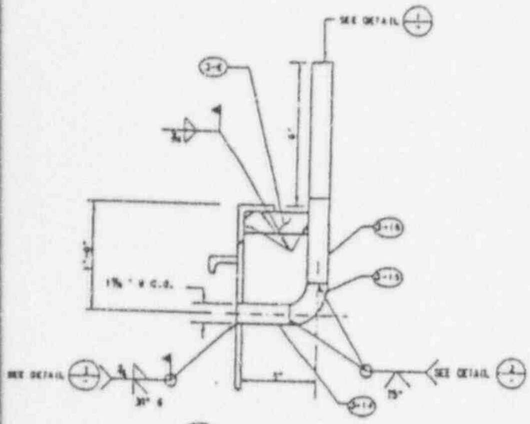
56


3A 24" SHELL MANWAY
3B 24" ROOF MANWAY
3-C 4" OVERFLOW
3J INLET
SA-1415-ML-012
3K PUMP SUCTION
SA-1415-ML-024
SECTION A
SECTION B
SECTION C
SECTION D
DETAIL 1
DETAIL 2
DETAIL

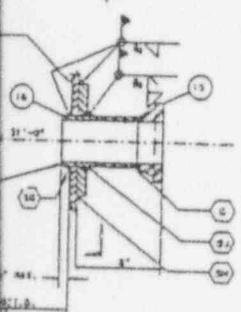
MARK			QTY	DESCRIPTION	SPEC	WT	P.O. NO.
3-A			1	24" SHELL MANWAY			
						251.5	
		3-1	1	PLATE 3/4" x 17 1/2" x 6'-4 3/4" LG.	SA-240-304	72.5	11
		3-2	1	PLATE 5/8" x 24 5/8" I.D. x 32 3/4" O.D.	SA-240-304	38.5	12
		3-3	1	PLATE 3/8" x 32 3/4" O.D.	SA-240-304	121	13
		3-4	2	BAR 5/8" x 12 5/8" LG. x SQ.	SA-479-304	3	14
		3-5	1	GASKET 1/8" THK. x 24" I.D. x 29 3/4" O.D.	RUBBER	1	15
		3-6	28	BOLT 3/4" Ø x 2 1/2" LG. HEX HEAD W/ HEAVY HEX NUT	SA-193-B7 SA-194-2H	15.5	[illegible]
		18	2	SPLIT RING REINFORCING PAD 25" I.D. x 37" O.D. 1/2" THK W/ 1/8" x NEEP HOLE 25'-0" RADIUS TANK	SA-240-304		
3-B			1	24" ROOF MANWAY			
						154	
		3-4	2	BAR 5/8" x 12 5/8" LG. x SQ.	SA-479-304	3	15
		3-7	1	PLATE 1/4" x 14" x 6'-4 7/8" ROLL TO 24" I.D.	SA-240-304	76	17
		3-8	1	PLATE 1/2" x 24 1/2" I.D. x 30" O.D.	SA-240-304	33	18
		3-9	1	PLATE 1/4" x 30" O.D.	SA-240-304	51	16
		3-10	1	GASKET 1/8" THK. x 24" I.D. x 30" O.D.	RUBBER	1	19
		3-11	20	BOLTS 5/8" Ø x 1 1/2" LG. HEX HEAD W/ HEAVY HEX NUT	SA-193-B7	6	20
3-C			2	4" OVERFLOW			
		1	1	PIPE 4" SCH. 80 x 2 3/16" LG. (COUNTER BORE ONE END TO SCH 40S)	SA-312-TP304		
		2	1	90° ELBOW 4" L.R. SCH. 40S	SA-403-WP304		
		3	1	PIPE 4" SCH. 40S x 10'-5" LG.	SA-312-TP304		
		4	1	PIPE 4" SCH. 40S x 10'-5" LG.	SA-312-TP304		
		5	1	PIPE 4" SCH. 40S x 10'-5" LG.	SA-312-TP304		
3-D				1" VENT		3.5	
		3-14	1	PIPE 1" SCH. 80 x 2 3/16" LG.	SA-312-304	1	63
		3-15	1	90° ELBOW 1" L.R. SCH. 80	SA-403-304	1	64
		3-16	1	PIPE 1" SCH. 80 x 1'-4 1/2" LG.	SA-312-304	1.5	63
3-E			2	FLAT BAR 1/4" x 2" x 4 3/16" LG.	SA-240-304	1	4
3-J		5	1L/F	PIPE 2 1/2" SCH. 40S (CUT TO SUIT)	SA-376-TP304		
		6	1	RING REINFORCING PAD 1/2" x 9 7/8" O.D.	SA-240-304		
		7	3	PLATE 1/2" x 2 1/2" x 1'-0" (CUT TO SUIT)	SA-240-304		
		8	1	FLANGE 2 1/2" 150# W.N.R.F., SCH. 40S	SA-182-F316		
3-K		9	1L/F	PIPE 4" SCH. 40S	SA-376-TP304		
		10	1	RING REINFORCING PAD 1/2" x 12" O.D.	SA-240-304		
		11	1	FLANGE 4" 150# W.N.R.F., SCH. 40S	SA-182-F316		
		12	3	PLATE 1/2" x 2 1/2" x 2'-0" (CUT TO SUIT)	SA-240-304		
		13	1	PLATE 1/4" x 4" x 18 3/4" LG.	SA-240-304		
		14	1	PLATE 1/2" x 4 1/4" x 0'-4 1/2" (CUT TO SUIT)	SA-240-304		
3-L		15	1	FLANGE 3" 150# W.N.R.F., SCH. 80 BR	SA-182-F316		
		16	1L/F	PIPE 3" SCH. 80S (CUT TO SUIT)	SA-376-TP304		
		17	1	RING REINFORCING PAD 1/2" x 9 3/4" O.D.	SA-240-304		

= WELD JOINT SYMBOL FOR ASME SECT. III CODE WELDS.

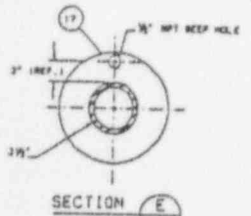
= WELD JOINT SYMBOL FOR ASME SECT. XI CODE WELDS.



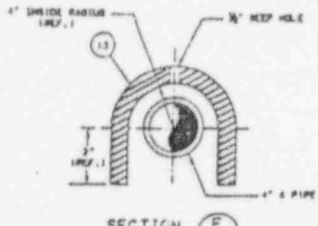
(3-D) 1" VENT



(3L) INLET RECIRC.
SA-1415-ML-056



SECTION (E)



SECTION (F)

ANSTEC
APERTURE
CARD

Also Available on
Aperture Card

NOTES:

1. FOR ALL NOZZLE LOCATIONS SEE DWG. SO23-407-3-61 SH. 2.
2. FOR CLASS "2", PIPE MATERIAL TO BE ASME SECTION III, CODE CLASS 2, 1989 EDITION, NO ADDENDA. WELDS TO BE SECTION IX, 1965 EDITION, NO ADDENDA.
3. DIMENSIONAL TOLERANCES ± 1/8".

* REVISE ON CADD SYSTEM ONLY *

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9603120065-06

THIS TANK HAS BEEN RECONCILED TO A.S.M.E. 1989 CODE SECTION III, NO ADDENDA. REFERENCE DESIGN CALCULATION M-DMC-288 DATA REPORT SA-1415-1.

QC II UNIT 3

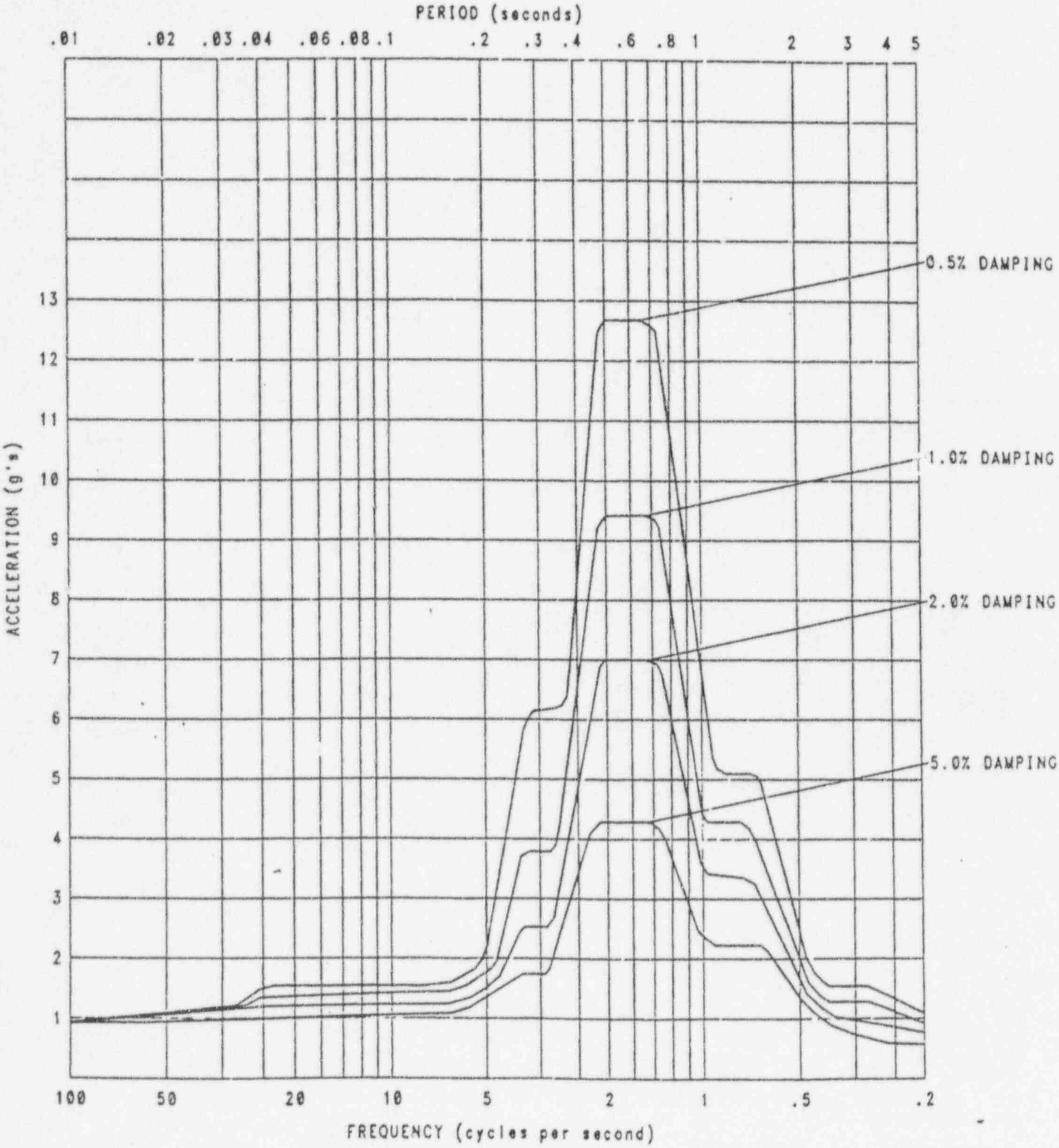
SAN ONOFRE NUCLEAR GENERATING STATION

40' DIA. x 34'-0" HIGH
PRIMARY PLANT MAKE-UP STORAGE TANK 035
NOZZLE

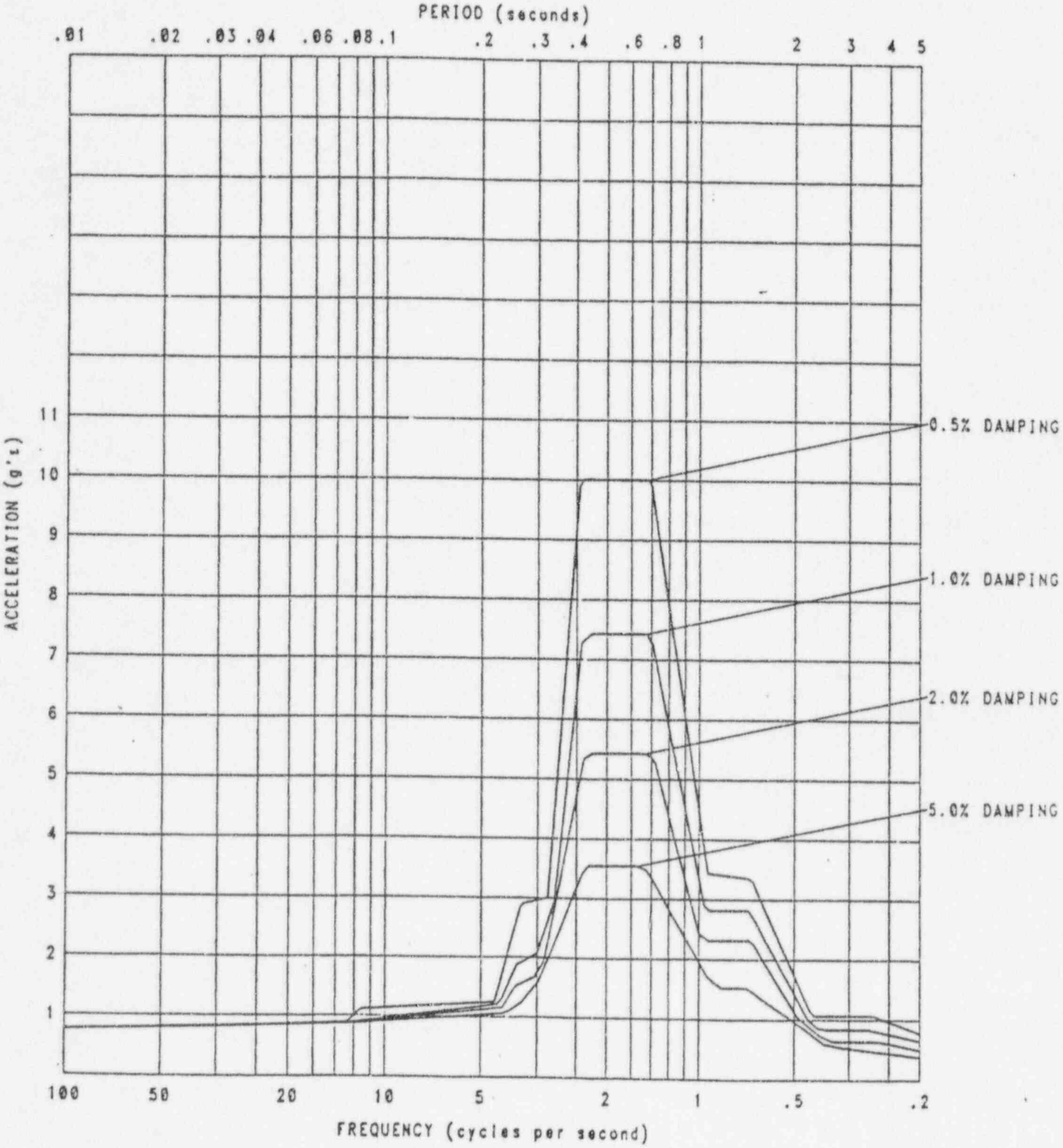
SOUTHERN CALIFORNIA EDISON

REFERENCES | REVISIONS

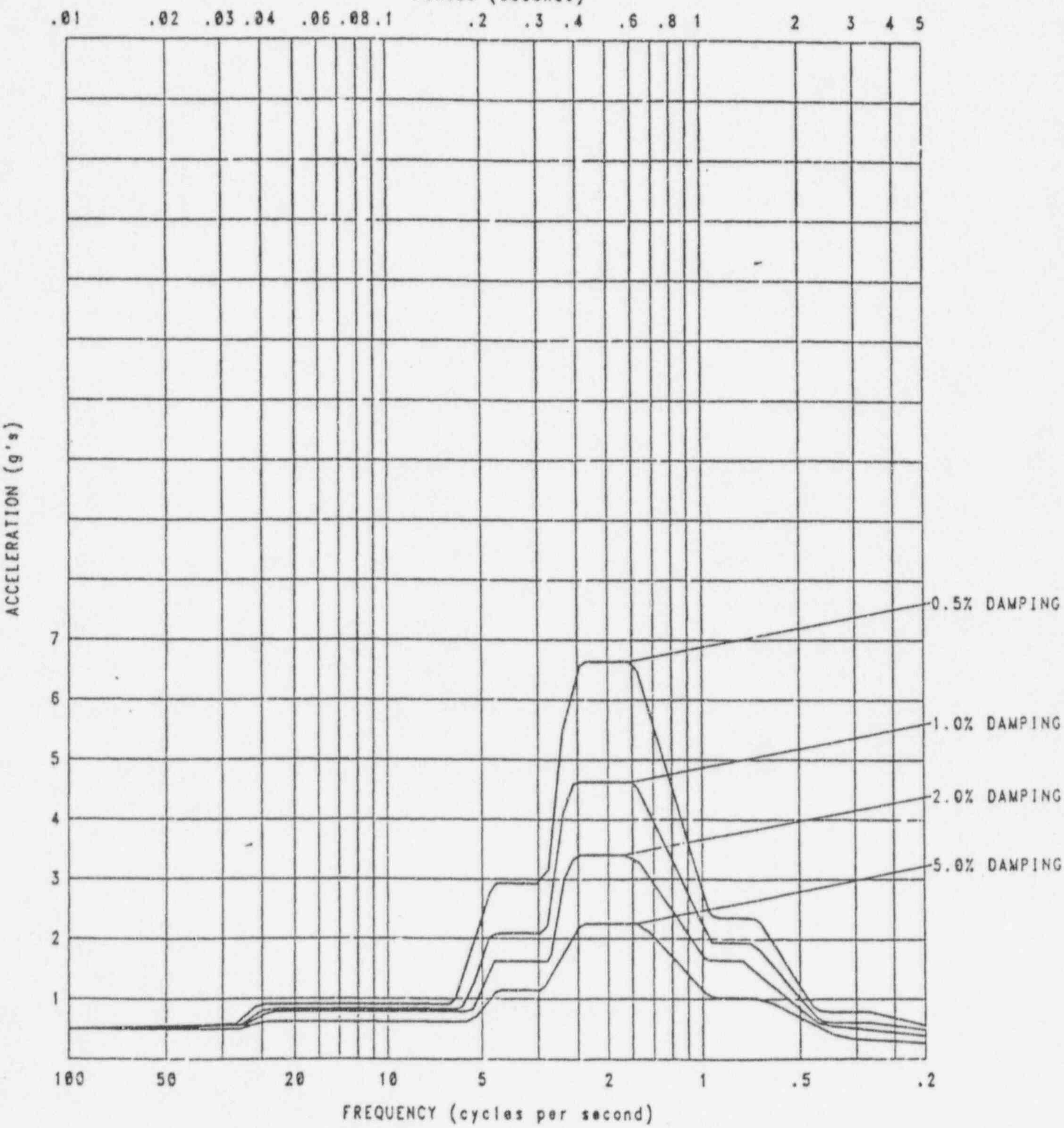
SO23-407-3-63 SH. 2 REV. 0



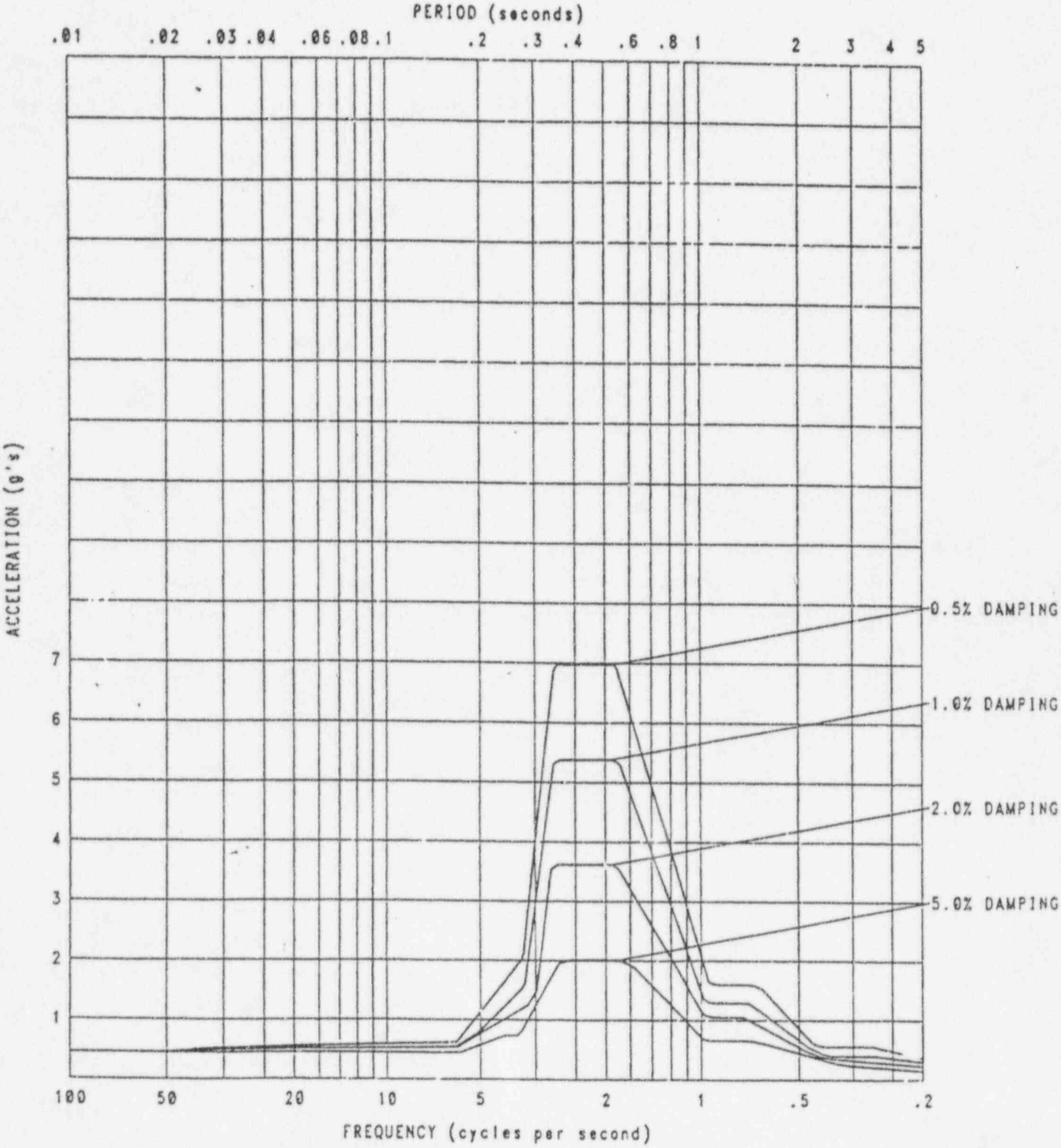
Design Basis Earthquake Horizontal Acceleration Response
Spectra, Elevation 9′-0″ of Auxiliary Building



Design Basis Earthquake Vertical Acceleration Response
Spectra, Elevation 9′-0″ of Auxiliary Building



Operating Basis Earthquake Horizontal Acceleration Response Spectra, Elevation 9′-0″ of Auxiliary Building



Operating Basis Earthquake Vertical Acceleration Response Spectra, Elevation 9′-0″ of Auxiliary Building

APPENDIX B

RESPONSE TO NRC QUESTIONS AND CONCERNS

RESPONSE TO NRC QUESTIONS AND CONCERNS

Reference : Telephone Discussion with the NRC on August 10, 1995.

1. The calculation did not discuss in detail how the code comparison between API 650 (original construction Code) and ASME (Section III Class 3) Code was performed and which parts of the ASME code were applicable and why. In particular, they would like to see more discussions on material, fabrication and installation, and testing and examination.

   RESPONSE : Table 2.1, Code Reconciliation Matrix of the Summary Report provides comparison between the ASME code and API and the reconciliations performed to satisfy technical requirements of the ASME code. The table addresses material, design, fabrication, installation, testing, examination, testing and overpressure protection requirements applicable to atmospheric storage tanks.

2. There was concern about use of qualifiers like "mainly" in Attachment D and "one major difference" in Section 11.3 in the calculation. Although they do not expect absolute terms, they would like to see more legalistic terms which provide a more specific description and should present a more general compliance with the ASME code.

   RESPONSE : The Summary Report provides more specific descriptions to show compliance with the technical requirements of the ASME code.

3. There was no conclusion given in the calculation about code equivalency of the shell to bottom weld deviation.

   RESPONSE: Section 5.3 of the Summary Report shows that the shell to bottom weld meets ASME code stress allowables under SSE loadings.

4. The NRC would like to see in a future letter a summary of results and conclusions showing that the modified tanks are equivalent to ASME Class 3 tanks except for the N-stamps.

   RESPONSE : Section 2 of the Summary Report provides a summary of results and conclusions to demonstrate that the modified tanks provide safety equivalent to ASME Class 3 tanks except for the N-stamping.

During a meeting on 10/03/1995, the NRC requested a comparison between two sloshing water pressure scenarios during a seismic event:

- Uniform pressure applied symmetrically to the tank roof, which was evaluated in SCE's tank upgrade reports,
- Asymmetric loading of the roof assuming that the sloshing water will apply pressure on part of the roof only.

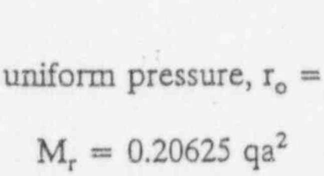
RESPONSE:

The following qualitative comparison is made with a circular plate loaded symmetrically by a uniformly distributed pressure, and by a linearly distributed load (asymmetric load):

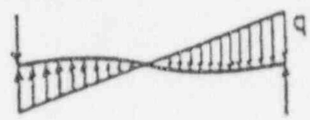
Per Roark's Formulas for Stress & Strain (Reference 35), Table 24, Case 10 (uniform pressure) and Case 22 (linearly distributed load), the bending moment, M_r, is given by,

10. Uniformly distributed pressure from r_o to a

Simply supported



22. Linearly distributed load symmetrical about a diameter; edge simply supported



uniform pressure, $r_o = 0$,

$$M_r = 0.20625\ qa^2$$

linearly distributed pressure

$$M_r = 0.0425\ qa^2$$

Therefore, M_r (uniform pressure) > M_r (linear distribution)

ENCLOSURE 4

RESPONSES TO QUESTIONS FROM NRC REVIEWERS

RESPONSES TO QUESTIONS FROM NRC REVIEWERS
ON THE SAN ONOFRE UNITS 2 AND 3 PRIMARY PLANT MAKEUP TANK UPGRADE

(1) 4.0 DESIGN INPUT, Sheet No. 270 - Confirm that the shell plate seam welds of the CCW tank are of SMAW type. The JIc of 990 in-lb/in2 used in this report is for SMAW at 550 degrees F. Estimate the value corresponding to the tank temperature of 104 degrees F, and revise the fracture mechanics analysis accordingly.

Response:

The shell plate seam welds of the tanks are of SMAW type. This is documented in the Data Report, SCE No. SA-1415-1, Page 371, a copy of which was sent to the NRC.

The JIc value of 990 in-lb/in2 at 550 degrees F was used to calculate the allowable KIc used in the fracture mechanics evaluation. This allowable KIc was calculated using the following correlation:

KIc	=	square root of (JIc times E)
		(where E is Young's modulus (25E6 psi))
	=	sqrt (990 * 25E6)
	=	157,321 psi sqrt(inch)
	=	157 ksi sqrt(inch)

At lower temperatures, no values of JIc or KIc are available. However, an estimate of the allowable KIc at 75 degrees F can be made based on available Charpy V-Notch (CVN) data at 75 degrees F. This estimate was made as follows:

CVN Value	=	150 ft-lb (Stainless Steel Technical Data, Allegheny Ludlum Steel Division, Pittsburgh, PA, Allegheny Ludlum Corporation)
KIc	=	12 times sqrt(CVN) ("The Practical Use of Fracture Mechanics," by D. Broek, 1989, Kluwer Academic Publishers)
	=	12 times sqrt(150) = 147 ksi sqrt(inch)

The value calculated above at 75 degrees F (147 ksi sqrt(inch)) is only 6% less than the value of 157 ksi sqrt(inch) at 550 degrees F used in the fracture mechanics evaluation. The effect of lowering the temperature is slight, as would be expected for austenitic stainless steel.

A Summary Report of the Primary Plant Makeup Storage Tank (PPMUT) upgrade (see Enclosure 3) includes a fracture mechanics evaluation which compares results against an allowable KIc of 135 ksi sqrt(inch) obtained from Generic Letter (GL) 90-05 for stainless steel. This allowable KIc is consistent with the lower-bound fracture toughness property used in Section XI of the ASME Code (See pages 43 and 44 of the Summary Report). The allowable KIc is also lower than the calculated KIc at 75 degrees F (147 ksi sqrt(inch)). Therefore, the value of JIc at 104 degrees F, while not available, would clearly be bounded between KIc at 75 degrees

F and KIc at 550 degrees F, which are both above the minimum allowable value established in GL 90-05.

(2) 8.1 STRESS CALCULATIONS, Sheet No. 277 - It was indicated that the loads, which produced the maximum hoop stress of 15.9 ksi from the tank FEM model, are the water sloshing SSE load and tank hydrostatic pressure. What about the inertia load of the tank itself under SSE loading? Provide a detailed definition and information about this water sloshing SSE load.

Response:

The inertia load of the tank under SSE was calculated in the design report as part of the GIP analysis steps, and an evaluation was made for the calculated overturning moment (see Steps 6 and 17 of the Summary Report). The overturning moment produces tensile stresses in the axial direction on one side of the tank and compressive stresses on the opposite side. The hoop stresses due to hydrostatic pressure are, however, much higher than the axial stresses due to the overturning moment. Therefore, the fracture mechanics evaluation was based on hoop stresses with the flaw assumed in a vertical seam which gives worst case results.

The hoop stresses due to water sloshing were incorporated in the fracture analysis by including an additional pressure component to the hydrostatic pressure. This additional pressure component is equivalent to the pressure of the sloshing water on the tank roof as calculated in SCE report numbers M-DSC-269 and M-DSC-280 (see Section 10.3 in either report). This total hydrostatic pressure was then applied to the tank shell in the finite element model to calculate the hoop stresses in the tank shell.

(3) What is the sloshing component number (i.e., sloshing component magnitude used in the sloshing component analysis)?

Response:

The total pressure in the tank, used to calculate the hoop stress in the tank wall for fracture mechanics analysis, consists of two components:

(a) The hydrostatic pressure with the tank filled to its maximum capacity, and

(b) The water sloshing component of 3.29 psi added to the hydrostatic pressure component. This value is based on DBE conditions.

Refer to the detailed report, Section 10.3, for the calculation of the equivalent sloshing pressure.

(4) In the responses sent to Dave Jeng, what is the Summary Report referred to? (Is it the same as the draft Summary Report provided to Mr. Jeng at his audit?)

Response:

The responses to Mr. Jeng's questions which refer to the Summary Report reference the final Summary Report which is provided as Enclosure 3. The final Summary Report replaces the draft Summary Report given to Mr. Jeng at the Makeup Tank Audit meeting.

(5) With regard to the hoop stresses, what were the added values of the pressure component?

Response:

See response to question number 3 above.

(6) Provide the reasons why Edison performed the code reconciliation to the 1989 code and not to the 1978 code.

Response:

The tank was re-evaluated to perform a new function other than the original function. A recent Code was considered more appropriate as basis for the evaluation.

(7) Perform an analysis to address specifically the flaw acceptability for the normal plus upset (non-faulted) PPMUT stress condition.

Response:

The analysis is attached. The analysis shows that the margin of safety remains acceptable (i.e., above three) for the normal plus upset (non-faulted) PPMUT stress condition.

(8) Perform an analysis for the PPMUT worst flaw.

Response:

See attached analysis. The maximum horizontal flaw is 4.875 inches. The maximum vertical flaw is 4.375 inches. The 95%/95% flaw was evaluated as a vertical flaw 3.5 inches in length. Each of these flaws was assessed and found to have a margin of safety which is greater than three regardless of whether the margin of safety is based on Generic Letter 90-05 or KIA (the crack arrest stress intensity factor). Therefore the margin of safety remains acceptable.

(9) Are the Unit 2 and Unit 3 PPMUT upgrades similar?

Response:

The original design and construction of the Unit 2 and the Unit 3 PPMUTs were the same. The Unit 2 and Unit 3 PPMUT upgrades are similar. Both the analysis methods (non-destructive examination, statistical analysis, fracture mechanics analysis, and seismic analysis) and construction criteria for the Units 2 and 3 PPMUT upgrades are the same.

Normal/Upset Flaw Evaluation

The fracture mechanics evaluation for the normal/upset flaw evaluation will be conservatively performed by using the faulted loads and comparing against normal/upset allowables. The following analysis steps summarize this fracture mechanics evaluation:

1. Identification of the Bounding Flaw Size (Unit-2 vs Unit-3)

Per radiographic examination results (References 2 and 3), the following are the bounding flaw for Unit-2 PPMS tank (T-056) and Unit-3 PPMS tank (T055):

	Flaw Size, Unit-2 PPMS Tank (inch)	Flaw Size, Unit-3 PPMS Tank (inch)
95% - 95% flaw size (all flaws)	1.625	3.5
maximum horizontal flaw	4.875 (flaw No. G2-3)	4.5 (flaw No. R4H3)
maximum vertical flaw	4.375 (flaw No. R3V5)	3.25 (flaw No. R1V5)

The flaw designation numbers in the table above are shown in Figure 1 for Unit-2 and Figure 2 for Unit-3. The location of each of these flaws are also shown in these two figures.

Based on the above comparison, the bounding evaluations were performed for the following flaws:

(a) Flaw size = 3.5" representing the flaw with 95% confidence that 95% of the flaw population will be smaller. This flaw is conservatively evaluated as a vertical through wall crack subjected to the maximum faulted hoop stress in the tank of 15.9 ksi per Figure 3 (same as Figure 5.8 of Reference 1),

(b) Horizontal flaw size = 4.875". This flaw size bounds all horizontal flaws in both tanks, and it will be evaluated using a through wall crack model and the maximum axial stress in the tank wall of 5.3 ksi per Reference 1,

(c) Vertical flaw size = 4.375". This Unit-2 flaw is located in the third row as shown in Figure 1. Conservatively, a through wall crack model was used in the fracture mechanics analysis. This crack is subjected to a hoop stress of 13.6 ksi at the crack location (see Figure 3). This flaw is bounding based on its size. The second largest vertical crack lies in the first row where the hoop stress is insignificant. Also, largest second row cracks are enveloped by case (a) above.

Stress intensity factor results were compared with the allowable $K_I = 135$ ksi$\sqrt{\text{inch}}$ obtained from Generic Letter 90-05 for stainless steel. This allowable is consistent with the lower bound fracture toughness property used in Section XI of the ASME Code. Results were also compared with $K_{IA} = 125.86$ ksi$\sqrt{\text{inch}}$ (80% of $K_{IC} = 157.32$ ksi$\sqrt{\text{inch}}$ per the Summary Report). Using the acceptance criteria given in Section XI, Subsection IWB-3640 as a guideline, the flaw is acceptable if a margin of safety=3 exists under Normal/Upset conditions.

2. Flaw Evaluation Results

The fracture mechanics evaluation program PCCRACK was used to perform the evaluation for the following cases:

(a) Vertical 3.5" flaw representing 95% confidence that 95% of the flaw population is smaller. Results of the evaluation are given in Attachment A.

$K_I = 40.54$ ksi$\sqrt{\text{inch}}$
Factor of safety (based on GL 90-05) = 135/40.54 = 3.33 [O.K.]
Factor of safety (based on K_{IA}) = 125.86/40.54 = 3.10 [O.K.]

(b) Horizontal 4.875" flaw (flaw No. G2-3). Results of the evaluation are given in Attachment B.

$K_I = 14.9$ ksi$\sqrt{\text{inch}}$
Factor of safety (based on GL 90-05) = 135/14.96 = 9.02 [O.K.]
Factor of safety (based on K_{IA}) = 125.86/14.96 = 8.41 [O.K.]

(c) Vertical 4.375" flaw (flaw No. R3-V5). The hoop stress at the flaw elevation is 14.3 ksi. Results of the evaluation are given in Attachment C.

$K_I = 40.7$ ksi$\sqrt{\text{inch}}$
Factor of safety (based on GL 90-05) = 135/40.7 = 3.31 [O.K.]
Factor of safety (based on K_{IA}) = 125.86/40.7 = 3.09 [O.K.]

It should be noted that in the above Normal/Upset evaluation, faulted loads were conservatively used. Based on the above results, it is concluded that applicable allowables are met.

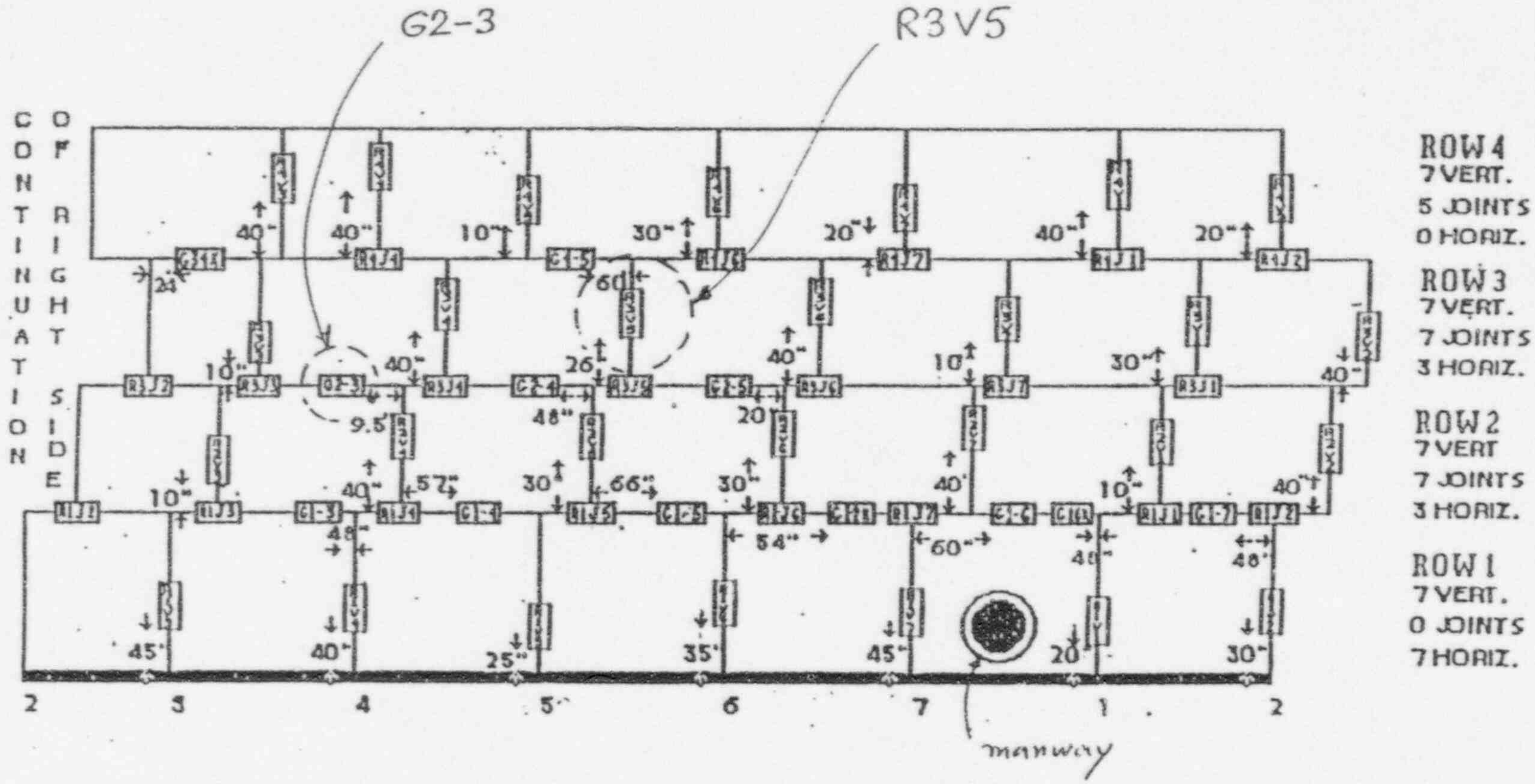


Figure 1 Unit-2 PPMS Tank Radiographic Examination Map

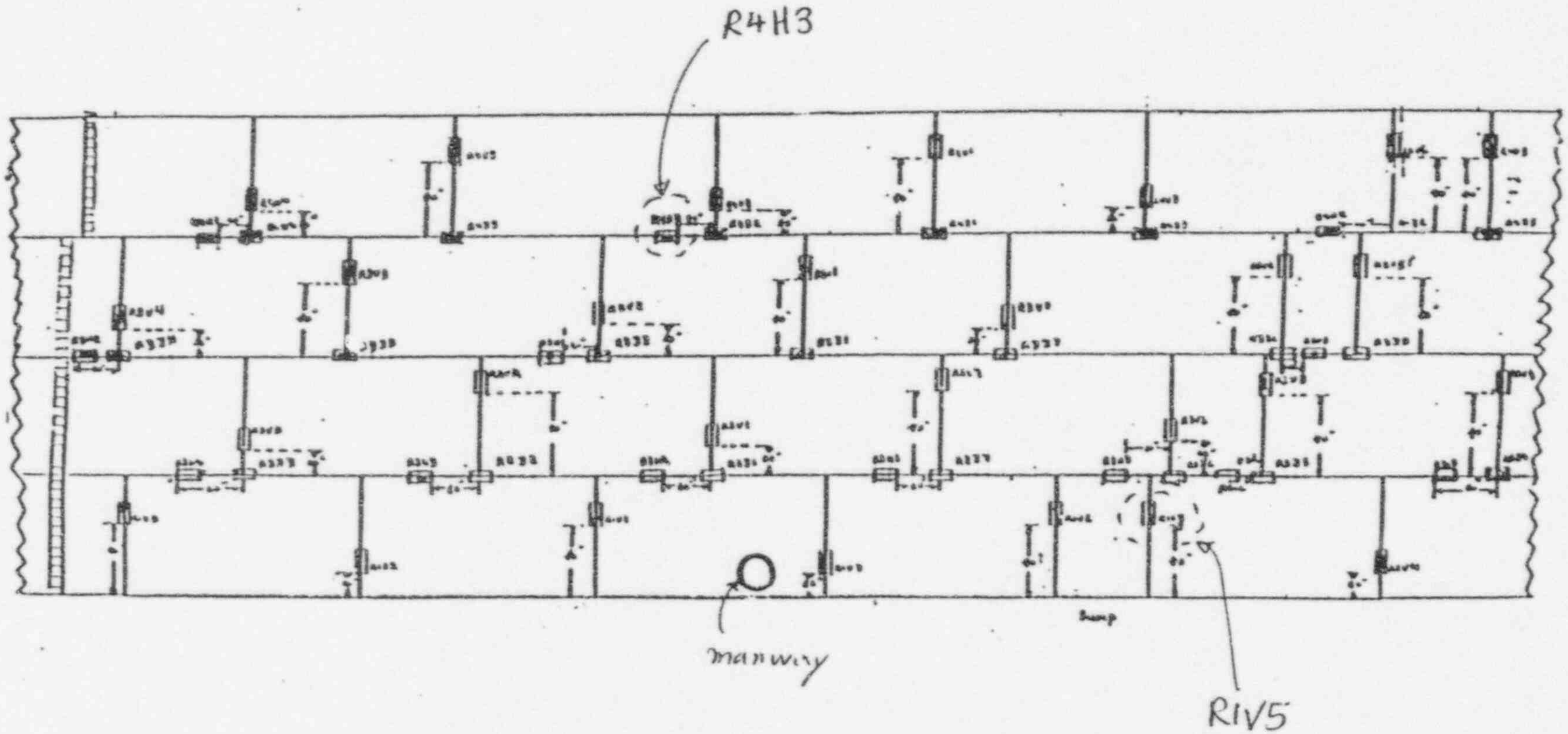


Figure 2 Unit-3 PPMS Tank Radiographic Examination Map

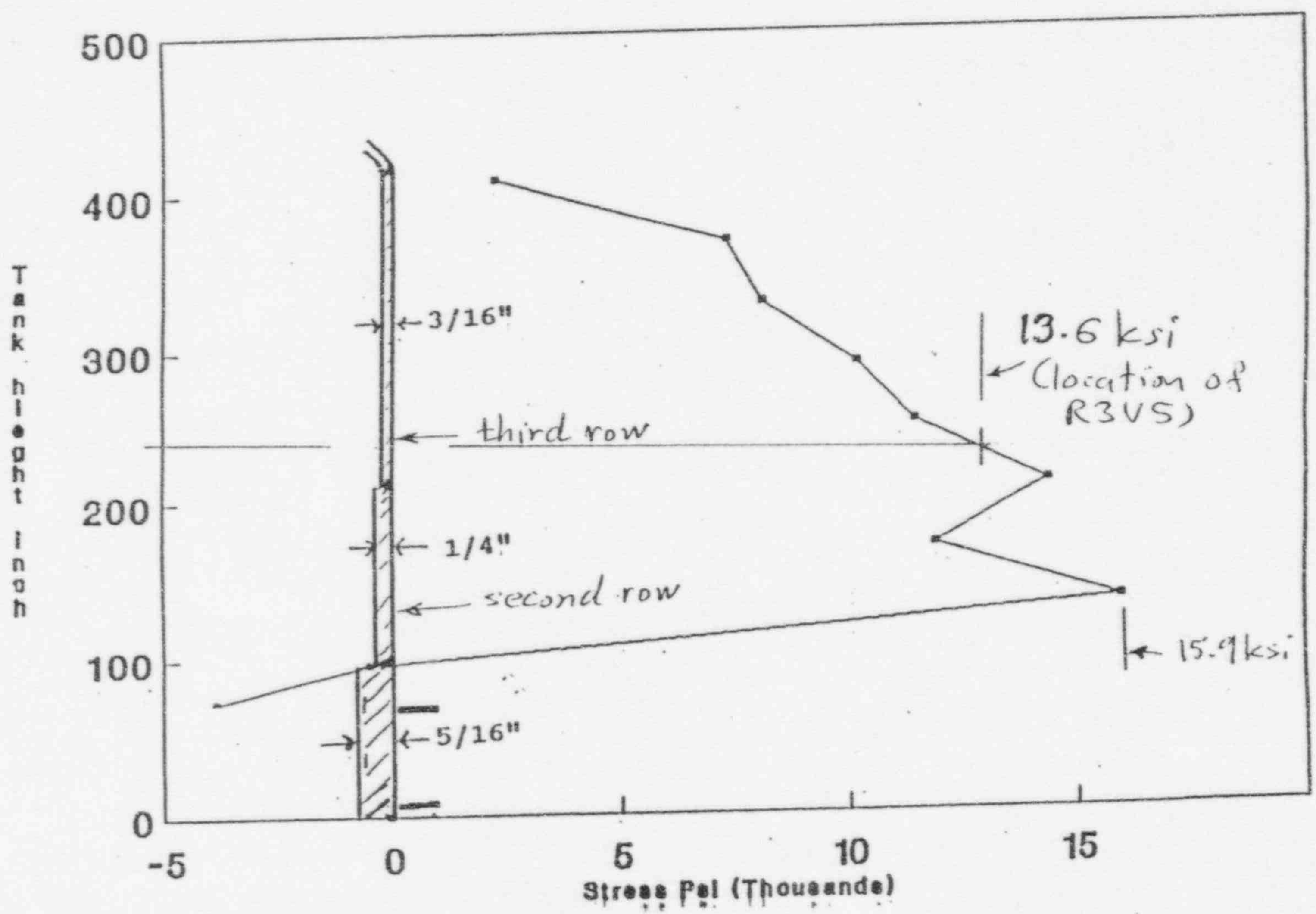


Figure 3 Hoop Stress Distribution in the Tank Shell

References

1. Summary Report,"Primary Plant Make Up Storage Tank Upgrade, San Onofre Nuclear Generating Station Units 2 and 3," October 1995

2. SCE calculation No. M-DSC-280, Revision 1,"SONGS 2 Primary Plant Make Up Storage Tank Upgrade."

3. SCE calculation No. M-DSC-269, Revision 0,"SONGS 3 Primary Plant Make Up Storage Tank Upgrade."

Attachment A to Normal/Upset Flaw Evaluation

PCCRACK Results for 3.5" Vertical Crack
(95% - 95% Flaw Size)

pc-CRACK tm
(C) COPYRIGHT 1984, 1990
STRUCTURAL INTEGRITY ASSOCIATES, INC
SAN JOSE, CA (408)978-8200
VERSION 2.1

Date: 22-Jul-1993
Time: 18:27:11.99

LINEAR ELASTIC FRACTURE MECHANICS EVALUATION

t56

crack model:THROUGH WALL AXIAL CRACK IN PRESSURIZED CYLINDER

WALL THICKNESS (t) = 0.2500
OUTER DIAMETER (OD)= 480.0000

CASE ID	STRESS
1	15.9000

1/2 CRACK SIZE	STRESS INTENSITY FACTOR CASE 1
0.1000	8.943
0.2000	12.693
0.3000	15.605
0.4000	18.092
0.5000	20.312
0.6000	22.347
0.7000	24.247
0.8000	26.042
0.9000	27.756
1.0000	29.403
1.1000	30.996
1.2000	32.544
1.3000	34.056
1.4000	35.536
1.5000	36.991
1.6000	38.424
1.7000	39.840
1.8000	41.240
1.9000	42.627
2.0000	44.005
2.1000	45.374
2.2000	46.737
2.3000	48.095
2.4000	49.450
2.5000	50.802

← half (95%-95%) crack length = 1.75"

$\Rightarrow K_I = 40.54$ ksi $\sqrt{\text{inch}}$

(full 95%-95% crack length = 3.5")

$$F.S. = \frac{135}{40.54} = 3.33$$ o.k.

Attachment B to Normal/Upset Flaw Evaluation

PCCRACK Results for 4.875" Horizontal Crack

tm
pc-CRACK
(C) COPYRIGHT 1984, 1990
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VERSION 2.1

Date: 25-Jan-1996
Time: 15:54:59.26

LINEAR ELASTIC FRACTURE MECHANICS EVALUATION

evaluation of flaw G2-3 in the PPMS tank - T056

crack model:THROUGH WALL CIRC. CRACK IN CYLINDER UNDER TENSION AND BENDING

WALL THICKNESS (t) = 0.1875
OUTER DIAMETER (OD)= 480.0000
POISSON RATIO = 0.3000

APPLIED STRESSES:

CASE ID	MEMBRANE	BENDING
1	0.0000	5.3000

1/2 CRACK SIZE	STRESS INTENSITY FACTOR CASE 1
0.1000	2.971
0.2000	4.202
0.3000	5.147
0.4000	5.945
0.5000	6.648
0.6000	7.286
0.7000	7.873
0.8000	8.421
0.9000	8.937
1.0000	9.427
1.1000	9.895
1.2000	10.343
1.3000	10.774
1.4000	11.191
1.5000	11.596
1.6000	11.989
1.7000	12.372
1.8000	12.745
1.9000	13.111
2.0000	13.469
2.1000	13.821
2.2000	14.166
2.3000	14.506
2.4000	14.841
2.5000	15.171
2.6000	15.497
2.7000	15.820

$FS = \frac{135}{14.96} = 9.02$

half crack length = 2.4375" ⇒ $K_I = 14.96$ ksi$\sqrt{\text{inch}}$

(Full crack length = 4.875 ksi$\sqrt{\text{inch}}$)

Attachment C to Normal/Upset Flaw Evaluation

PCCRACK Results for 4.375" Vertical Crack

tm
pc-CRACK

STRUCTURAL INTEGRITY ASSOCIATES, INC.
SAN JOSE, CA (408)978-8200
VERSION 2.1

Date: 30-Jan-1996
Time: 12:13:13.23

LINEAR ELASTIC FRACTURE MECHANICS EVALUATION

evaluation of flaw r3v5 in the ppms tank - t -056

crack model:THROUGH WALL AXIAL CRACK IN PRESSURIZED CYLINDER

WALL THICKNESS (t) = 0.1875
OUTER DIAMETER (OD)= 480.0000

CASE ID	STRESS
1	13.6000

1/2 CRACK SIZE	STRESS INTENSITY FACTOR CASE 1
0.1000	7.653
0.2000	10.870
0.3000	13.373
0.4000	15.514
0.5000	17.432
0.6000	19.195
0.7000	20.845
0.8000	22.409
0.9000	23.906
1.0000	25.350
1.1000	26.752
1.2000	28.119
1.3000	29.457
1.4000	30.773
1.5000	32.070
1.6000	33.352
1.7000	34.622
1.8000	35.883
1.9000	37.136
2.0000	38.385
2.1000	39.629
2.2000	40.872
2.3000	42.113
2.4000	43.355
2.5000	44.599
2.6000	45.844
2.7000	47.093
2.8000	48.345
2.9000	49.602

$$FS = \frac{135}{40.72} = 3.31$$

half crack length= 2.1875 $\Rightarrow K_I = 40.72$ ksi$\sqrt{\text{inch}}$
(Full crack length= 4.375")