ENCLOSURE 2

UNIT 3 PPMUT UPGRADE CALCULATION M-DSC-269

Southern California Edison Company	CALC NO. M-DSC-269	ICCN NO./ PRELIM. CCN NO. F-565	PAGE 1	TOTAL NO. OF PAGES 277
INTERIM CALCULATION CHANGE NOTICE (ICCN)/ ~~CALCULATION CHANGE NOTICE (CCN)~~	BASE CALC. REV. 0 / UNIT 3	CCN CONVERSION: CCN NO. CCN- 1		CALC. REV. 0
	CALCULATION SUBJECT: SONGS-3 PRIMARY PLANT MAKE-UP STORAGE TANK UPGRADE			
CALCULATION CROSS-INDEX ☑ New/Updated Index Included ☐ Existing Index is Complete	ENGINEERING SYSTEM NUMBER/PRIMARY STATION SYSTEM DESIGNATOR 1203/EGA			Q-CLASS II
	CONTROLLED PROGRAM OR DATABASE IN ACCORDANCE WITH NES&L 41-5-1 ☐ PROGRAM ☐ DATABASE	PROGRAM/DATABASE NAME (S) ☐ ALSO, LISTED BELOW		VERSION/RELEASE NO.(S)

1. BRIEF DESCRIPTION OF ICCN / CCN:

The purpose of this ICCN is to void ICCN F-498, and replace sheets 2 through 237 by attached sheets 2 through 279 to include the results of the statistical and fracture mechanics analyses performed in response to the results of the radiographic examination of the tank performed by QC, and to reflect as-built conditions.

INITIATING DOCUMENT (DCP/MMP, FCN, OTHER) 2836742.07 SM, QC Report 3RT-035-93 Rev. 0

2. OTHER AFFECTED DOCUMENTS (CHECK AS APPLICABLE FOR CCN ONLY):

☐ YES ☐ NO OTHER AFFECTED DOCUMENTS EXIST AND ARE IDENTIFIED ON ATTACHED FORM 26-503.

3. APPROVAL: DISCIPLINE/ESC: NEDO/CIVIL PD

NABIL M. EL-AKILY / NME 51782 — ORIGINATOR (Print name/initial) PAX

[signature] — GS (Signature)

[signature] — OTHER (Signature)

JUN GAOR / T.G. 51327 — IRE (Print name/initial) PAX

[signature] — NES&L DM (Signature)

11/23/93 — DATE

4. ASSIGNED SUPPLEMENT ALPHA DESIGNATOR/ CONVERSION TO CCN DATE 2-3-94

Barbara Echevarria — SCE CDM-SONGS

SCE 26-122-1 REV. 9/91

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CALCULATION CROSS-INDEX

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	CCN CONVERSION: CCN NO. CCN--

Calculation No. M-DSC-269 Sheet No. 2

Calc. rev. number and responsible supervisor initials and date	INPUTS These interfacing calculations and /or documents provide input to the subject calculation, and if revised may require revision of the subject calculation. Calc/ Document No.	Rev. No.	OUTPUTS Results and conclusions of the subject calculation are used in these interfacing calculations and/or documents. Calc/ Document No.	Rev. No.	Does the output interface calc/ document require revision? YES / NO	Identify output interface calc/document CCN, DCN, TCN/Rev. or FIDCN
[initials] 11/18	DCP 283 6742.07SM	0	S023-407-3-97 (Design Report for PPMS 40' Dia. Tank)	0	Yes	IDCN S-1
	M-1203-476-3A	0				
	M-1203-478-3A	0				
	S-1415-56 ICCN C-1		P&ID 40133		Yes	IDCN S-6
	S-1415-04 ICCN C-1					
	S-1415-07 ICCN C-1		S023-407-3-61	2	Yes	IDCN S-2
[initials] 11/18	S-1415-37 ICCN C-1		S023-407-3-64	1	Yes	IDCN S-1
	P-450-1.22 ICCN C-2		S023-407-3-63	3	Yes	IDCN S-2
	807 ICCN C-1					

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1. PURPOSE/BACKGROUND

The existing Component Cooling Water (CCW) system at SONGS 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, using the temporary connection, as required by NRC Q&R 010.49. This arrangement, however, is very labor intensive to operate, and the 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 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 Primary Plant Make-Up Storage (PPMS) tank, T-056 for Unit 2 and T-055 for Unit 3. These tanks were originally designed to API-620, 5th. Edition, and constructed and tested to API-650, 5th. Edition; and were classified as Seismic Class II components. Both tanks will be upgraded to Quality Class II, Seismic Category I to establish ASME Code, Section III, Class 3 equivalency without ASME stamping. This tank upgrade is necessary in order to qualify as an integral part of the CCW system, as explained above. Comparison between the API 650 Code, which was the basis for the original tank construction and testing, and the ASME Code was made to identify and reconcile the differences between the requirements of the two codes. These differences will be resolved, as part of the tank upgrade analysis.

The purpose of this calculation is to document the analyses, and the Code reconciliation performed to upgrade SONGS 3 PPMS tank to seismic class I, and to qualify these tanks per ASME Code, Section III, Class 3 to meet the requirements described above. This calculation includes the analyses and ASME Code reconciliation performed to achieve the desired tank upgrade.

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Additional supporting calculations are provided in section 8. The design calculation performed by Structural Integrity Associates is provided in Appendix A. Appendix B, provides the development of the tank shell stick model. ANSYS input files are provided in Appendix C; and in Appendix D some reference documents are compiled. The statistical analysis for the radiographic sampling results are provided in Appendix E. Appendix F provides the results of the fracture mechanics evaluation made for a bounding size defect.

ICCN F-565 is issued to incorporate comments made by Quality Assurance (QA). These comments have minor impact on the results, and do not impact the previous conclusions.

This analysis is for SONGS Unit-3 only.

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2. RESULTS/CONCLUSIONS

1. For the existing tanks to meet the seismic loads and Generic Implementation Procedure (GIP) it is recommended that each tank be reinforced by 36 vertical stringers and 34 additional anchor bolts. Details can be found in Appendix A and Reference 1 (a copy is attached in Appendix D).

2. Anchor bolt chairs are to be replaced by a new ring-type chairs. Details can be found in Appendix A, and Reference 1 (a copy is attached in Appendix D).

3. The water inside the tank is expected to slosh against the roof. However, the roof was shown to be capable of withstanding the sloshing loads during a DBE seismic event.

4. A 1/4" thick reinforcing pad is to be added to the man hole of each tank. Details are given in Appendix A, and Reference 1 (a copy is attached in Appendix D).

5. Reinforcing pads are to be added to some nozzles so that local stresses in the shell do not exceed their allowables. See Section 8 for a list of the nozzles requiring reinforcing pads.

6. Some anchor bolts may be moved radially out a distance up to 1 5/16" to avoid interference with the rebars in the concrete base without exceeding any of the allowable stress limits. Similarly, anchor bolt chairs may be moved up to 4" in the circumferential direction from their nominal position to avoid interference with tank attachments.

7. The existing tank wall-to-bottom weld is within the allowable of the weld material.

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8. The modified tank has been evaluated for buckling per the Generic Implementation Procedure (GIP) for Seismic Verification of Nuclear Plant Equipment, Revision 2 (Reference 17, Appendix A). This evaluation shows that the modified tank meets the GIP requirements. Furthermore, the tank has been evaluated for buckling at higher elevations, above the reinforcing stringers, using Code Case N-284 and shown to be acceptable. It should be noted that this additional evaluation, at higher elevations, is not required by the GIP. It was performed basically to ensure that the analysis covers the entire tank shell height.

   Also, the tank does not have any large asymmetric openings; therefore, axisymmetric analysis techniques should be applicable.

9. ASME Code reconciliation is summarized below:

- A detailed ASME Code reconciliation is included in the PPMS tank design report (Appendix A, Sections 10 and 11). Results can be summarized as follows:

  (a) Tank Shell Design, the minimum tank shell requirements of ND-3324.3, which is referred to by ND-3842, are satisfied at all elevations.

  (b) Tank Bottom Design, the requirements of ND-3831 are satisfied by the tank bottom. The foundation also meets the requirements of ND-3831, since the PPMS tanks were built to the standards of API-650.

  (c) Tank Roof Design, the tank roof satisfies all the requirements of ND-3856. Furthermore, it is shown in Appendix A that the roof, and the junction to the cylindrical shell will withstand the water pressure caused by sloshing.

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(d) Tank Manway, the tank manway, reinforced by a 0.25" thick plate, meets the requirements of ND-3332.

(e) Code Stress Limits, the stresses in the tank shell meets the requirements of ND-3821.5 under Design, Operating Basis Earthquake (OBE), and Design Basis Earthquake (DBE) conditions.

- A survey of SONGS-3 tank, T055, was performed for roundness at elevations 7' above the bottom and 6' below the top. Results of the survey are attached in Appendix D. Based on these results, it is concluded the tank meets the out-of-roundness requirements of the ASME Code (maximum out-of-roundness is 0.2' per the survey results; maximum allowed per Section ND-4224 is 0.4', as shown in Section 8).

- The National Board Inspection Code (NBIC) procedure for State approval is not applicable since atmospheric tanks are exempted by the State of California (California Code of Regulations, Title 8, Chapter 4, dated 5/1/1992). However, tank design and modification will be performed to the ASME Code, Section III.

- The Certified Material Test Reports (CMTRs), and all other documentation required to establish ASME Code equivalency are not part of the scope of this calculation. This issue is addressed separately.

- The tank will be pressure tested according to ASME Code, Section III, Subsection ND-6000 requirements after the modifications are implemented.

  Details of the tank structural modifications can be found in the attached Interim Design Change Notice (see Appendix D for a copy of this IDCN).

- The results of the radiographic survey of the weld seams of Unit-3 PPMS tank revealed unacceptable defect sizes that range from 1/16" long to 4.5". The bulk of the defects is below 1/4" long. A statistical analysis was performed to attempt to describe the worst defect that can exist in the welding with 95% reliability and 95% confidence level. Result of the

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statistical analysis, based on sample size of 61 radiographs that represent a population of defects of flaws 126, showed that the worst defect described above to be less than 3.5".

- The statistical analysis was followed by fracture mechanics analysis of maximum defect size 5", that was assumed to exist at the highest stress location of the tank shell. The defect was analyzed by two methods: (1) The defect was assumed to be infinitely long, and its depth is equal to half the thickness of the shell, and (2) a 5" through-wall defect was assumed. Results of the analysis showed that such a defect is acceptable with factor of safety 3.

ICCN F-565 results are in agreement with previous results with only minor differences, which do not impact the calculation conclusions. As mentioned in Section 1 of this calculation, ICCN F-565 is issued to incorporate the comments made by Quality Assurance.

Results of this calculation do not impact Technical Specifications or Surveillance Procedures.

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3. ASSUMPTIONS

1. The nozzles, and the ladder attached to the PPMS tank were not included in the finite element models. It is assumed that their effect on the anchor bolt load distribution is negligible, since their weight is very small compared to the weight of the tank and its contents.

2. For calculating the maximum stress in the PPMS tank shell due to hydrostatic pressure, the maximum water height in the tank is conservatively assumed to be 34 ft, which is the maximum height of the tank (2 ft higher than the overflow line elevation per S023-407-3-97-0). Hydrostatic water head of 34 ft, therefore, exceeds the maximum possible water head in the tank.

3. Design Basis Earthquake (DBE) = 2 * Operating Basis Earthquake (OBE).

4. The WRC Bulletin 297 is the best practical method presently available for estimating tank nozzle stiffness values. However, it provides data on a narrow range of parameters and therefore some interpolation and estimation are performed to obtain approximate stiffness values. The magnitude of nozzle stiffness obtained are adequate to provide a realistic translational and rotational restraint conditions at the tank connections.

   (Note : The ASME code flexibility factor equations are not sufficient to calculate nozzle flexibilities in tanks with D/T ratio > 100, and do not have flexibility guidance on thrust loadings).

   Based on the data available, only the translational load (radial), in-plane moment load and out-plane moment load cause significant tank shell deformations.

5. Stresses due to dead weight of the tank shell are not included in the local stress check at the nozzle locations. Per Appendix A, the combined weight of the tank roof and the cylindrical shell is 53,077 lb. The corresponding compressive stress at the base of the cylindrical shell is only 113 psi, which is considerably smaller than the other stress components.

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4. DESIGN INPUT

4.1 Tank Description and Geometry

The Primary Plant Make-Up Storage Tank (PPMS) is a 40 ft inside diameter x 34 ft high atmospheric tank with capacity of 300,000 gallons (Reference 25). The tank is made up of stainless steel, SA 240-304, plates; and is anchored to the foundation by 36 equally-spaced anchor bolts. The anchor bolt chair material is A-36 (Reference 24). A more detailed description of the tank and the anchor bolt assemblies can be found in Appendix A of this calculation.

Figure 4.1 shows the main dimensions of the PPMS tank. It shows the tank diameter, height, and plate wall thickness of the bottom, wall, and roof (Reference 25).

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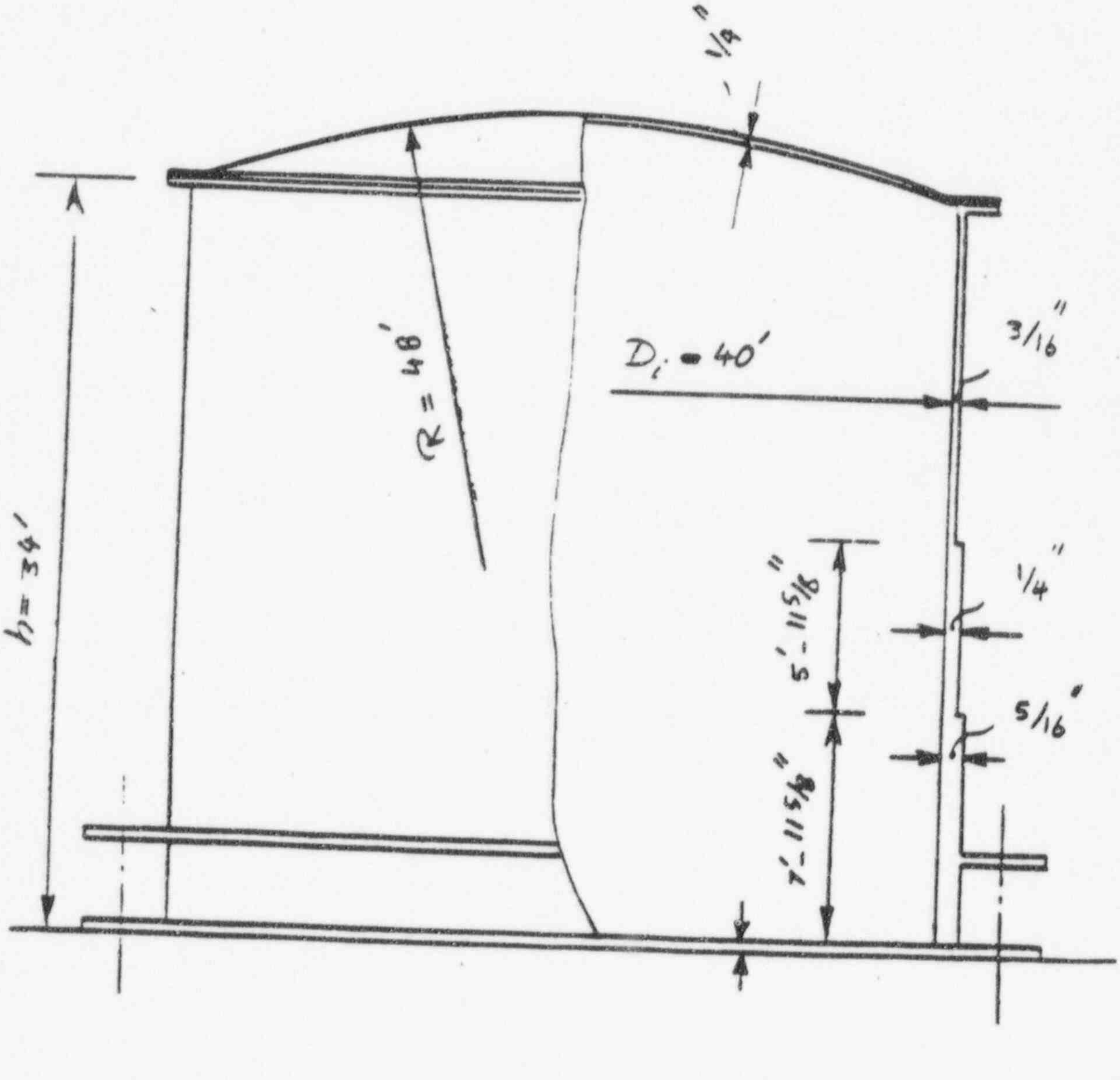

Figure 4.1 Main Dimensions of the PPMS tank

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4.2 Material Properties

Tank Shell 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) = 28.0×10^6 psi,

Poisson's ratio (ν) = 0.3

Allowable stress intensity (S_m) = 20,000 psi

The anchor bolt chair material: A-36 (Reference 24)

The following material properties of A-36, at 110°F used for external members in the design report, Appendix A, were used in the analysis:

Yield stress (f_y) = 35.68 ksi (Reference 2)

Allowable stress (S) = 12.6 ksi

The allowable stress above is at 120°F (see Note (1) below).

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 reference temperature for material properties is conservative.

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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. 1.5" bolts (36 existing anchor bolts),

2. 2" bolts (34 new anchor bolts).

Also, a ring will be welded to the outside edge of the bottom plate as shown in Figure 4.2. Holes for anchor bolts will be drilled in the ring (1 5/8" for the existing bolts, and 2 1/8" 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 Not used.

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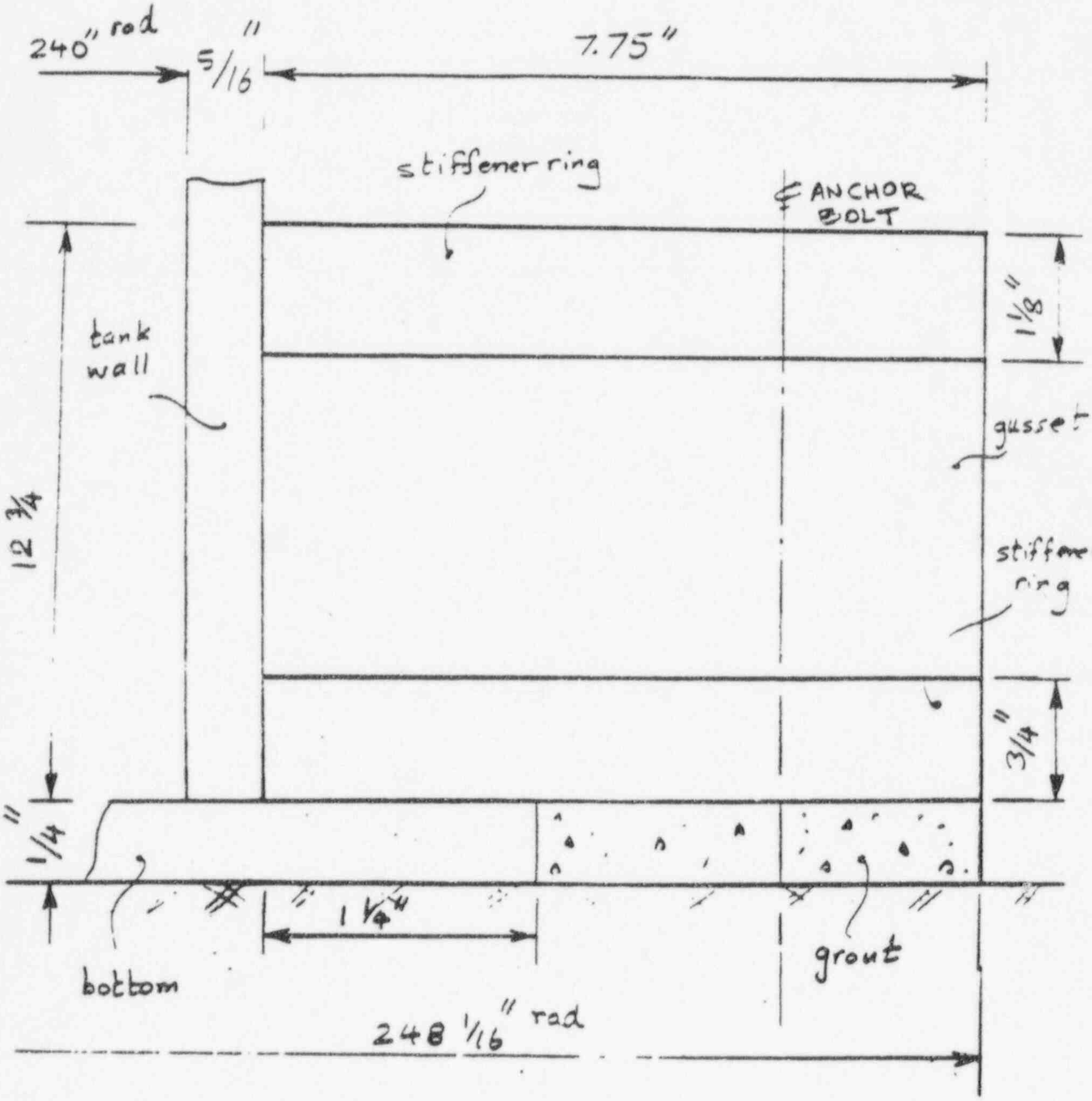

Figure 4.2 Modified Anchor Bolt Assembly

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4.6 Nozzle and Piping Data

The nozzle loads evaluated are given in data sheets, attached in Appendix D, which were extracted from various calculations as noted in the nozzle load data sheets.

Per References 23 and 24, the following piping is attached to the PPMS tank:

4" Sch. 40S SA-312 TP304 @ elev. 31'-0"

3" Sch. 40S SA-312 TP304 @ elev. 10'-7"

2-1/2" Sch. 40S SA-312 TP304 @ elev. 31'-0"

2" Sch. 80S SA-312 TP304 @ elev. 31'-0" (two places)

1" Sch. 80S SA-312 TP304 @ elev. 16'-0"

4.7 Out-of-Roundness Measurements

Field tests were conducted on both PPMS tank, T-055 and T-056, to measure the diameter at different angles. These measurements were taken at two elevations for each tank. Results of the survey are documented in Reference 26, and a copy is attached in Appendix D of this calculation.

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5. METHODOLOGY

The tank design report was prepared by Structural Integrity Associates, Inc. This report is included, in its entirety, in Appendix A of this calculation. The methodology of the analysis is based on "Generic Implementation Procedure (GIP) for Seismic Verification of Nuclear Plant Equipment," Reference 5; and ASME Boiler and Pressure Vessel Code, Reference 2. Details of the tank design methodology can be found in Section 5 of Appendix A.

The methodology of developing the tank stick model is included in Appendix B of this calculation. This stick model was used in the analysis of the piping attached to the PPMS tanks.

In addition to the above analyses, this calculation comprises the following supporting analyses:

1. Angular shear stress distribution in the anchor bolts,
2. Bolt location adjustment due to the rebars,
3. Calculation of translational and rotational nozzle stiffness,
4. Local stress check,
5. Out-of-roundness check,
6. Statistical analysis of tank examination data. The methodology of this analysis can be found in Appendix E, and
7. Fracture mechanics evalaution. The methodology of this evaluation can be found in Appendix E.

The methodologies used in these analyses are summarized in the following subsections (Subsections 5.1 through 5.5).

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5.1 Angular Distribution of Shear Load in the Anchor Bolts

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 compute 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 anchor bolts.

Two model, with different loading conditions, were used:

1. In the first model, the horizontal seismic load is represented by a concentrated horizontal force, of 10^6 lb, applied near the top of the shell in the x-direction, as shown by Figure 5.2a.

2. In the second model, the horizontal seismic load is represented by a distributed horizontal load, as shown by Figure 5.2b. A force of 1000 lb, acting in the x-direction, was applied at each node of the tank shell above the bottom.

In both models, all displacement components were constrained at the anchor bolt locations.

Results of the analysis were obtained in the form of horizontal (shear) reaction forces, and vertical (pull) reaction forces at all anchor bolt locations. These forces were normalized and plotted versus the angle (θ) measured from the positive x-directions, as shown by Figure 5.1.

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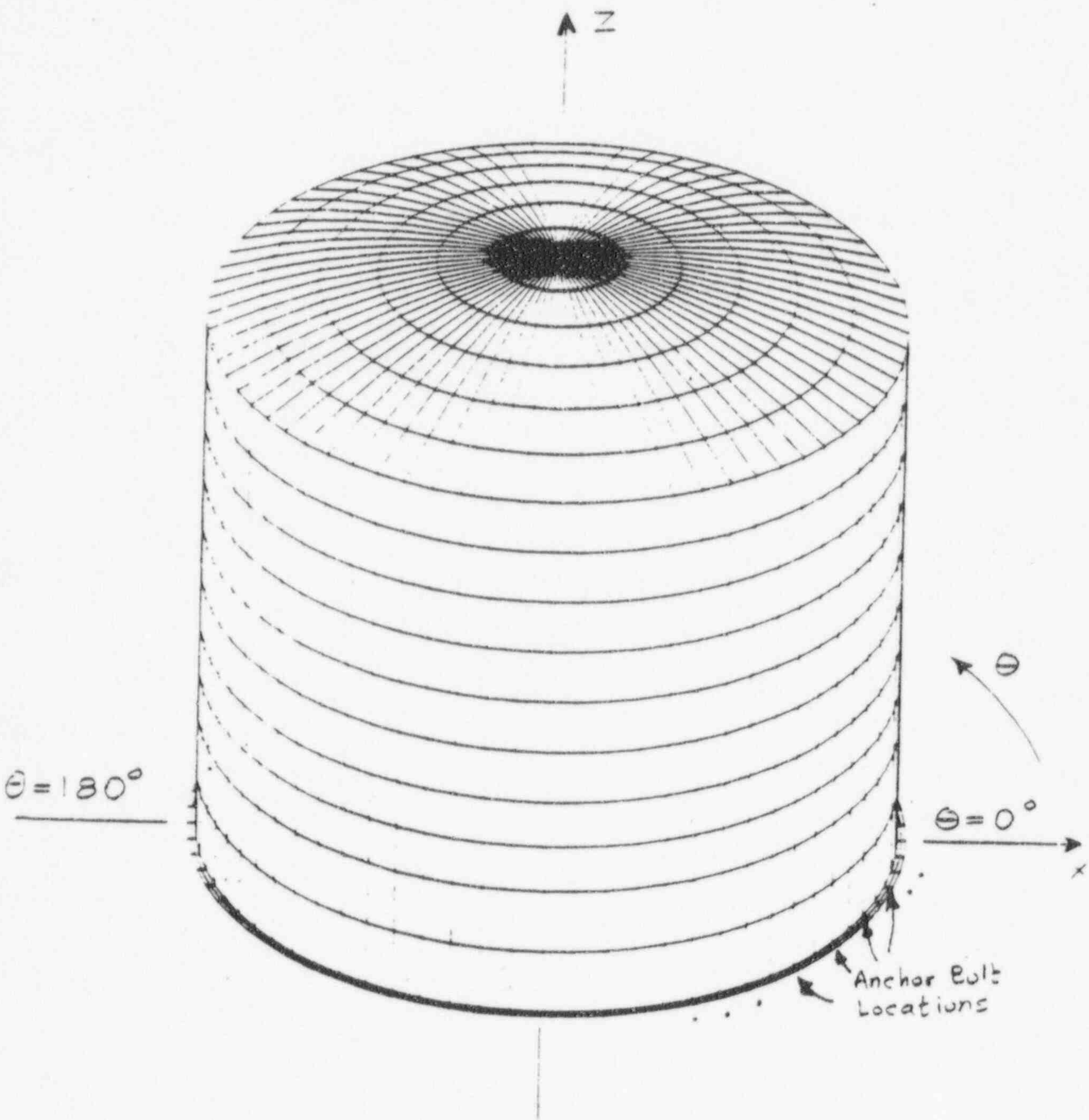

Figure 5.1 Computer Plot of the Tank Finite Element Model

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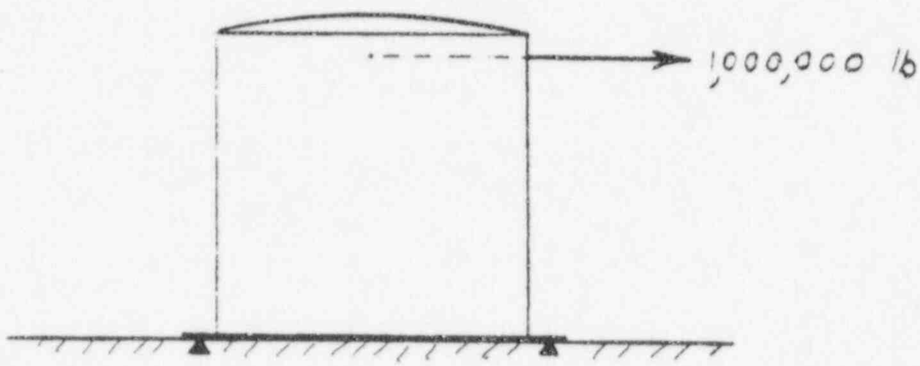

Figure 5.2a Concentrated Force Near the Top of the Tank

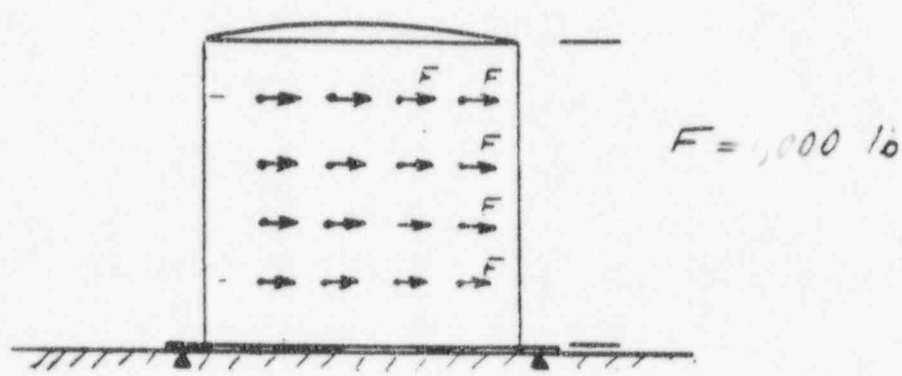

Figure 5.2b Distributed Force Acting on the Shell of the Tank

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5.2 Effect of Relocation of Some Anchor Bolts

The nominal bolt circle diameter for the new bolts is 40'-8" per Appendix A of this calculation, which corresponds to eccentricity (e) of 3.6875". However, to avoid interference with the rebars, some of the new anchor bolts may have to be moved radially outward. The effect of increasing the eccentricity of the anchor bolts is evaluated in this subsection. This evaluation is based on the methodology of the design report (Appendix A of this calculation). This methodology consists of several analysis steps, and only those steps impacted by the increased eccentricity are re-analyzed in this appendix, namely:

1. Tank Shell Stress

   Step 9, Section 9 of Appendix A is impacted. The allowable tensile bolt stress to compute the overturning moment (F_r) is calculated based on the re-calculated tank shell stress. The new tank shell stress is obtained using the equations given in Appendix A with:

   a) Modified eccentricity representing the relocated bolts,

   b) Modified chair height to account for the differences in geometry from the geometry used in Appendix A.

2. Vertical Stiffener Plate

   Step 10, Section 9 of Appendix A is impacted. The adequacy of the stiffener plates is evaluated using plate size (k) from the modified anchor bolt assembly.

3. Chair-to-Tank Weld

   Step 11, Section 9 of Appendix A is impacted. Modified weld stress (W_w lb/in) is calculated based on the eccentricity of the relocated anchor bolts, and compared with the allowable specified by Reference 2.

4. Buckling Bending Moment Capacity

   Step 17, Section 9 of Appendix A is impacted. A modified value of the bending moment capacity (M_{CAP}) is calculated based on the re-calculated value of F_r.

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Mathematical formulas used in the above steps can be found in the tank design report (Appendix A of this calculation), or Reference 2.

Finally, methodology of Reference 7 (and Reference 8) was used to evaluate the added bottom ring. This ring, which is not included in the design report, is added for better constructibility of the modified anchor bolt chairs. The methodology of these two references can be summarized as follows:

1. Tearout Failure

   A tearout stress check is performed to calculate the shear stress on the area shown in Figure 5.3a. The allowable shear stress is conservatively taken equal to 13 ksi per Reference 2 (Subsection ND-3852.6).

2. Pure Tension Rupture

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

3. Failure by Crushing

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

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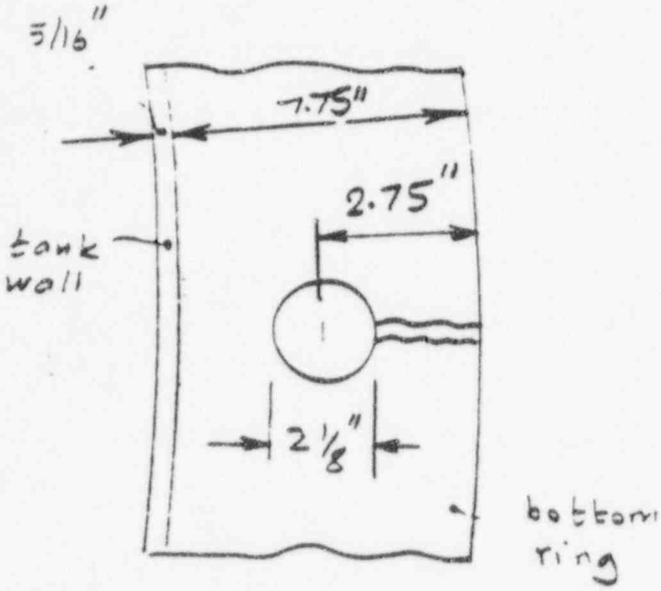

Figure 5.3a Tearout Failure

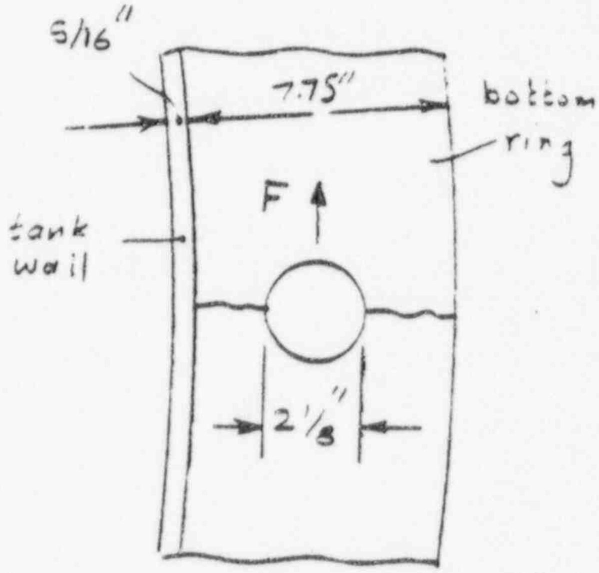

Figure 5.3b Tensile Failure

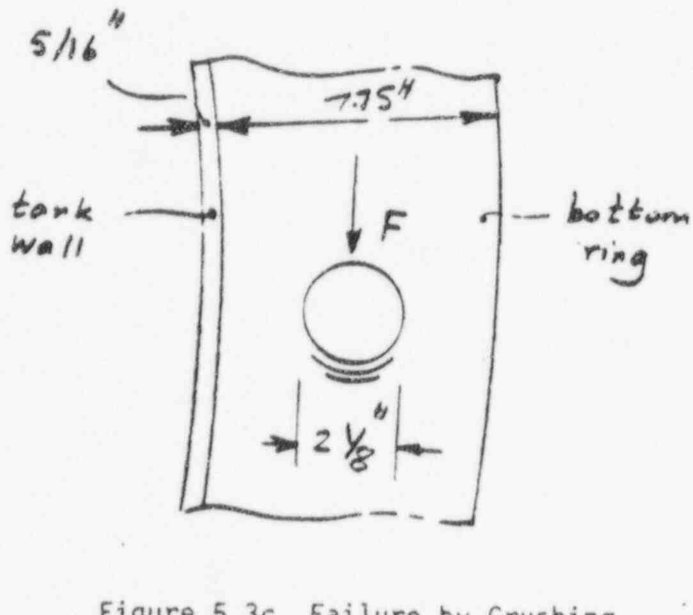

Figure 5.3c Failure by Crushing

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5.3 Nozzle Stiffness Evaluation

The nozzle stiffness values 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 will be used as appropriate. The magnitude of nozzle stiffness obtained by this process give a realistic translational and rotational end reactions at the nozzle-shell connections and therefore reasonable piping design analysis.

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5.4 Local Stress Check

The local stresses were calculated using computer program ME101LS (Reference 12). The maximum local stress intensities calculated are combined with the pressure and seismic stresses of the tank. The combined stresses are then compared against the ASME code allowables (Reference 2). It should be noted that the stresses due to the dead weight of the tank shell have been ignored in the local stress calculation since they are much smaller than the other stress components, as shown in Section 3.

DBE primary moment loads at the tank shell are used to evaluate primary stresses under Design conditions and will give conservative results.

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5.5 Out-of-Roundness Requirements

Per reference 2, Subsection ND-4224, the tank must meet the out of roundness requirement outlined in that subsection. This can be summarized as follows:

1. Step 1
   Calculate $D_{ave}/100$, where D_{ave} is the average diameter of the tank in inches.

2. Step 2
   Based on field measurements, calculate the maximum diametral out-of-roundness for each tank.

The PPMS tanks meet the Code requirements if the maximum measured out-of-roundness is less than the amount calculated in step 1.

Note:

It should be noted that all calculations were carried out by hand or by verified computer programs; and the calculation capability of the word processing program was never used.

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
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6. REFERENCES

1. IDCN S-2 to drawing No. S023-407-3-61, Rev. 2, IDCN S-2 to drawing No. S023-407-3-63, Rev. 3 and IDCN S-1 to drawing No. S023-407-3-64, Rev. 1.

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

3. ANSYS User's Manual, Revision 4.4, Swanson Analysis Systems Inc., May 1, 1989.

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. "Standard Handbook of Machine Design," Editors Shigley, J. E., and Mischke, C. R., 1986, McGraw-Hill Book Company.

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.

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

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	NABIL M. EL-AKILY	10/12/93	JUN GAOR J.G.	10/12/93					

16. Calculation number M-1203-476-3A, Revision 0.
17. Calculation number M-1203-478-3A, Revision 0.
18. Calculation number S-1415-04, Revision 0.
19. Calculation number 807, Revision 0.
20. Calculation number S-1415-07, 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. Telecopy from G. Vechinski to N. El-Akily, dated 10/15/1993. Subject: As-Built Inside Tank Radius T055. (attached in Appendix D).

Additional references are listed in the reference sections of Appendix A and Appendix B.

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7. NOMENCLATURE

A = Area, in^2

C1 = Maximum length of nozzle in circumferential direction, inch

C2 = Maximum length of nozzle in longitudinal direction, inch

d = Outside diameter of nozzle, in.

D_i = Inside diameter, inch.

D_o = Outside diameter, inch.

DBE Design Basis Earthquake

e = Bolt eccentricity, in

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, in

j = Distance between stiffener plates, in

k = Stiffener plate width, in

L = Height of tank, in.

M = Overturning moment, in-lb

MA = Resultant moment at the tank shell due to primary loads, ft-lbs

MB = Resultant moment at the tank shell due to primary+secondary loads, ft-lbs

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

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MC = Circumferential, moment, in-lbs

ML = Longitudinal moment, in-lbs

MT = Torsional moment, in-lbs

OBE Operating Base Earthquake

P = Radial load, lbs

R = Radius, inch

S = Allowable stress, psi

SHA Shape of nozzle (CIR = circular)

t = Thickness, inch

VC = Circumferential load, lbs

VD = Mean diameter of tank, inch

VL = Longitudinal load, lbs

VT = Tank wall thickness, inch

w = Radial deflection due to P, inch

ν = Poisson's ratio

σ = Stress, psi

θ = Angle, degrees

θ = Rotation at centerline of nozzle, radians

τ = Shear stress, psi

See also the nomenclature section in Appendix A.

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8. CALCULATIONS

The following analyses are covered in this section:

1. Angular shear stress distribution in the anchor bolts,
2. Bolt location adjustment due to the rebars,
3. Calculation of translational and rotational nozzle stiffness,
4. Local stress check, and
5. Out-of-roundness check.

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8.1 <u>Angular Distribution of Shear Load in the Anchor Bolts</u>

Analysis was performed using the general purpose finite element analysis program ANSYS. Description of the model is given in Section 5 of this appendix; and a computer plot of the model is shown by Figure 5.1. Figures 5.2a and 5.2b show the two analyzed cases with concentrated and distributed external loading.

Results of the analysis confirm the validity of the sinusoidal shear force distribution in the angular direction used in the tank design report (Appendix A). Results were obtained for the two models described in Section 5:

1. Model with concentrated horizontal shear force,
2. Model with distributed horizontal force.

Figures 8.1 and 8.2 show the normalized shear force in the anchor bolts for both models plotted versus the angle (θ) measured from the positive x-direction, as shown in Figure 5.1. These two figures also show a true sinusoidal distribution plotted for comparison purposes. Both figures show that the actual distribution matches the true sinusoidal distribution. Figures 8.3 and 8.4 show the corresponding plots for the axial (pull) force distribution plotted along with a true sinusoidal distribution. These figures show that the actual distribution and the true sinusoidal distribution are identical.

Therefore, the sinusoidal load distribution of bolt loads is supported by the analysis results.

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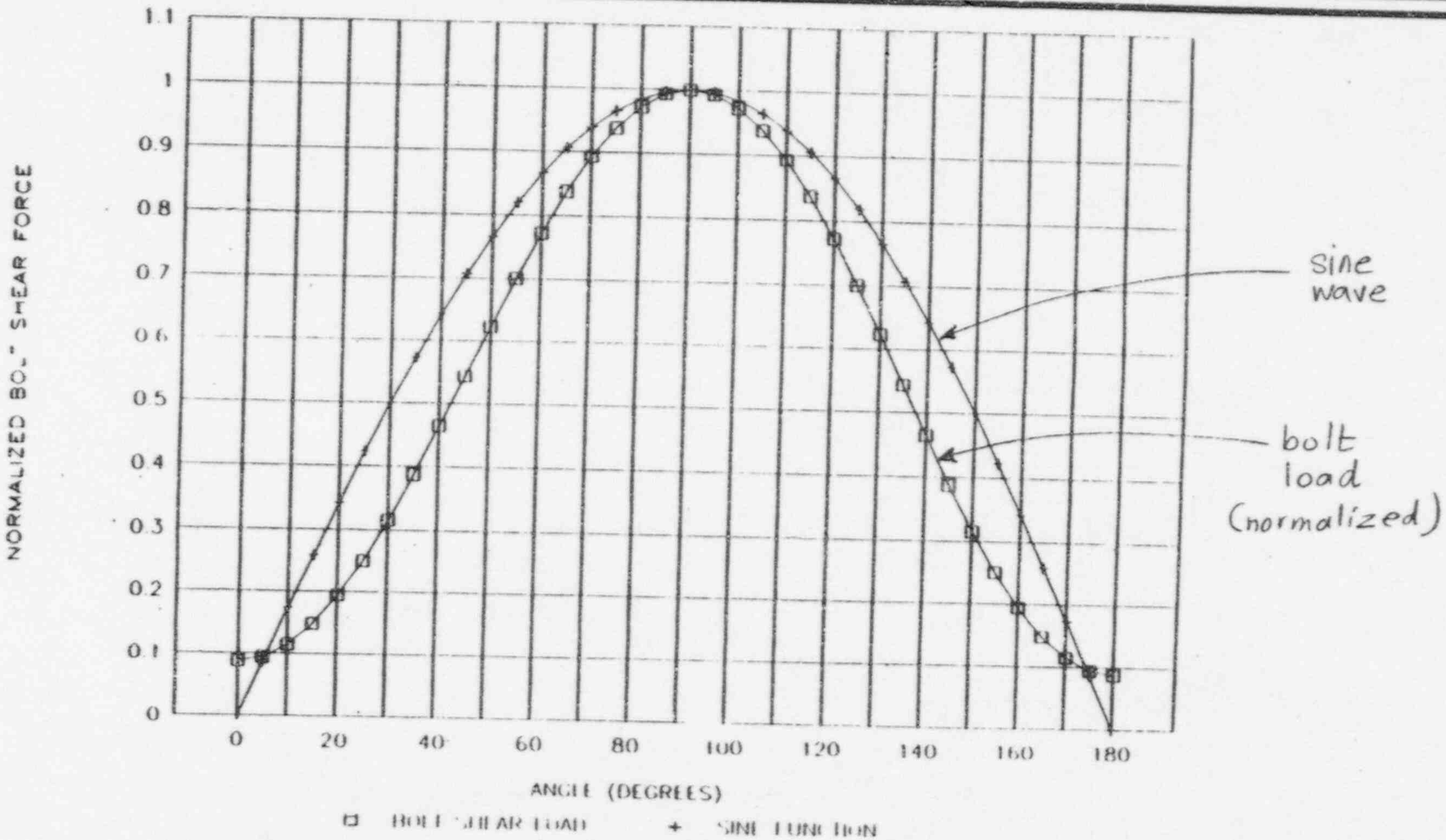

Figure 8.1 Normalized Bolt Shear Force (Model with Concentrated Force)

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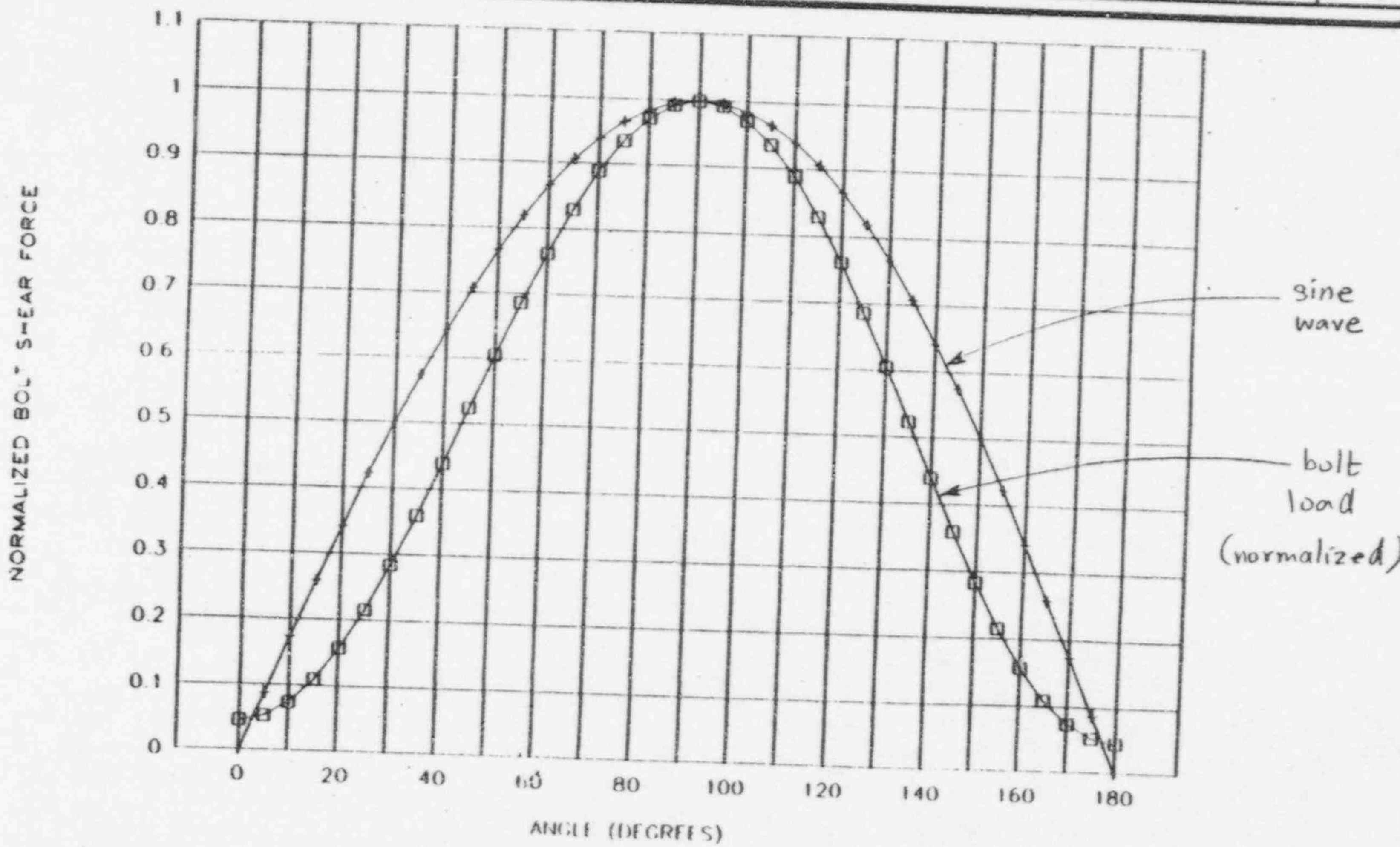

Figure 8.2 Normalized Bolt Shear Force (Model with Distributed Force)

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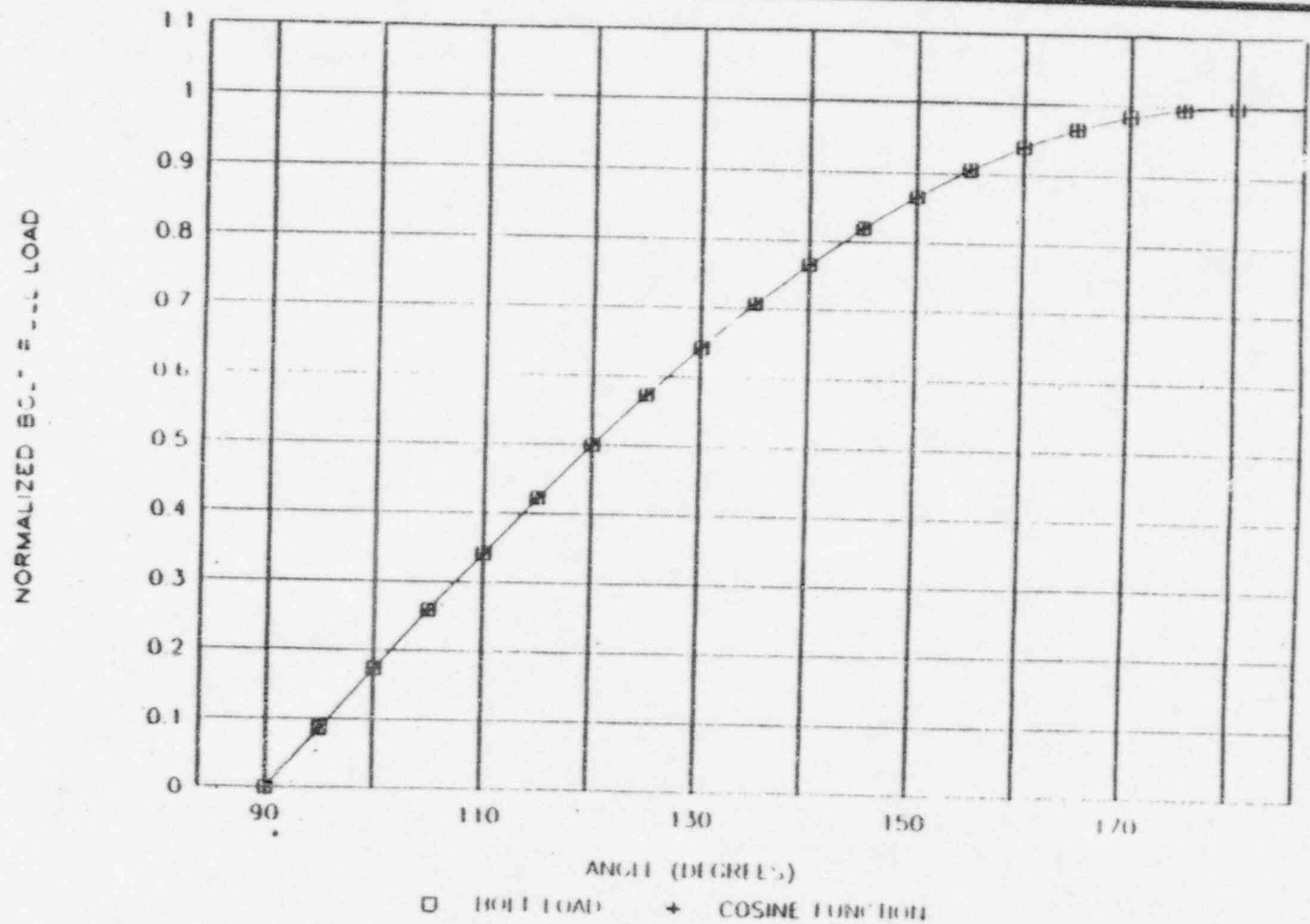

Figure 8.3 Normalized Bolt Tensile Force (Model with Concentrated Force)

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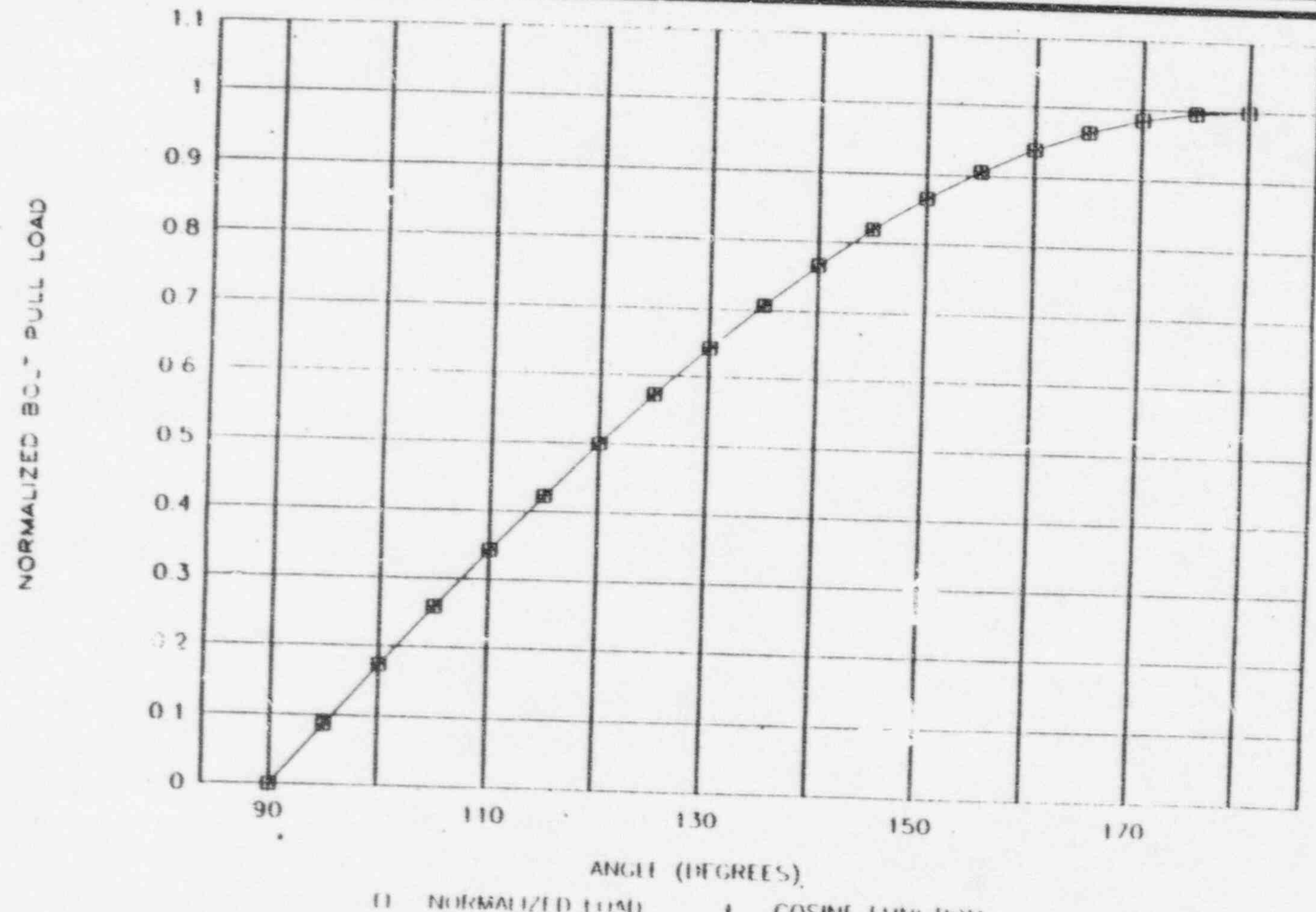

Figure 8.4 Normalized Bolt Tensile Force (Model with Distributed Force)

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8.2 Effect of Relocation of Some Anchor Bolts

As explained in Section 5, the bolt eccentricity (e), for the new anchor bolts, may be increased to 5" to avoid interference with the reinforcing bars in the tank base. To assess the effect of the increased eccentricity, some steps of the design report (Appendix A) are repeated using the modified value of e (=5") to ensure that stress limits are not exceeded. Similarly, some anchor bolt chairs may have to be moved, in the circumferential direction, from their nominal position to avoid interference with tank attachments.

8.2.1 Tank Shell Stress

Using the formula given in Appendix A of this calculation, Section 9, Step 9, the tank shell stress (σ) was re-calculated based on Reference 5 using the following input:

a) Eccentricity (e) = 5", and

b) Adjusted chair height (h) = 12" instead of the 12.75" used in Appendix A. This adjustment reflects the modified geometry of the anchor bolt chair shown in Figure 8.6.

All other input is per Appendix A.

It follows that

$$\sigma = 74{,}062 \text{ psi}$$

$$\sigma > f_y$$

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

$$= 33{,}941\,(29{,}000/74062)$$

$$= 13{,}290 \text{ psi}$$

Figure 8.5 shows the geometry used in the design report (Appendix A); and the definition of the height (h), and the eccentricity (e).

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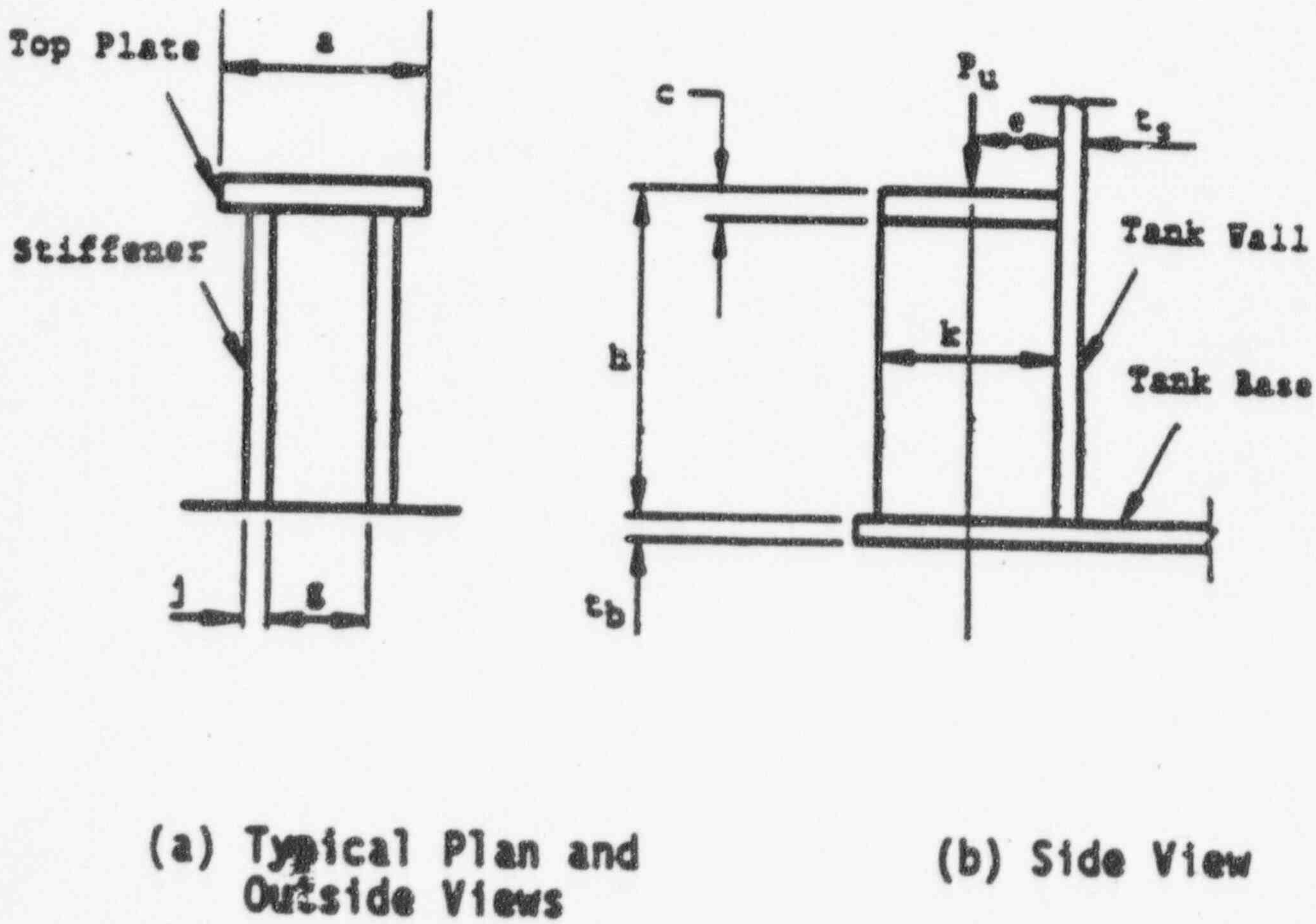

Figure 8.5 Anchor Bolt Chair Geometry Used in the Design Report (Appendix A)

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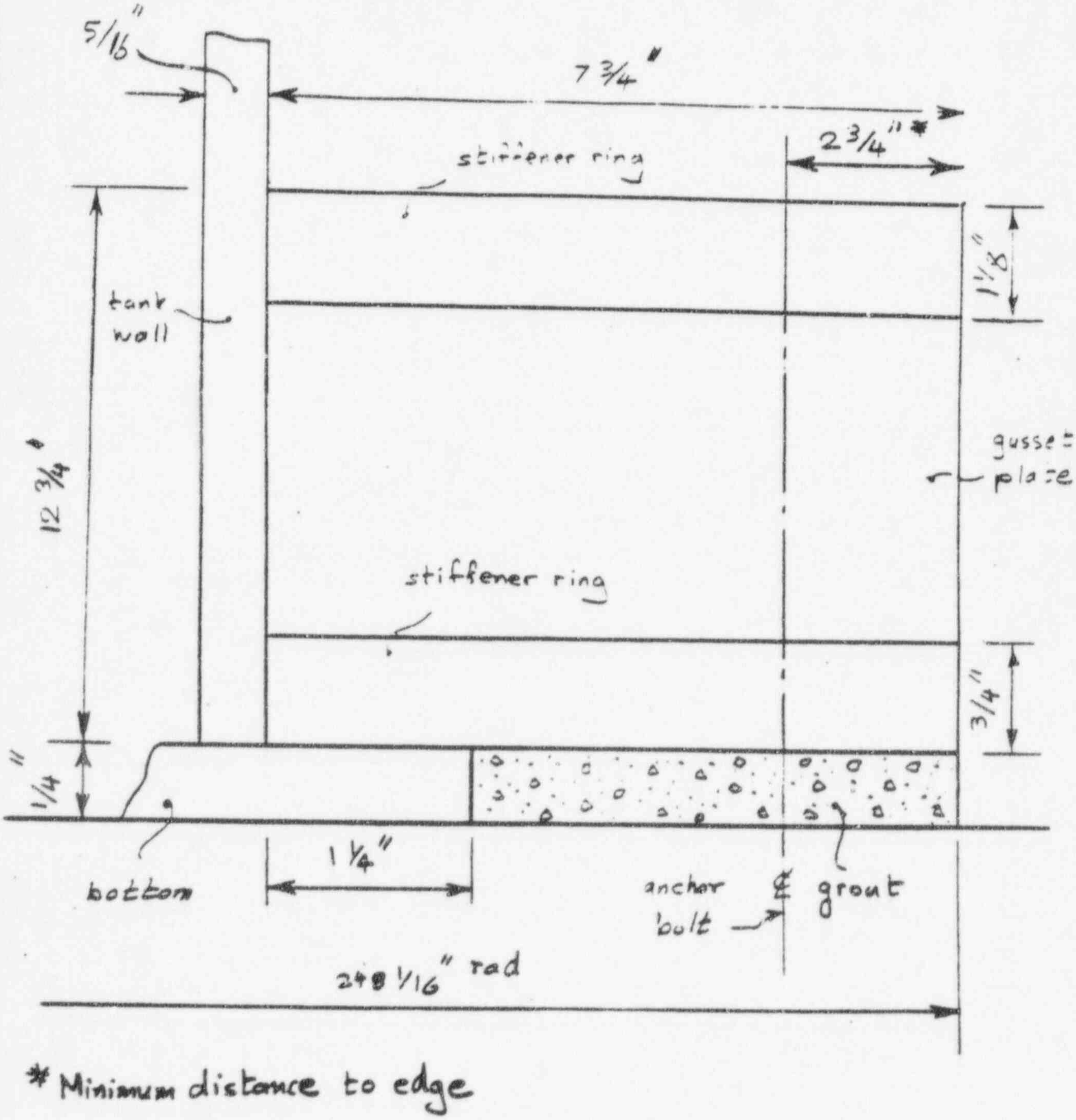

Figure 8.6 Details of the Added Cicumferential Ring

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8.2.2 Vertical Stiffener Plate

The vertical stiffener plates were checked in Appendix A of this calculation, Section 9, Step 10. This check is repeated using the modified plate width (k) of 7.5".

$$k/j = 7.5/0.75$$

$$= 10 < 95/(\sqrt{f_y/1000}) = 15.9$$

Also,

$$P_u/(2kj) = 76,368/(2*7.5*0.75)$$

$$= 6,788 < 21,000 \text{ psi}$$

Thus, the vertical stiffener plates meet Reference 5 requirements.

8.2.3 Chair-to-Tank Weld

Per Appendix A, Section 9, Step 11, the chair-to-Tank weld is checked as follows (using e=5"):

$$W_w = P_u \sqrt{[1/(a+2h)]^2 + [e/(ah+0.667h^2)]^2}$$

where,

a (circumferential distance between bolts) = 20.94"

h (chair height) = 12" (modified)

e (eccentricity) = 5"

It follows that:

$$W_w = 2,024 \text{ lb/in} < 30,600\ t_w/\sqrt{2} = 5,409 \text{ lb/in}$$

Thus, the chair-to-tank weld meets Reference 5 requirements.

8.2.4 <u>Buckling Bending Moment Capacity</u>

Per Appendix A of this calculation, Section 9, Step 17, the parameter M'_{CAP} is calculated as follows:

$$(\sigma_c/F_r)(h_c/h_b) = (10{,}938/13{,}290)(12/40.75)$$

$$= 0.23$$

$$c' = 0.1 \qquad \text{(per Appendix A)}$$

where values above are per Appendix A, except for F_r and h_c. From Reference 5, Figure 7-12, M'_{CAP} is given by:

$$M'_{CAP} = 0.2$$

It follows that,

$$M_{CAP} = M'_{CAP}(2F_r)(R^2\ t_{se})(h_b/h_c)\ \alpha$$

where,

F_r = 13,290 psi, (per Section 8.2.1)

M'_{CAP} = 0.2

h_c = 12"

All other quantities are per Appendix A, Section 9, Step 17.

Therefore,

$$M_{CAP} = 4.95 \times 10^8 \text{ in-lb} > M\ (M=3.82\times10^8 \text{ in-lb}) \quad [\text{O.K.}]$$

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8.2.5 Bottom Plate Shear Evaluation

As part of the anchor chair modification, a circular ring is welded to the outside of the bottom plate, as shown by Figure 8.6. Through-holes, for the anchor bolts, will be drilled in this ring. Per Appendix A of this calculation, part of the shear load is taken by the anchor bolts; and it is assumed that the shear load is sinusoidally distributed around the circumference with a maximum value of 28,620 lb. Stress analysis of the ring, shown below, is based on calculating average stresses on different sections; and comparing these average stresses with material allowables. This methodology is detailed in References 7 and 8.

An edge distance of 2.5", shown by Figure 8.6, is in accordance with Reference 9 for plates with rolled edges (1.25 x bolt diameter). The thickness of the ring is calculated as follows:

- Assuming a tearout failure mode at the existing anchor bolts, as shown in Figure 5.3a. The average shear stress is given by:

$$\tau = F/A,$$

where,

$$F = 28,620 \text{ lb},$$

$$A = 2 \times (2.75-2.125/2) \times t \qquad \text{(see Figure 5.3a, b and c)}$$
$$= 3.375\ t$$

For τ = 13,000 psi (per Reference 2, Subsection ND-3852.6), it follows that:

$$t = 0.65''$$

let $t = 3/4''$

- Assuming a tensile mode failure, illustrated in Figure 5.3b, the area (A) subjected to tension is given by:

$$A = 7.75 \times 3/4 - 2.125 \times 3/4$$

$$= 4.21875 \text{ in}^2$$

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Therefore, the average tensile stress is given by

$$\sigma = 28{,}620/4.21875$$

$$= 6{,}784 \text{ psi} < S \qquad \text{(per Section 4, S=12.6 ksi)}$$

- Assuming a crushing type failure, illustrated in Figure 5.3c, the minimum bearing area (a) corresponding to the smaller size existing bolts is given by:

$$A = 1.5\ (3/4)$$

$$= 1.125 \text{ in}^2$$

Therefore, the average stress is given by

$$\sigma = 28{,}620/1.125$$

$$= 25440 \text{ psi} < f_y \quad (f_y = 36{,}000 \text{ psi}) \qquad \text{[O.K.]}$$

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8.2.6 Wall-to-Bottom Weld

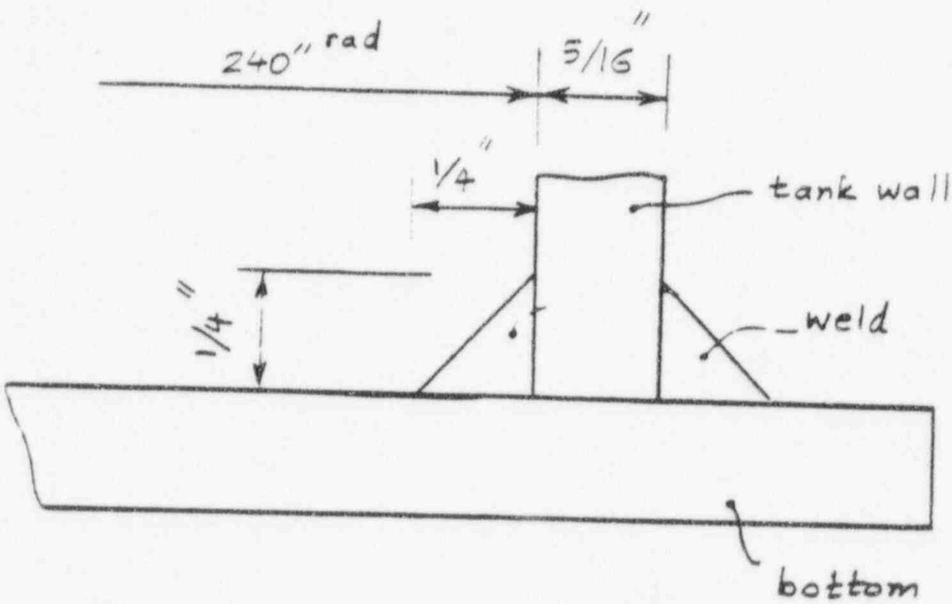

Figure 8.7 Tank Wall-to-Bottom Weld (Reference 24)

As shown in Figure 8.7, the tank shell is welded to the bottom by a double 1/4" filet weld. The weld was checked for bothe shear load and moment load as follows:

(a) Shear Load

The total weld throat area is, therefore, given by

$$\text{Total throat area} = 2 \times 480 \times \pi\ (0.25)/(2)^{0.5}$$

$$= 533\ \text{in}^2$$

Average base shear load = 2,048,175 (see Appendix A, Section 9, Step 5)

It follows that,

Average shear stress in the weld (τ_{ave}) = 2,048,175/533
= 3,842 psi

A factor of 1.5 to the average shear stress to account for the non-uniform shear stress distribution,

Maximum shear stress (τ_{max}) = 1.5 x 3,842

= 5,763 < 13,600 psi [O.K.]

Where the allowable of 13,600 is per Reference 2, Subsection ND-3852.6.

Similarly, the maximum shear stress in the base metal is given by,
5,763 x 0.707 = 4,075 < 13,000 psi [O.K.]

(b) <u>Moment Load</u>

Per Appendix A, Section 8, Step 6, the overturning moment load (M) at the base of the tank shell is given by:

$M = 3.82 \times 10^8$ in-lb

The section modulus (S) of the weld is given by,

$S = 2\pi\ (0.707 \times 0.25)(480)^2/4$

$= 6.4 \times 10^4\ in^3$

It follows that,

Normal stress (σ) = M/S = 5,972 psi

The normal stress (σ) and the maximum shear stress (τ_{max}) are combined to obtain the maximum normal stress (σ_{max}) as follows:

Maximum normal stress (σ_{max}) = $\sigma/2 + \sqrt{(\sigma/2)^2 + \tau^2}$

= 9,477 psi < allowable (=13,000 psi) [O.K.]

Where the shear allowable was conservatively used.

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8.2.7 Deviation from Nominal Position in the Cicumferential Direction

The design report (Appendix A) assumes that the tank is anchored to the foundation by equally-spaced anchor bolts. Few anchor bolts may have to be moved, up to 4" in the circumferential direction, to avoid interference with the tank attachments. This small adjustment in the anchor bolt location is considered acceptable based on:

1.

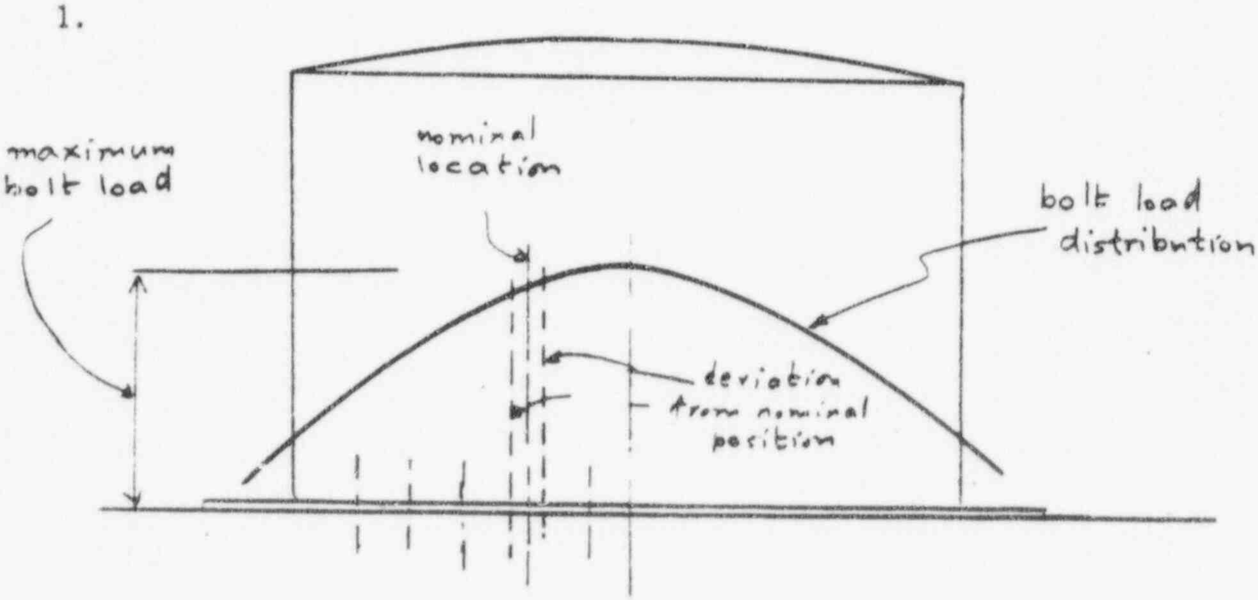

Figure 8.8 Bolt Load Distribution

Figure 8.8 shows the bolt load distribution, based on the results of the finite element analysis, Section 8.1. It can be seen that the change in bolt load is gradual since a large number of closely-spaced anchor bolts are used. Therefore, a slight deviation from the nominal location in the circumferential direction should not result in any appreciable change in bolt load, including the maximum bolt load.

2. Per Appendix A, Section 9, Steps 7 and 9, a large margin exists between the bolt tensile capacity (33,943 psi) and the reduced bolt capacity actually used for design purposes (19,509 psi).

It is, therefore, concluded that slight deviations, in the circumferential direction, from nominal bolt locations have no impact.

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8.3 Tank Nozzle Stiffness Calculations

The equations and figures used in the stiffness calculations are based on WRC 297 (Reference 14).

Tank Data (Bottom of Tank Elevation is 9'-0"):

Inside diameter = 480"

shell thickness, t = 5/16" (el. 9.0' to 16.97')
= 1/4" (el. 16.97' to 22.94')
= 3/16" (el. 22.94' to el. 43')

Height of cylindrical shell = 34'

1. 4" Nozzle - Suction Line Elev. 31'-0".

d = 4.5", t = 0.237", Mean tank diameter, D = 480.1875"

L1 = (31'-0") - (9'-0") = 22*12 = 264"

L2 = 34*12 - 264 = 144"

$L = 8L1L2/(L1^{1/2} + L2^{1/2})^2$

$= 8*264*144/(264^{1/2} + 144^{1/2})^2 = 381"$

$\Lambda = L/(DT)^{1/2} = 381/(480.1875*0.1875)^{1/2} = 40.15$

$\lambda = (d/D)(D/T)^{1/2} = (4.5/480.1875)(480.1875/0.1875)^{1/2}$
$= 0.47$

T/t = 0.1875/0.237 = 0.79

$\alpha = 1.2$ (Fig. 59)

$M_L/ET^3\theta = 0.9$ (Fig. 60)

$M_C/ET^3\theta = 0.49$ (Fig. 60)

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$$P/w = \alpha(4.95\ ET^2/(D\Lambda^{1/2})$$
$$= 1.2(4.95*28.3E6*0.1875^2)/(480.1875*40.15^{1/2})$$

Nozzle Stiffness due to Radial Loads :

P/w = 1942 lbs/in.

Nozzle Stiffness due to Longitudinal (In-plane) Moment Loads :

$$M_L/\theta = E(3.14*d^3*t/8)/(d*k)$$

$$k = (1/0.9)(3.14/8)(d/t)^2(t/T)^3$$
$$= (1/0.9)(3.14/8)(4.5/0.237)^2(0.237/0.1875)^3$$
$$= 317$$

$$M_L/\theta = 28.3E6*(3.14*4.5^3*0.237/8)/(4.5*317)$$

M_L/θ = 1.68E5 in-lbs/rad

Nozzle Stiffness due to Circumferential (Out-plane) Moment Loads :

$$M_C/\theta = 1.68E6*0.49/0.9$$

M_C/θ = 9.15E4 in-lbs/rad

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	NABIL M. EL-AKILY	10/12/93	JUN GAOR J.G.	10/12/93					

2. <u>2-1/2" Nozzle - Line 011 @ el. 31'-0"</u>.

$d = 2.875"$, $t = 0.203"$, $D = 480.1875"$

$L = 381"$ (same as for 4" nozzle above)

$\Lambda = 40.15$

$\lambda = (2.875/480.1875)(480.1875/0.1875)^{1/2}$
$= 0.30$

$T/t = 0.1875/0.203 = 0.92$

$\alpha = 1.1$ (Fig. 59)

$M_L/ET^3\theta = 0.68$

$M_C/ET^3\theta = 0.42$ (Fig. 60)

$P/w = 1.1(4.95*28.3E6*0.1875^2)/(480.1875*40.15^{1/2})$

P/w = 1780 lbs/in.

$M_L/\theta = (28.3E6*3.14*2.875^3*t/8)/(2.875*k)$

$k = (1/0.68)(3.14/8)(2.875/0.203)^2(0.203/0.1875)^3$
$= 147$

M_L/θ = 1.27E5 in-lbs/rad

$M_C/\theta = 1.27E5*0.42/0.68$

M_C/θ = 7.84E4 in-lbs/rad

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	NABIL M. EL-AKILY	10/12/93	JUN GAOR J-G.	10/12/93					

3. (a) <u>2" Nozzle - Line 023 @ el. 31'-0"</u>.

$d = 2.375"$, $t = 0.218"$, $D = 480.1875"$

$L = 381"$

$\Lambda = 40.15$

$\lambda = (2.375/480.1875)(480.1875/0.1875)^{1/2}$
$= 0.25$

$T/t = 0.1875/0.218 = 0.86$

$\alpha = 1.05$ (Fig. 59)

$M_L/ET^3\theta = 0.6$ (Fig. 60)

$M_C/ET^3\theta = 0.39$ (Fig. 60)

$P/w = 1.05(4.95*28.3E6*0.1875^2)/(480.1875*40.15^{1/2})$

$P/w = 1700$ lbs/in.

$M_L/\theta = (28.3E6*3.14*2.375^3*0.218/8)/(2.375*k)$

$k = (1/0.6)(3.14/8)(2.375/0.218)^2(0.218/0.1875)^3$
$= 122$

$M_L/\theta = 1.12E5$ in-lbs/rad

$M_C/\theta = 1.12E5*0.39/0.6$

$M_C/\theta = 7.28E4$ in-lbs/rad

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	NABIL M. EL-AKILY	10/12/93	JUN GAOR J.G.	10/12/93					

4. <u>1" Nozzle - Miniflow @ el. 16'-0"</u>.

d = 1.315", t = 0.179", D = 480.3125"

L1 = 7*12 = 84"
L2 = 34*12 - 84 = 324"

$L = 8*84*324/(84^{1/2} + 324^{1/2})^2 = 295"$

$\Lambda = 295/(480.3125*0.3125)^{1/2} = 24$

$\lambda = (1.315/480.3125)(480.3125/0.3125)^{1/2} = 0.107$

T/t = 0.3125/0.179 = 1.75

$\alpha = 1.0$ (Fig. 59)

$M_L/ET^3\theta = 0.4$ (Fig. 60)

$M_C/Et^3\theta = 0.3$ (Fig. 60)

$P/w = 1.0(4.95*28.3E6*0.3125^2)/480.3125*24^{1/2})$

P/w = 5814 lbs/in

$M_L/\theta = (28.3E6*3.14*1.315^3*0.179/8)/(1.315*k)$

$k = (1/0.4)(3.14/8)(1.315/0.179)^2(0.179/0.3125)^3$
$= 9.95$

M_L/θ = 3.45E5 in-lbs/rad

$M_C/\theta = 3.45E5*0.3/0.4$

M_C/θ = 2.59E5 in-lbs/rad

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	NABIL M. EL-AKILY	10/12/93	JUN GAOR J.G.	10/12/93					

5. 3" Nozzle - Suction Line @ el. 10-7".

d = 3.5", t = 0.216", D = 480.3125"

L1 = 19"
L2 = 389"

$L = 8*19*389/(19^{1/2} + 389^{1/2})^2 = 102"$

$\Lambda = 102/(480.3125*0.3125)^{1/2} = 8.32$

$\lambda = (3.5/480.3125)(480.3125/0.3125)^{1/2} = 0.286$

T/t = 0.3125/0.216 = 1.45

$\alpha = 1.17$ (Fig. 59 use $\Lambda = 10$)

$M_L/ET^3\theta = 0.6$ (Fig. 60)

$M_C/ET^3\theta = 0.4$ (Fig. 60)

$P/w = 1.17(4.95*28.3E6*0.3125^2)/(480.3125*8.32^{1/2})$

P/w = 11553 lbs/in

$M_L/\theta = (28.3E6*3.14*3.5^3*0.216/8)/(3.5*k)$

$k = (1/0.6)(3.14/8)(3.5/0.216)^2(0.216/0.3125)^3$
$= 56.72$

M_L/θ = 5.18E5 in-lbs/rad

$M_C/\theta = 5.18E5*0.4/0.6$

M_C/θ = 3.45E5 in-lbs/rad

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	NABIL M. EL-AKILY	10/12/93	JUN GAOR J.G.	10/12/93					

Summary of Tank Nozzle Stiffness Values

Nozzle Size, NPS	Sch.	Elev.	Radial Loads, Lbs/in	Longitudinal Moment, in-lbs/rad	Circumferential Moment, in-lbs/rad
4"	40S	31'-0"	1942	1.68E5	9.15E4
2-1/2"	40S	31'-0"	1780	1.27E5	7.84E4
2"	80S	31'-0"	1700	1.12E5	7.28E4
1"	80S	16'-0"	5814	3.45E5	2.59E5
3"	40S	10'-7"	11553	5.18E5	3.45E5

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	NABIL M. EL-AKILY	10/12/93	JUN GAOR J.G.	10/12/93					

8.4 <u>Local Stress Check</u>

The hydrostatic pressure at the base (elevation 9'-0") and at elevation 31'-0" (22' from the base of the tank are) :

P_0 = (34') * (62.4 lbs/cu.ft)/144 = 14.73 psi use 15 psi.

P_{22} = (34'-22') * (62.4)/144 = 5 psi.

The maximum moment load due to DBE seismic at the base of the tank is taken from Appendix A (design report),

M_B = 382,172,097 in-lb = 31,847,675 ft-lbs.

The maximum moment load due to DBE at elevation 31' (22' above the tank base) is obtained by linear interpolation as follows :

The seismic load is zero at the top of the tank (34' high) and maximum (M_B) at the base of the tank. Therefore, by ratio, at elevation 31', the moment load is,

$M_{B'}$ = 382,172,097 * (34-22)/34

= 134,884,270 in-lb = 11,240,356 ft=lbs.

For Nozzles A, B, and J, P_0 = 15 psi and M_B = 31,847,675 ft-lbs.

For Nozzles F, G and H, P_{22} = 5 psi and $M_{B'}$ = 11,240,356 ft-lbs.

The pressure and moment loads are included in the local stress analysis using ME101LS program.

Reinforcing pads 3/8" thick at nozzle F and reinforcing pads 1/2" thick at nozzles G and H are required to meet stress limits. To account for the reinforcing pad in the local stress analysis, an effective local shell wall thickness equal to the square root of the sum (SRSS) of the shell thickness and pad thickness is used. This effective local wall thickness is conservative when compared to the effective wall thickness (shell thickness + pad thickness) recommended in Reference 15 for local stress analysis.

To facilitate construction, one size (1/2" thick) reinforcing pads will be specified for nozzles F, G, and H.

The local stress allowables, shown below, are based on the stress intensity concept equivalent to the allowables for Class 1 components (ASME Code Subsection NB-3200). These allowables can be summarized as follows:

Primary membrane plus bending stress = 1.5 Sm

Primary plus secondary stress = 3.0 Sm

Where, Sm = allowable design stress intensity (≈20 ksi, as shown in Section 4.2).

No detailed analysis was performed for the following nozzles:

1. Nozzle K

This is a 3" drain line connected at the bottom of the tank. The local stresses are judged acceptable for the following reasons:

(a) this nozzle is reinforced; and it is located far from the highly stressed area of the bottom, which occurs in the vicinity of the anchor bolt chairs and the shell to bottom weld.

(b) the calculated piping stress at the nozzle connection is small (about 3,600 psi for combined weight and OBE per piping stress calculation number S-1415-56, Revision 0).

(c) Since the primary stress allowable is 30,000 psi, the nozzle is judged acceptable. No further analysis is required.

2. Nozzle L

These are two 2" instrument taps at elev. 9-6" and 42'-0". A 2" X 3/4" swage reducer and a 3/4" gate valves is welded to each nozzle and tubing attached for instrumentation. Nozzle loads are judged acceptable by inspection and comparison to the loads and stress results calculated for Nozzle B which is a 1" unreinforced nozzle and therefore more restrictive than the 2" nozzle.

3. The support connections at the tank are reinforced by 1/2" X 8" X 8" pad. The maximum local stresses at the tank due to the support loads are judged acceptable by comparison to the loadings obtained for the 4" nozzle H (see References 16 through 22 for nozzle and support loads).

Results of the local stress analyses using ME101LS are shown in the following pages.

NES&L DEPARTMENT
CALCULATION SHEET

ICCN NO./ PRELIM. CCN NO. F-565	PAGE 56 OF 279
	CCN CONVERSION CCN NO. CCN - 1

Project or DCP/MMP SONGS 3 Calc No. M-DSC-269

Subject See Title Sheet Sheet No. 56

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	NABIL M. EL-AKILY	10/12/93	JUN GAOR J.G.	10/12/93					

1. Tank 055/56 - Nozzle A

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ME101LS      Version M10     start on 02/25/93 at 07:25:56
     BIJLAARD STRESS ANALYSIS FOR CYLINDERS                          ME101/M10  S. C. Edison         02/25/93 PG2556  PAGE      1

     LOCAL STRESS ANALYSIS FOR CCW TANK T-055/T-056, NOZZLE A

                                I N P U T       D A T A
                                --------------------------------

             ----------1---------2---------3---------4---------5---------6---------7---------8

         1       LOCAL STRESS ANALYSIS FOR CCW TANK T-055/T-056, NOZZLE A
         2       LDC
         3       VD=480.3125,VT=0.3125,C1=3.5,C2=3.5,SHA=CIR,
         4       P=927,VL=126,VC=361,ML=4726,MC=3972,MT=1884,
         5       CAS=SO,
         6       MA=31847675,
         7       PD=15,
         8       SM=20,
         9       LDC
        10       P=927,VL=126,VC=361,ML=4726,MC=3972,MT=1884,
        11       CAS=SE,
        12       MB=31847675,
        13       PD=15,
        14       SM=20,
1
     BIJLAARD STRESS ANALYSIS FOR CYLINDERS                          ME101/M10  S. C. Edison         02/25/93 PG2556  PAGE      2

     LOCAL STRESS ANALYSIS FOR CCW TANK T-055/T-056, NOZZLE A

                                I N P U T       D A T A
                                --------------------------------

             P         ML         MC         MT         VL          VC         MA         MB       STRESS
           (LBS)   (IN-LBS)   (IN-LBS)   (IN-LBS)     (LBS)       (LBS)    (FT-LBS)   (FT-LBS)     LEVEL
        ---------------------------------------------------------------------------------------------------
   1      927.0     4726.0     3972.0     1884.0      126.0       361.031847676.0          .0        SO
   2      927.0     4726.0     3972.0     1884.0      126.0       361.0           .031847676.0       SE

          VESTHK    VESDIA       C1          C2        SHAPE       SCALE        SM      PRESSURE    BEND R
           (IN)      (IN)       (IN)        (IN)                  FACTOR 1     (KSI)      (PSI)      (IN)
        -----------------------------------------------------------------------------------------------------
   1       .312    480.312     3.500       3.500     CIRCULAR       .000        20.0       15.0        .000
   2       .312    480.312     3.500       3.500     CIRCULAR       .000        20.0       15.0        .000
1
     BIJLAARD STRESS ANALYSIS FOR CYLINDERS                          ME101/M10  S. C. Edison         02/25/93 PG2556  PAGE      3

     LOCAL STRESS ANALYSIS FOR CCW TANK T-055/T-056, NOZZLE A

     CASE  1
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NES&L DEPARTMENT
CALCULATION SHEET

ICCN NO./ PRELIM. CCN NO. F-565 | PAGE 57 OF 279
CCN CONVERSION CCN NO. CCN - 1

Project or DCP/MMP SONGS 3 Calc No. M-DSC-269

Subject See Title Sheet Sheet No. 57

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	NABIL M. EL-AKILY	10/12/93	JUN GAOR J.G.	10/12/93					

VESSEL DIAMETER = 480.312 INCHES C1 = 3.500 INCHES C2 = 3.500 INCHES
GAMMA = 768.500 BETA1 = .006 BETA2 = .006

*** COMBINED STRESS INTENSITY, S(KSI), AT ***

MOM. VESSEL THICKNESS (INCHES)	INWARD END OF LONG. MOM. OUTSIDE OF SHELL	INSIDE OF SHELL	OUTWARD END OF LONG. MOM. OUTSIDE OF SHELL	INSIDE OF SHELL	INWARD END OF CIRC. MOM. OUTSIDE OF SHELL	INSIDE OF SHELL	OUTWARD END OF CIRC. MOM. OUTSIDE OF SHELL	INSIDE OF SHELL
	MAXIMUM PRIMARY PLUS SECONDARY STRESS INTENSITY							
.3125	-26.29	19.08	15.72	-6.96	-30.24	23.78	10.48	-9.84
	MAXIMUM PRIMARY MEMBRANE STRESS INTENSITY							
	-6.36	-6.36	4.71	4.71	-3.59	-3.59	2.12	2.12

BIJLAARD STRESS ANALYSIS FOR CYLINDERS ME101/M10 S. C. Edison 02/25/93 PG2556 PAGE 5

LOCAL STRESS ANALYSIS FOR CCW TANK T-055/T-056, NOZZLE A

CASE 1 THIS CALCULATION IS FOR A LUG ON STRAIGHT PIPE

MAXIMUM PRIMARY PIPING STRESS INTENSITY------------------------------ 12.5 (KSI)

MAXIMUM PRIMARY LOCAL MEMBRANE STRESS INTENSITY---------------------- 6.4 (KSI)

MAXIMUM COMBINED PRIMARY MEMBRANE STRESS INTENSITY------------------- 18.9 (KSI)

ALLOWABLE (1.500 Sm)-- 30.0 (KSI)

1

BIJLAARD STRESS ANALYSIS FOR CYLINDERS ME101/M10 S. C. Edison 02/25/93 PG2556 PAGE 6

LOCAL STRESS ANALYSIS FOR CCW TANK T-055/T-056, NOZZLE A

CASE 2

VESSEL DIAMETER = 480.312 INCHES C1 = 3.500 INCHES C2 = 3.500 INCHES
GAMMA = 768.500 BETA1 = .006 BETA2 = .006

*** COMBINED STRESS INTENSITY, S(KSI), AT ***

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	NABIL M. EL-AKILY	10/12/93	JUN GAOR J-G	10/12/93					

MOM. VESSEL THICKNESS (INCHES)	INWARD END OF LONG. MOM. OUTSIDE OF SHELL	INSIDE OF SHELL	OUTWARD END OF LONG. MOM. OUTSIDE OF SHELL	INSIDE OF SHELL	INWARD END OF CIRC. MOM. OUTSIDE OF SHELL	INSIDE OF SHELL	OUTWARD END OF CIRC. MOM. OUTSIDE OF SHELL	INSIDE OF SHELL
	MAXIMUM PRIMARY PLUS SECONDARY STRESS INTENSITY							
.3125	-26.29	19.08	15.72	-6.96	-30.24	23.78	10.48	-9.84
	MAXIMUM PRIMARY MEMBRANE STRESS INTENSITY							
	-6.36	-6.36	4.71	4.71	-3.59	-3.59	2.12	2.12

BIJLAARD STRESS ANALYSIS FOR CYLINDERS ME101/M10 S. C. Edison 02/25/93 PG2556 PAGE 8

LOCAL STRESS ANALYSIS FOR CCW TANK T-055/T-056, NOZZLE A

CASE 2 THIS CALCULATION IS FOR A LUG ON STRAIGHT PIPE

MAXIMUM SECONDARY PIPING STRESS INTENSITY---------------------------- 18.3 (KSI)

MAXIMUM PRIMARY PLUS SECONDARY LOCAL MEMBRANE STRESS INTENSITY------- 30.2 (KSI)

MAXIMUM COMBINED PRIMARY PLUS SECONDARY MEMBRANE STRESS INTENSITY----- 48.5 (KSI)

ALLOWABLE (3.000 Sm)-- 60.0 (KSI)

1

BIJLAARD STRESS ANALYSIS FOR CYLINDERS ME101/M10 S. C. Edison 02/25/93 PG2556 PAGE 9

LOCAL STRESS ANALYSIS FOR CCW TANK T-055/T-056, NOZZLE A

SUMMARY TABLE
(KSI)

CASE	PIPING PRIMARY	PIPING SECONDARY	LOCAL PRIMARY	LOCAL SECONDARY + PRIMARY	COMBINED	ALLOWABLE	MAX SHEAR	ALLOWABLE
1	12.5	.0	6.4	.0	18.9	30.0	.0	.0
2	.0	18.3	.0	30.2	48.5	60.0	.0	.0

1

BIJLAARD STRESS ANALYSIS FOR CYLINDERS ME101/M10 S. C. Edison 02/25/93 PG2556 PAGE 10

NES&L DEPARTMENT
CALCULATION SHEET

ICCN NO./ PRELIM. CCN NO. F-565	PAGE 59 OF 279
	CCN CONVERSION CCN NO. CCN - 1

Project or DCP/MMP SONGS 3 Calc No. M-DSC-269

Subject See Title Sheet Sheet No. 59

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	NABIL M. EL-AKILY	10/12/93	JUN GAOR J.G.	10/12/93					

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ME101LS     Version M10    stop   on 02/25/93 at 07:25:56
ME101LS     Version M10    run time      .00 seconds
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REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	NABIL M. EL-AKILY	10/12/93	JUN GAOR J.G.	10/12/93					

2. Tank T055/56 - N[illegible]e B

1

BIJLAARD STRESS ANALYSIS FOR CYLINDERS ME101/M10 S. C. Edison 01/19/93 JJ3456 PAGE 1

LOCAL STRESS ANALYSIS FOR CCW TANK T-055/T-056, NOZZLE B

I N P U T D A T A

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---------1---------2---------3---------4---------5---------6---------7---------8

   1    LOCAL STRESS ANALYSIS FOR CCW TANK T-055/T-056, NOZZLE B
   2    LDC
   3    VD=480.3125,VT=0.3125,C1=1.315,C2=1.315,SHA=CIR,
   4    P=66,VL=32,VC=55,ML=264,MC=1560,MT=72,
   5    CAS=SO,
   6    MA=31847675,
   7    PD=15,
   8    SM=20,
   9    LDC
  10    P=66,VL=32,VC=55,ML=264,MC=1560,MT=72,
  11    CAS=SE,
  12    MB=31847675,
  13    PD=15,
  14    SM=20,
```

1

BIJLAARD STRESS ANALYSIS FOR CYLINDERS ME101/M10 S. C. Edison 01/19/93 JJ3456 PAGE 2

LOCAL STRESS ANALYSIS FOR CCW TANK T-055/T-056, NOZZLE B

I N P U T D A T A

	P (LBS)	ML (IN-LBS)	MC (IN-LBS)	MT (IN-LBS)	VL (LBS)	VC (LBS)	MA (FT-LBS)	MB (FT-LBS)	STRESS LEVEL
1	66.0	264.0	1560.0	72.0	32.0	55.0	31847676.0	.0	SO
2	66.0	264.0	1560.0	72.0	32.0	55.0	.0	31847676.0	SE

	VESTHK (IN)	VESDIA (IN)	C1 (IN)	C2 (IN)	SHAPE	SCALE FACTOR 1	SM (KSI)	PRESSURE (PSI)	BEND R (IN)
1	.312	480.312	1.315	1.315	CIRCULAR	.000	20.0	15.0	.000
2	.312	480.312	1.315	1.315	CIRCULAR	.000	20.0	15.0	.000

1

BIJLAARD STRESS ANALYSIS FOR CYLINDERS ME101/M10 S. C. Edison 01/19/93 JJ3456 PAGE 3

LOCAL STRESS ANALYSIS FOR CCW TANK T-055/T-056, NOZZLE B

CASE 1

NES&L DEPARTMENT
CALCULATION SHEET

ICCN NO./ PRELIM. CCN NO. F-565

CCN CONVERSION CCN NO. CCN - 1

Project or DCP/MMP SONGS 3 Calc No. M-DSC-269

Subject See Title Sheet Sheet No. 61

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	NABIL M. EL-AKILY	10/12/93	JUN GAOR J.G.	10/12/93					

VESSEL DIAMETER = 480.312 INCHES C1 = 1.315 INCHES C2 = 1.315 INCHES
GAMMA = 768.500 BETA1 = .002 BETA2 = .002

*** C O M B I N E D S T R E S S I N T E N S I T Y, S (K S I), A T ***

MOM. VESSEL THICKNESS (INCHES)	INWARD END OF LONG. MOM. OUTSIDE OF SHELL	INSIDE OF SHELL	OUTWARD END OF LONG. MOM. OUTSIDE OF SHELL	INSIDE OF SHELL	INWARD END OF CIRC. MOM. OUTSIDE OF SHELL	INSIDE OF SHELL	OUTWARD END OF CIRC. OUTSIDE OF SHELL	INSIDE OF SHELL
	MAXIMUM PRIMARY PLUS SECONDARY STRESS INTENSITY							
.3125	-3.80	2.54	2.99	-1.49	-21.95	18.73	20.34	-17.67
	MAXIMUM PRIMARY MEMBRANE STRESS INTENSITY							
	-.93	-.93	.75	.75	-2.66	-2.66	2.54	2.54

BIJLAARD STRESS ANALYSIS FOR CYLINDERS ME101/M10 S. C. Edison 01/19/93 JJ3456 PAGE 5

LOCAL STRESS ANALYSIS FOR CCW TANK T-055/T-056, NOZZLE B

CASE 1 THIS CALCULATION IS FOR A LUG ON STRAIGHT PIPE

MAXIMUM PRIMARY PIPING STRESS INTENSITY------------------------------ 12.5 (KSI)

MAXIMUM PRIMARY LOCAL MEMBRANE STRESS INTENSITY----------------------- 2.7 (KSI)

MAXIMUM COMBINED PRIMARY MEMBRANE STRESS INTENSITY-------------------- 15.2 (KSI)

ALLOWABLE (1.500 Sm)--- 30.0 (KSI)

1

BIJLAARD STRESS ANALYSIS FOR CYLINDERS ME101/M10 S. C. Edison 01/19/93 JJ3456 PAGE 6

LOCAL STRESS ANALYSIS FOR CCW TANK T-055/T-056, NOZZLE B

CASE 2

VESSEL DIAMETER = 480.312 INCHES C1 = 1.315 INCHES C2 = 1.315 INCHES
GAMMA = 768.500 BETA1 = .002 BETA2 = .002

*** C O M B I N E D S T R E S S I N T E N S I T Y, S (K S I), A T ***

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	NABIL M. EL-AKILY	10/12/93	JUN GAOR JG	10/12/93					

MOM. VESSEL THICKNESS (INCHES)	INWARD END OF LONG. MOM. OUTSIDE OF SHELL	INSIDE OF SHELL	OUTWARD END OF LONG. MOM. OUTSIDE OF SHELL	INSIDE OF SHELL	INWARD END OF CIRC. MOM. OUTSIDE OF SHELL	INSIDE OF SHELL	OUTWARD END OF CIRC. OUTSIDE OF SHELL	INSIDE OF SHELL
	MAXIMUM PRIMARY PLUS SECONDARY STRESS INTENSITY							
.3125	-3.80	2.54	2.99	-1.49	-21.95	18.73	20.34	-17.67
	MAXIMUM PRIMARY MEMBRANE STRESS INTENSITY							
	-.93	-.93	.75	.75	-2.66	-2.66	2.54	2.54

BIJLAARD STRESS ANALYSIS FOR CYLINDERS ME101/M10 S. C. Edison 01/19/93 JJ3456 PAGE 8

LOCAL STRESS ANALYSIS FOR CCW TANK T-055/T-056, NOZZLE B

CASE 2 THIS CALCULATION IS FOR A LUG ON STRAIGHT PIPE

MAXIMUM SECONDARY PIPING STRESS INTENSITY---------------------------- 18.3 (KSI)

MAXIMUM PRIMARY PLUS SECONDARY LOCAL MEMBRANE STRESS INTENSITY------- 21.9 (KSI)

MAXIMUM COMBINED PRIMARY PLUS SECONDARY MEMBRANE STRESS INTENSITY----- 40.2 (KSI)

ALLOWABLE (3.000 Sm)--- 60.0 (KSI)

1

BIJLAARD STRESS ANALYSIS FOR CYLINDERS ME101/M10 S. C. Edison 01/19/93 JJ3456 PAGE 9

LOCAL STRESS ANALYSIS FOR CCW TANK T-055/T-056, NOZZLE B

SUMMARY TABLE
(KSI)

CASE	PIPING PRIMARY	PIPING SECONDARY	LOCAL PRIMARY	LOCAL SECONDARY + PRIMARY	COMBINED	ALLOWABLE	MAX SHEAR	ALLOWABLE
1	12.5	.0	2.7	.0	15.2	30.0	.0	.0
2	.0	18.3	.0	21.9	40.2	60.0	.0	.0

1

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	NABIL M. EL-AKILY	10/12/93	JUN GAOR J.G.	10/12/93					

BIJLAARD STRESS ANALYSIS FOR CYLINDERS ME101/M10 S. C. Edison 01/19/93 JJ3456 PAGE 11

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ME101LS     Version M10     stop  on 01/19/93 at 10:34:56
ME101LS     Version M10     run time      .00 seconds
```

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	NABIL M. EL-AKILY	10/12/93	JUN GAOR J.G.	10/12/93					

3. <u>Tank T055/56 - Nozzle C</u> (This nozzle is deleted - included for info only)

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1
   BIJLAARD STRESS ANALYSIS FOR CYLINDERS                    ME101/M10  S. C. Edison        01/20/93 KJ1428  PAGE    1

   LOCAL STRESS ANALYSIS FOR CCW TANK T-055/T-056, NOZZLE C

                                  I N P U T     D A T A
                                  ---------------------------------

          ---------1---------2---------3---------4---------5---------6---------7---------8

      1     LOCAL STRESS ANALYSIS FOR CCW TANK T-055/T-056, NOZZLE C
      2     LDC
      3     VD=480.1875,VT=0.42,C1=2.375,C2=2.375,SHA=CIR,
      4     P=159,VL=491,VC=280,ML=11508,MC=7848,MT=696,
      5     CAS=SO,
      6     MA=11240356,
      7     PD=5,
      8     SM=20,
      9     LDC
     10     P=159,VL=491,VC=280,ML=11508,MC=7848,MT=696,
     11     CAS=SE,
     12     MB=11240356,
     13     PD=5,
     14     SM=20,
1
   BIJLAARD STRESS ANALYSIS FOR CYLINDERS                    ME101/M10  S. C. Edison        01/20/93 KJ1428  PAGE    2

   LOCAL STRESS ANALYSIS FOR CCW TANK T-055/T-056, NOZZLE C

                                  I N P U T     D A T A
                                  ---------------------------------
```

	P (LBS)	ML (IN-LBS)	MC (IN-LBS)	MT (IN-LBS)	VL (LBS)	VC (LBS)	MA (FT-LBS)	MB (FT-LBS)	STRESS LEVEL
1	159.0	11508.0	7848.0	696.0	491.0	280.0	11240356.0	.0	SO
2	159.0	11508.0	7848.0	696.0	491.0	280.0	.0	11240356.0	SE

	VESTHK (IN)	VESDIA (IN)	C1 (IN)	C2 (IN)	SHAPE	SCALE FACTOR 1	SM (KSI)	PRESSURE (PSI)	BEND R (IN)
1	.420	480.188	2.375	2.375	CIRCULAR	.000	20.0	5.0	.000
2	.420	480.188	2.375	2.375	CIRCULAR	.000	20.0	5.0	.000

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1
   BIJLAARD STRESS ANALYSIS FOR CYLINDERS                    ME101/M10  S. C. Edison        01/20/93 KJ1428  PAGE    3

   LOCAL STRESS ANALYSIS FOR CCW TANK T-055/T-056, NOZZLE C

   CASE  1
```

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	NABIL M. EL-AKILY	10/12/93	JUN GAOR JG	10/12/93					

VESSEL DIAMETER = 480.188 INCHES   C1 = 2.375 INCHES   C2 = 2.375 INCHES
GAMMA = 571.652   BETA1 = .004   BETA2 = .004

*** C O M B I N E D   S T R E S S   I N T E N S I T Y, S (K S I), A T ***

MOM. VESSEL THICKNESS (INCHES)	INWARD END OF LONG. MOM. OUTSIDE OF SHELL	INSIDE OF SHELL	OUTWARD END OF LONG. MOM. OUTSIDE OF SHELL	INSIDE OF SHELL	INWARD END OF CIRC. MOM. OUTSIDE OF SHELL	INSIDE OF SHELL	OUTWARD END OF CIRC. OUTSIDE OF SHELL	INSIDE OF SHELL
	MAXIMUM PRIMARY PLUS SECONDARY STRESS INTENSITY							
.4200	-43.13	30.82	41.90	-29.35	-32.78	28.56	30.62	-27.13
	MAXIMUM PRIMARY MEMBRANE STRESS INTENSITY							
	-9.94	-9.94	9.71	9.71	-3.13	-3.13	3.09	3.09

1

BIJLAARD STRESS ANALYSIS FOR CYLINDERS   ME101/M10 S. C. Edison   01/20/93 KJ1428 PAGE 5

LOCAL STRESS ANALYSIS FOR CCW TANK T-055/T-056, NOZZLE C

CASE 1   THIS CALCULATION IS FOR A LUG ON STRAIGHT PIPE

MAXIMUM PRIMARY PIPING STRESS INTENSITY------------------------------ 3.2 (KSI)

MAXIMUM PRIMARY LOCAL MEMBRANE STRESS INTENSITY----------------------- 9.9 (KSI)

MAXIMUM COMBINED PRIMARY MEMBRANE STRESS INTENSITY-------------------- 13.1 (KSI)

ALLOWABLE (1.500 Sm)-- 30.0 (KSI)

1

BIJLAARD STRESS ANALYSIS FOR CYLINDERS   ME101/M10 S. C. Edison   01/20/93 KJ1428 PAGE 6

LOCAL STRESS ANALYSIS FOR CCW TANK T-055/T-056, NOZZLE C

CASE 2

VESSEL DIAMETER = 480.188 INCHES   C1 = 2.375 INCHES   C2 = 2.375 INCHES
GAMMA = 571.652   BETA1 = .004   BETA2 = .004

*** COMBINED STRESS INTENSITY, S(KSI), AT ***

MOM. VESSEL THICKNESS (INCHES)	INWARD END OF LONG. MOM. OUTSIDE OF SHELL	INWARD END OF LONG. MOM. INSIDE OF SHELL	OUTWARD END OF LONG. MOM. OUTSIDE OF SHELL	OUTWARD END OF LONG. MOM. INSIDE OF SHELL	INWARD END OF CIRC. MOM. OUTSIDE OF SHELL	INWARD END OF CIRC. MOM. INSIDE OF SHELL	OUTWARD END OF CIRC. MOM. OUTSIDE OF SHELL	OUTWARD END OF CIRC. MOM. INSIDE OF SHELL
	MAXIMUM PRIMARY PLUS SECONDARY STRESS INTENSITY							
.4200	-43.13	30.82	41.90	-29.35	-32.78	28.56	30.62	-27.13
	MAXIMUM PRIMARY MEMBRANE STRESS INTENSITY							
	-9.94	-9.94	9.71	9.71	-3.13	-3.13	3.09	3.09

1

BIJLAARD STRESS ANALYSIS FOR CYLINDERS   ME101/M10 S. C. Edison   01/20/93 KJ1428 PAGE 8

LOCAL STRESS ANALYSIS FOR CCW TANK T-055/T-056, NOZZLE C

CASE 2   THIS CALCULATION IS FOR A LUG ON STRAIGHT PIPE

MAXIMUM SECONDARY PIPING STRESS INTENSITY---------------------------- 4.6 (KSI)

MAXIMUM PRIMARY PLUS SECONDARY LOCAL MEMBRANE STRESS INTENSITY------- 43.1 (KSI)

MAXIMUM COMBINED PRIMARY PLUS SECONDARY MEMBRANE STRESS INTENSITY----- 47.8 (KSI)

ALLOWABLE (3.000 Sm)-- 60.0 (KSI)

1

BIJLAARD STRESS ANALYSIS FOR CYLINDERS   ME101/M10 S. C. Edison   01/20/93 KJ1428 PAGE 9

LOCAL STRESS ANALYSIS FOR CCW TANK T-055/T-056, NOZZLE C

SUMMARY TABLE
(KSI)

CASE	PIPING PRIMARY	PIPING SECONDARY	LOCAL PRIMARY	LOCAL SECONDARY + PRIMARY	COMBINED	ALLOWABLE	MAX SHEAR	ALLOWABLE
1	3.2	.0	9.9	.0	13.1	30.0	.0	.0
2	.0	4.6	.0	43.1	47.8	60.0	.0	.0

1

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	NABIL M. EL-AKILY	10/12/93	JUN GAOR J.G.	10/12/93					

BIJLAARD STRESS ANALYSIS FOR CYLINDERS ME101/M10 S. C. Edison 01/20/93 KJ1428 PAGE 11

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ME101LS     Version M10    stop  on 01/20/93 at 10:14:28
ME101LS     Version M10    run time     .00 seconds
```

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	NABIL M. EL-AKILY	10/12/93	JUN GAOR JL.	10/12/93					

4. Tank T055/56 - Nozzle F

1

BIJLAARD STRESS ANALYSIS FOR CYLINDERS ME101/M10 S. C. Edison 01/27/93 RQ1456 PAGE 1

LOCAL STRESS ANALYSIS FOR CCW TANK T-055/T-056, NOZZLE F

I N P U T D A T A

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---------1---------2---------3---------4---------5---------6---------7---------8

LOCAL STRESS ANALYSIS FOR CCW TANK T-055/T-056, NOZZLE F
LDC
VD=480.1875,VT=0.42,C1=2.875,C2=2.875,SHA=CIR,
P=231,VL=554,VC=149,ML=14352,MC=3228,MT=852,
CAS=SO,
MA=11240356,
PD=5,
SM=20,
LDC
P=231,VL=554,VC=149,ML=14352,MC=3228,MT=852,
CAS=SE,
MB=11240356,
PD=5,
SM=20,
```

1

BIJLAARD STRESS ANALYSIS FOR CYLINDERS ME101/M10 S. C. Edison 01/27/93 RQ1456 PAGE 2

LOCAL STRESS ANALYSIS FOR CCW TANK T-055/T-056, NOZZLE F

I N P U T D A T A

	P (LBS)	ML (IN-LBS)	MC (IN-LBS)	MT (IN-LBS)	VL (LBS)	VC (LBS)	MA (FT-LBS)	MB (FT-LBS)	STRESS LEVEL
1	231.0	14352.0	3228.0	852.0	554.0	149.0	11240356.0	.0	SO
2	231.0	14352.0	3228.0	852.0	554.0	149.0	.0	11240356.0	SE

	VESTHK (IN)	VESDIA (IN)	C1 (IN)	C2 (IN)	SHAPE	SCALE FACTOR 1	SM (KSI)	PRESSURE (PSI)	BEND R (IN)
1	.420	480.188	2.875	2.875	CIRCULAR	.000	20.0	5.0	.000
2	.420	480.188	2.875	2.875	CIRCULAR	.000	20.0	5.0	.000

1

BIJLAARD STRESS ANALYSIS FOR CYLINDERS ME101/M10 S. C. Edison 01/27/93 RQ1456 PAGE 3

LOCAL STRESS ANALYSIS FOR CCW TANK T-055/T-056, NOZZLE F

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	NABIL M. EL-AKILY	10/12/93	JUN GAOR J.G.	10/12/93					

CASE 1

VESSEL DIAMETER = 480.188 INCHES C1 = 2.875 INCHES C2 = 2.875 INCHES
GAMMA = 571.652 BETA1 = .005 BETA2 = .005

*** COMBINED STRESS INTENSITY, S (KSI), AT ***

VESSEL THICKNESS (INCHES)	INWARD END OF LONG. MOM. OUTSIDE OF SHELL	INSIDE OF SHELL	OUTWARD END OF LONG. MOM. OUTSIDE OF SHELL	INSIDE OF SHELL	INWARD END OF CIRC. MOM. OUTSIDE OF SHELL	INSIDE OF SHELL	OUTWARD END OF CIRC. MOM. OUTSIDE OF SHELL	INSIDE OF SHELL
	MAXIMUM PRIMARY PLUS SECONDARY STRESS INTENSITY							
.4200	-43.87	31.43	42.13	-29.34	-12.27	10.43	9.22	-8.42
	MAXIMUM PRIMARY MEMBRANE STRESS INTENSITY							
	-10.22	-10.22	9.91	9.91	-1.24	-1.24	1.14	1.14

1

BIJLAARD STRESS ANALYSIS FOR CYLINDERS ME101/M10 S. C. Edison 01/27/93 RQ1456 PAGE 5

LOCAL STRESS ANALYSIS FOR CCW TANK T-055/T-056, NOZZLE F

CASE 1 THIS CALCULATION IS FOR A LUG ON STRAIGHT PIPE

MAXIMUM PRIMARY PIPING STRESS INTENSITY------------------------------ 3.2 (KSI)

MAXIMUM PRIMARY LOCAL MEMBRANE STRESS INTENSITY----------------------- 10.2 (KSI)

MAXIMUM COMBINED PRIMARY MEMBRANE STRESS INTENSITY-------------------- 13.4 (KSI)

ALLOWABLE (1.500 Sm)--- 30.0 (KSI)

1

BIJLAARD STRESS ANALYSIS FOR CYLINDERS ME101/M10 S. C. Edison 01/27/93 RQ1456 PAGE 6

LOCAL STRESS ANALYSIS FOR CCW TANK T-055/T-056, NOZZLE F

CASE 2

VESSEL DIAMETER = 480.188 INCHES C1 = 2.875 INCHES C2 = 2.875 INCHES
GAMMA = 571.652 BETA1 = .005 BETA2 = .005

*** COMBINED STRESS INTENSITY, S(KSI), AT ***

MOM. VESSEL THICKNESS (INCHES)	INWARD END OF LONG. MOM. OUTSIDE OF SHELL	INSIDE OF SHELL	OUTWARD END OF LONG. MOM. OUTSIDE OF SHELL	INSIDE OF SHELL	INWARD END OF CIRC. MOM. OUTSIDE OF SHELL	INSIDE OF SHELL	OUTWARD END OF CIRC. OUTSIDE OF SHELL	INSIDE OF SHELL
	MAXIMUM PRIMARY PLUS SECONDARY STRESS INTENSITY							
.4200	-43.87	31.43	42.13	-29.34	-12.27	10.43	9.22	-8.42
	MAXIMUM PRIMARY MEMBRANE STRESS INTENSITY							
	-10.22	-10.22	9.91	9.91	-1.24	-1.24	1.14	1.14

1

BIJLAARD STRESS ANALYSIS FOR CYLINDERS ME101/M10 S. C. Edison 01/27/93 RQ1456 PAGE 8

LOCAL STRESS ANALYSIS FOR CCW TANK T-055/T-056, NOZZLE F

CASE 2 THIS CALCULATION IS FOR A LUG ON STRAIGHT PIPE

MAXIMUM SECONDARY PIPING STRESS INTENSITY---------------------------- 4.6 (KSI)

MAXIMUM PRIMARY PLUS SECONDARY LOCAL MEMBRANE STRESS INTENSITY------- 43.9 (KSI)

MAXIMUM COMBINED PRIMARY PLUS SECONDARY MEMBRANE STRESS INTENSITY----- 48.5 (KSI)

ALLOWABLE (3.000 Sm)--- 60.0 (KSI)

1

BIJLAARD STRESS ANALYSIS FOR CYLINDERS ME101/M10 S. C. Edison 01/27/93 RQ1456 PAGE 9

LOCAL STRESS ANALYSIS FOR CCW TANK T-055/T-056, NOZZLE F

SUMMARY TABLE
(KSI)

CASE	PIPING PRIMARY	SECONDARY	LOCAL PRIMARY	SECONDARY + PRIMARY	COMBINED	ALLOWABLE	MAX SHEAR	ALLOWABLE
1	3.2	.0	10.2	.0	13.4	30.0	.0	.0
2	.0	4.6	.0	43.9	48.5	60.0	.0	.0

1

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	NABIL M. EL-AKILY	10/12/93	JUN GAOR J.G.	10/12/93					

BIJLAARD STRESS ANALYSIS FOR CYLINDERS ME101/M10 S. C. Edison 01/27/93 RQ1456 PAGE 11

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ME101LS    Version M10    stop  on 01/27/93 at 17:14:57
ME101LS    Version M10    run time      .00 seconds
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REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	NABIL M. EL-AKILY	10/12/93	JUN GAOR J.G.	10/12/93					

5. Tank T055/56 - Nozzle G

1

BIJLAARD STRESS ANALYSIS FOR CYLINDERS ME101/M10 S. C. Edison 01/27/93 RQ3318 PAGE 1

LOCAL STRESS ANALYSIS FOR CCW TANK T-055/T-056, NOZZLE G

I N P U T D A T A

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---------1---------2---------3---------4---------5---------6---------7---------8

   1    LOCAL STRESS ANALYSIS FOR CCW TANK T-055/T-056, NOZZLE G
   2    LDC
   3    VD=480.1875,VT=0.53,C1=2.375,C2=2.375,SHA=CIR,
   4    P=122,VL=1088,VC=167,ML=15852,MC=4788,MT=840,
   5    CAS=SO,
   6    MA=11240356,
   7    PD=5,
   8    SM=20,
   9    LDC
  10    P=122,VL=1088,VC=167,ML=15852,MC=4788,MT=840,
  11    CAS=SE,
  12    MB=11240356,
  13    PD=5,
  14    SM=20,
```

1

BIJLAARD STRESS ANALYSIS FOR CYLINDERS ME101/M10 S. C. Edison 01/27/93 RQ3318 PAGE 2

LOCAL STRESS ANALYSIS FOR CCW TANK T-055/T-056, NOZZLE G

I N P U T D A T A

	P (LBS)	ML (IN-LBS)	MC (IN-LBS)	MT (IN-LBS)	VL (LBS)	VC (LBS)	MA (FT-LBS)	MB (FT-LBS)	STRESS LEVEL
1	122.0	15852.0	4788.0	840.0	1088.0	167.0	11240356.0	.0	SO
2	122.0	15852.0	4788.0	840.0	1088.0	167.0	.0	11240356.0	SE

	VESTHK (IN)	VESDIA (IN)	C1 (IN)	C2 (IN)	SHAPE	SCALE FACTOR 1	SM (KSI)	PRESSURE (PSI)	BEND R (IN)
1	.530	480.188	2.375	2.375	CIRCULAR	.000	20.0	5.0	.000
2	.530	480.188	2.375	2.375	CIRCULAR	.000	20.0	5.0	.000

1

BIJLAARD STRESS ANALYSIS FOR CYLINDERS ME101/M10 S. C. Edison 01/27/93 RQ3318 PAGE 3

LOCAL STRESS ANALYSIS FOR CCW TANK T-055/T-056, NOZZLE G

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	NABIL M. EL-AKILY	10/12/93	JUN GAOR J.G.	10/12/93					

CASE 1

VESSEL DIAMETER = 480.188 INCHES C1 = 2.375 INCHES C2 = 2.375 INCHES
GAMMA = 453.007 BETA1 = .004 BETA2 = .004

*** COMBINED STRESS INTENSITY, S(KSI), AT ***

MOM. VESSEL THICKNESS (INCHES)	INWARD END OF LONG. MOM. OUTSIDE OF SHELL	INSIDE OF SHELL	OUTWARD END OF LONG. MOM. OUTSIDE OF SHELL	INSIDE OF SHELL	INWARD END OF CIRC. MOM. OUTSIDE OF SHELL	INSIDE OF SHELL	OUTWARD END OF CIRC. MOM. OUTSIDE OF SHELL	INSIDE OF SHELL
	MAXIMUM PRIMARY PLUS SECONDARY STRESS INTENSITY							
.5300	-36.74	30.29	36.03	-29.55	-12.62	11.13	11.65	-10.51
	MAXIMUM PRIMARY MEMBRANE STRESS INTENSITY							
	-7.99	-7.99	7.87	7.87	-1.25	-1.25	1.49	1.49

1

BIJLAARD STRESS ANALYSIS FOR CYLINDERS ME101/M10 S. C. Edison 01/27/93 RQ3318 PAGE 5

LOCAL STRESS ANALYSIS FOR CCW TANK T-055/T-056, NOZZLE G

CASE 1 THIS CALCULATION IS FOR A LUG ON STRAIGHT PIPE

MAXIMUM PRIMARY PIPING STRESS INTENSITY------------------------------ 2.5 (KSI)

MAXIMUM PRIMARY LOCAL MEMBRANE STRESS INTENSITY----------------------- 8.0 (KSI)

MAXIMUM COMBINED PRIMARY MEMBRANE STRESS INTENSITY------------------- 10.5 (KSI)

ALLOWABLE (1.500 Sm)--- 30.0 (KSI)

1

BIJLAARD STRESS ANALYSIS FOR CYLINDERS ME101/M10 S. C. Edison 01/27/93 RQ3318 PAGE 6

LOCAL STRESS ANALYSIS FOR CCW TANK T-055/T-056, NOZZLE G

CASE 2

VESSEL DIAMETER = 480.188 INCHES C1 = 2.375 INCHES C2 = 2.375 INCHES
GAMMA = 453.007 BETA1 = .004 BETA2 = .004

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	NABIL M. EL-AKILY	10/12/93	JUN GAOR J.G.	10/12/93					

*** COMBINED STRESS INTENSITY, S(KSI), AT ***

MOM. VESSEL THICKNESS (INCHES)	INWARD END OF LONG. MOM. OUTSIDE OF SHELL	INSIDE OF SHELL	OUTWARD END OF LONG. MOM. OUTSIDE OF SHELL	INSIDE OF SHELL	INWARD END OF CIRC. MOM. OUTSIDE OF SHELL	INSIDE OF SHELL	OUTWARD END OF CIRC. OUTSIDE OF SHELL	INSIDE OF SHELL
	MAXIMUM PRIMARY PLUS SECONDARY STRESS INTENSITY							
.5300	-36.74	30.29	36.03	-29.55	-12.62	11.13	11.65	-10.51
	MAXIMUM PRIMARY MEMBRANE STRESS INTENSITY							
	-7.99	-7.99	7.87	7.87	-1.25	-1.25	1.49	1.49

1

BIJLAARD STRESS ANALYSIS FOR CYLINDERS ME101/M10 S. C. Edison 01/27/93 RQ3318 PAGE 8

LOCAL STRESS ANALYSIS FOR CCW TANK T-055/T-056, NOZZLE G

CASE 2 THIS CALCULATION IS FOR A LUG ON STRAIGHT PIPE

MAXIMUM SECONDARY PIPING STRESS INTENSITY---------------------------- 3.7 (KSI)

MAXIMUM PRIMARY PLUS SECONDARY LOCAL MEMBRANE STRESS INTENSITY------- 36.7 (KSI)

MAXIMUM COMBINED PRIMARY PLUS SECONDARY MEMBRANE STRESS INTENSITY----- 40.4 (KSI)

ALLOWABLE (3.000 Sm)-- 60.0 (KSI)

1

BIJLAARD STRESS ANALYSIS FOR CYLINDERS ME101/M10 S. C. Edison 01/27/93 RQ3318 PAGE 9

LOCAL STRESS ANALYSIS FOR CCW TANK T-055/T-056, NOZZLE G

SUMMARY TABLE (KSI)

CASE	PIPING PRIMARY	PIPING SECONDARY	LOCAL PRIMARY	LOCAL SECONDARY + PRIMARY	COMBINED	ALLOWABLE	MAX SHEAR	ALLOWABLE
1	2.5	.0	8.0	.0	10.5	30.0	.0	.0
2	.0	3.7	.0	36.7	40.4	60.0	.0	.0

1

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	NABIL M. EL-AKILY	10/12/93	JUN GAOR J.G.	10/12/93					

1

BIJLAARD STRESS ANALYSIS FOR CYLINDERS ME101/M10 S. C. Edison 01/27/93 RQ3318 PAGE 11

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ME101LS     Version M10     stop  on 01/27/93 at 17:33:18
ME101LS     Version M10     run time      .00 seconds
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REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	NABIL M. EL-AKILY	10/12/93	JUN GAOR J.G.	10/12/93					

6. Tank T055/56 - Nozzle H

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1
     BIJLAARD STRESS ANALYSIS FOR CYLINDERS                    ME101/M10  S. C. Edison        01/25/93 PP3443  PAGE    1

     LOCAL STRESS ANALYSIS FOR CCW TANK T-055/T-056, NOZZLE H

                                        I N P U T       D A T A
                                        --------------------------------

            ---------1---------2---------3---------4---------5---------6---------7---------8

         1  LOCAL STRESS ANALYSIS FOR CCW TANK T-055/T-056, NOZZLE H
         2  LDC
         3  VD=480.1875,VT=0.53,C1=4.5,C2=4.5,SHA=CIR,
         4  P=291,VL=1265,VC=476,ML=43740,MC=15912,MT=1380,
         5  CAS=SO,
         6  MA=11240356,
         7  PD=5,
         8  SM=20,
         9  LDC
        10  P=291,VL=1265,VC=476,ML=43740,MC=15912,MT=1380,
        11  CAS=SE,
        12  MB=11240356,
        13  PD=5,
        14  SM=20,
1
     BIJLAARD STRESS ANALYSIS FOR CYLINDERS                    ME101/M10  S. C. Edison        01/25/93 PP3443  PAGE    2

     LOCAL STRESS ANALYSIS FOR CCW TANK T-055/T-056, NOZZLE H

                                        I N P U T       D A T A
                                        --------------------------------

            P         ML         MC         MT        VL         VC        MA         MB       STRESS
          (LBS)    (IN-LBS)   (IN-LBS)   (IN-LBS)    (LBS)     (LBS)    (FT-LBS)   (FT-LBS)    LEVEL
       ----------------------------------------------------------------------------------------------
   1      291.0    43740.0    15912.0     1380.0    1265.0     476.011240356.0         .0        SO
   2      291.0    43740.0    15912.0     1380.0    1265.0     476.0          .011240356.0       SE

         VESTHK    VESDIA       C1         C2       SHAPE      SCALE       SM      PRESSURE    BEND R
          (IN)      (IN)       (IN)       (IN)                FACTOR 1   (KSI)     (PSI)       (IN)
       -------------------------------------------------------------------------------------------------
   1      .530    480.188     4.500      4.500     CIRCULAR      .000      20.0        5.0       .000
   2      .530    480.188     4.500      4.500     CIRCULAR      .000      20.0        5.0       .000
1
     BIJLAARD STRESS ANALYSIS FOR CYLINDERS                    ME101/M10  S. C. Edison        01/25/93 PP3443  PAGE    3

     LOCAL STRESS ANALYSIS FOR CCW TANK T-055/T-056, NOZZLE H
```

CASE 1

VESSEL DIAMETER = 480.188 INCHES C1 = 4.500 INCHES C2 = 4.500 INCHES
GAMMA = 453.007 BETA1 = .008 BETA2 = .008

*** COMBINED STRESS INTENSITY, S(KSI), AT ***

VESSEL THICKNESS (INCHES)	INWARD END OF LONG. MOM. OUTSIDE OF SHELL	INWARD END OF LONG. MOM. INSIDE OF SHELL	OUTWARD END OF LONG. MOM. OUTSIDE OF SHELL	OUTWARD END OF LONG. MOM. INSIDE OF SHELL	INWARD END OF CIRC. MOM. OUTSIDE OF SHELL	INWARD END OF CIRC. MOM. INSIDE OF SHELL	OUTWARD END OF CIRC. MOM. OUTSIDE OF SHELL	OUTWARD END OF CIRC. MOM. INSIDE OF SHELL
	MAXIMUM PRIMARY PLUS SECONDARY STRESS INTENSITY							
.5300	-50.10	41.02	48.56	-39.37	-21.80	19.10	19.34	-17.47
	MAXIMUM PRIMARY MEMBRANE STRESS INTENSITY							
	-11.47	-11.47	11.20	11.20	-1.90	-1.90	1.73	1.73

1

BIJLAARD STRESS ANALYSIS FOR CYLINDERS ME101/M10 S. C. Edison 01/25/93 PP3443 PAGE 5

LOCAL STRESS ANALYSIS FOR CCW TANK T-055/T-056, NOZZLE H

CASE 1 THIS CALCULATION IS FOR A LUG ON STRAIGHT PIPE

MAXIMUM PRIMARY PIPING STRESS INTENSITY------------------------------ 2.5 (KSI)

MAXIMUM PRIMARY LOCAL MEMBRANE STRESS INTENSITY---------------------- 11.5 (KSI)

MAXIMUM COMBINED PRIMARY MEMBRANE STRESS INTENSITY-------------------- 14.0 (KSI)

ALLOWABLE (1.500 Sm)--- 30.0 (KSI)

1

BIJLAARD STRESS ANALYSIS FOR CYLINDERS ME101/M10 S. C. Edison 01/25/93 PP3443 PAGE 6

LOCAL STRESS ANALYSIS FOR CCW TANK T-055/T-056, NOZZLE H

CASE 2

VESSEL DIAMETER = 480.188 INCHES C1 = 4.500 INCHES C2 = 4.500 INCHES
GAMMA = 453.007 BETA1 = .008 BETA2 = .008

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	NABIL M. EL-AKILY	10/12/93	JUN GAOR J.G.	10/12/93					

*** COMBINED STRESS INTENSITY, S(KSI), AT ***

MOM. VESSEL THICKNESS (INCHES)	INWARD END OF LONG. MOM. OUTSIDE OF SHELL	INWARD END OF LONG. MOM. INSIDE OF SHELL	OUTWARD END OF LONG. MOM. OUTSIDE OF SHELL	OUTWARD END OF LONG. MOM. INSIDE OF SHELL	INWARD END OF CIRC. MOM. OUTSIDE OF SHELL	INWARD END OF CIRC. MOM. INSIDE OF SHELL	OUTWARD END OF CIRC. MOM. OUTSIDE OF SHELL	OUTWARD END OF CIRC. MOM. INSIDE OF SHELL
	MAXIMUM PRIMARY PLUS SECONDARY STRESS INTENSITY							
.5300	-50.10	41.02	48.56	-39.37	-21.80	19.10	19.34	-17.47
	MAXIMUM PRIMARY MEMBRANE STRESS INTENSITY							
	-11.47	-11.47	11.20	11.20	-1.90	-1.90	1.73	1.73

1

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LOCAL STRESS ANALYSIS FOR CCW TANK T-055/T-056, NOZZLE H

CASE 2 THIS CALCULATION IS FOR A LUG ON STRAIGHT PIPE

MAXIMUM SECONDARY PIPING STRESS INTENSITY---------------------------- 3.7 (KSI)

MAXIMUM PRIMARY PLUS SECONDARY LOCAL MEMBRANE STRESS INTENSITY------- 50.1 (KSI)

MAXIMUM COMBINED PRIMARY PLUS SECONDARY MEMBRANE STRESS INTENSITY----- 53.8 (KSI)

ALLOWABLE (3.000 Sm)-- 60.0 (KSI)

1

BIJLAARD STRESS ANALYSIS FOR CYLINDERS ME101/M10 S. C. Edison 01/25/93 PP3443 PAGE 9

LOCAL STRESS ANALYSIS FOR CCW TANK T-055/T-056, NOZZLE H

SUMMARY TABLE
(KSI)

CASE	PIPING PRIMARY	PIPING SECONDARY	LOCAL PRIMARY	LOCAL SECONDARY + PRIMARY	COMBINED	ALLOWABLE	MAX SHEAR	ALLOWABLE
1	2.5	.0	11.5	.0	14.0	30.0	.0	.0
2	.0	3.7	.0	50.1	53.8	60.0	.0	.0

1

1

Project or DCP/MMP SONGS 3 Calc No. M-DSC-269

CCN CONVERSION
CCN NO. CCN - 1

Subject See Title Sheet Sheet No. 79

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	NABIL M. EL-AKILY	10/12/93	JUN GAOR J.G.	10/12/93					

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```
ME101LS     Version M10     stop  on 01/25/93 at 16:34:43
ME101LS     Version M10     run time       .00 seconds
```

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	NABIL M. EL-AKILY	10/12/93	JUN GAOR JL.	10/12/93					

7. Tank T055/56 - Nozzle J

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1
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     LOCAL STRESS ANALYSIS FOR CCW TANK T-055/T-056, NOZZLE J

                                   I N P U T       D A T A
                                   -------------------------------

              ---------1---------2---------3---------4---------5---------6---------7---------8

          1    LOCAL STRESS ANALYSIS FOR CCW TANK T-055/T-056, NOZZLE J
          2    LDC
          3    VD=480.3125,VT=0.3125,C1=4.5,C2=4.5,SHA=CIR,
          4    P=93,VL=1183,VC=90,ML=8976,MC=1236,MT=2040,
          5    CAS=SO,
          6    MA=31847675,
          7    PD=15,
          8    SM=20,
          9    LDC
         10    P=93,VL=1183,VC=90,ML=8976,MC=1236,MT=2040,
         11    CAS=SE,
         12    MB=31847675,
         13    PD=15,
         14    SM=20,
1
     BIJLAARD STRESS ANALYSIS FOR CYLINDERS                    ME101/M10  S. C. Edison        02/17/93 H05443  PAGE    2

     LOCAL STRESS ANALYSIS FOR CCW TANK T-055/T-056, NOZZLE J

                                   I N P U T       D A T A
                                   -------------------------------

             P        ML        MC        MT        VL        VC        MA        MB      STRESS
           (LBS)   (IN-LBS)  (IN-LBS)  (IN-LBS)   (LBS)     (LBS)   (FT-LBS)  (FT-LBS)    LEVEL
         ----------------------------------------------------------------------------------------
   1       93.0    8976.0    1236.0    2040.0    1183.0     90.031847676.0        .0      SO
   2       93.0    8976.0    1236.0    2040.0    1183.0     90.0         .031847676.0     SE

         VESTHK    VESDIA      C1        C2      SHAPE     SCALE       SM     PRESSURE   BEND R
          (IN)      (IN)      (IN)      (IN)              FACTOR 1   (KSI)     (PSI)      (IN)
         ----------------------------------------------------------------------------------------
   1       .312   480.312    4.500     4.500   CIRCULAR     .000      20.0      15.0      .000
   2       .312   480.312    4.500     4.500   CIRCULAR     .000      20.0      15.0      .000
1
     BIJLAARD STRESS ANALYSIS FOR CYLINDERS                    ME101/M10  S. C. Edison        02/17/93 H05443  PAGE    3

     LOCAL STRESS ANALYSIS FOR CCW TANK T-055/T-056, NOZZLE J

     CASE  1
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REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	NABIL M. EL-AKILY	10/12/93	JUN GAOR JG.	10/12/93					

VESSEL DIAMETER = 480.312 INCHES C1 = 4.500 INCHES C2 = 4.500 INCHES
GAMMA = 768.500 BETA1 = .008 BETA2 = .008

* * * C O M B I N E D S T R E S S I N T E N S I T Y, S (K S I), A T * * *

MOM. VESSEL THICKNESS (INCHES)	INWARD END OF LONG. MOM. OUTSIDE OF SHELL	INSIDE OF SHELL	OUTWARD END OF LONG. MOM. OUTSIDE OF SHELL	INSIDE OF SHELL	INWARD END OF CIRC. MOM. OUTSIDE OF SHELL	INSIDE OF SHELL	OUTWARD END OF CIRC. MOM. OUTSIDE OF SHELL	INSIDE OF SHELL
	MAXIMUM PRIMARY PLUS SECONDARY STRESS INTENSITY							
.3125	-30.01	17.69	29.02	-16.31	-5.78	4.73	4.17	-3.67
	MAXIMUM PRIMARY MEMBRANE STRESS INTENSITY							
	-7.88	-7.88	7.68	7.68	-.95	-.95	1.52	1.52

BIJLAARD STRESS ANALYSIS FOR CYLINDERS ME101/M10 S. C. Edison 02/17/93 H05443 PAGE 5

LOCAL STRESS ANALYSIS FOR CCW TANK T-055/T-056, NOZZLE J

CASE 1 THIS CALCULATION IS FOR A LUG ON STRAIGHT PIPE

MAXIMUM PRIMARY PIPING STRESS INTENSITY------------------------------ 12.5 (KSI)

MAXIMUM PRIMARY LOCAL MEMBRANE STRESS INTENSITY---------------------- 7.9 (KSI)

MAXIMUM COMBINED PRIMARY MEMBRANE STRESS INTENSITY------------------- 20.4 (KSI)

ALLOWABLE (1.500 Sm)-- 30.0 (KSI)

1

BIJLAARD STRESS ANALYSIS FOR CYLINDERS ME101/M10 S. C. Edison 02/17/93 H05443 PAGE 6

LOCAL STRESS ANALYSIS FOR CCW TANK T-055/T-056, NOZZLE J

CASE 2

VESSEL DIAMETER = 480.312 INCHES C1 = 4.500 INCHES C2 = 4.500 INCHES
GAMMA = 768.500 BETA1 = .008 BETA2 = .008

* * * C O M B I N E D S T R E S S I N T E N S I T Y, S (K S I), A T * * *

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	NABIL M. EL-AKILY	10/12/93	JUN GAOR J.G.	10/12/93					

MOM. VESSEL THICKNESS (INCHES)	INWARD END OF LONG. MOM. OUTSIDE OF SHELL	INSIDE OF SHELL	OUTWARD END OF LONG. MOM. OUTSIDE OF SHELL	INSIDE OF SHELL	INWARD END OF CIRC. MOM. OUTSIDE OF SHELL	INSIDE OF SHELL	OUTWARD END OF CIRC. OUTSIDE OF SHELL	INSIDE OF SHELL
	MAXIMUM PRIMARY PLUS SECONDARY STRESS INTENSITY							
.3125	-30.01	17.69	29.02	-16.31	-5.78	4.73	4.17	-3.67
	MAXIMUM PRIMARY MEMBRANE STRESS INTENSITY							
	-7.88	-7.88	7.68	7.68	-.95	-.95	1.52	1.52

BIJLAARD STRESS ANALYSIS FOR CYLINDERS ME101/M10 S. C. Edison 02/17/93 H05443 PAGE 8

LOCAL STRESS ANALYSIS FOR CCW TANK T-055/T-056, NOZZLE J

CASE 2 THIS CALCULATION IS FOR A LUG ON STRAIGHT PIPE

MAXIMUM SECONDARY PIPING STRESS INTENSITY---------------------------- 18.3 (KSI)

MAXIMUM PRIMARY PLUS SECONDARY LOCAL MEMBRANE STRESS INTENSITY------- 30.0 (KSI)

MAXIMUM COMBINED PRIMARY PLUS SECONDARY MEMBRANE STRESS INTENSITY----- 48.3 (KSI)

ALLOWABLE (3.000 Sm)--- 60.0 (KSI)

1

BIJLAARD STRESS ANALYSIS FOR CYLINDERS ME101/M10 S. C. Edison 02/17/93 H05443 PAGE 9

LOCAL STRESS ANALYSIS FOR CCW TANK T-055/T-056, NOZZLE J

SUMMARY TABLE
(KSI)

CASE	PIPING PRIMARY	PIPING SECONDARY	LOCAL PRIMARY	LOCAL SECONDARY + PRIMARY	COMBINED	ALLOWABLE	MAX SHEAR	ALLOWABLE
1	12.5	.0	7.9	.0	20.4	30.0	.0	.0
2	.0	18.3	.0	30.0	48.3	60.0	.0	.0

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	NABIL M. EL-AKILY	10/12/93	JUN GAOR J.G.	10/12/93					

8.5 Allowable Maximum Out-of-Roundness

Per ASME Code, Subsection ND-4224 (Reference 2), the difference in inches between the maximum and minimum diameters at any cross section shall not exceed 1% of the average diameter, or $D_{ave}/100$, where D_{ave} is the average diameter of the PPMS tank under consideration or 12" whichever is less. The same Code Subsection also specifies that diameter should be measured 6 ft or one plate width from top or bottom junctures, respectively.

It follows that:

$$D_{ave} = 480 + 0.2278 = 480.2278"$$

where the average wall thickness is 0.2278" per Appendix A of this calcualtion. It follows that the tolerance is given by:

$$D_{ave}/100 = 480.227/100 = 4.8"$$

Therefore, the maximum allowable difference in cross-sectional diameters is 4.8" (0.4').

A survey of SONGS-3 tank, T055, was performed for roundness at elevations 7' above the bottom and 6'below the top. Results of the survey (Reference 26) are attached in Appendix D. These results can be summarized as follows:

a) At elevation 7'from the bottom:

Maximum diameter = 40.07',
Minimum diameter = 39.96'

b) At elevation 6' below the top:

Maximum diameter = 40.10',
Minimum diameter = 39.90'

The above measurements correspond to a maximum out-of-roundness of 0.2' (2.4"), which meets the ASME Code requirements calculated above.

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Subject See Title Sheet Sheet No. 84

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	NABIL M. EL-AKILY	10/12/93	JUN GAOR JG	10/12/93					

APPENDIX - A

PPMS DESIGN REPORT

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Q-Class = I

Report No.: SIR-92-063
Revision No.: 0
Project No.: SCE-16Q
February, 1993

Evaluation and Modification of Primary Plant Make-Up Storage Tanks for SONGS, Units 2 & 3

Prepared for:

Southern California Edison Company

Prepared by:

Structural Integrity Associates, Inc.

Prepared by: A. Y. Kuo Date: 2/18/93

Reviewed by: R. A. Mattson Date: 2/18/93

STRUCTURAL INTEGRITY ASSOCIATES INC

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STRUCTURAL INTEGRITY ASSOCIATES INC

CCN 1

1.0 PURPOSE

The two Primary Plant Makeup Storage Tanks (PPMST) at Southern California Edison's (SCE) San Onofre Nuclear Generating Station (SONGS), Units 2 and 3 were originally designed to American Petroleum Institute (API) Standard 620, 5th Edition; and constructed and tested to API Standard 650, 5th Edition (Reference 3). These tanks were originally classified as Seismic Class II components. SCE desires to upgrade its PPMS tanks at SONGS 2 and 3 to Seismic Class I components in order to qualify these tanks as ASME Section III, Class 3 tanks. Also, SCE desires to evaluate the PPMS tanks for the issues related to Nuclear Regulatory Commission (NRC) Unresolved Safety Issues (USI) A-46. This report provides the re-qualification analysis of the PPMS tanks at SONGS 2 and 3 as ASME Section III, Class 3 tanks and the resolution of the USI A-46 issues.

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2.0 RESULTS AND CONCLUSIONS

The existing PPMST design does not meet all requirements contained in the Generic Implementation Procedure (GIP) [17]. It is recommended that the existing PPMST be reinforced with thirty-six (36) vertical stringers and thirty-four (34) additional anchor bolts around the circumference of the tank, the existing anchor chairs be removed and replaced by a new, stronger, ring-type anchor chair, and annular pad plates as illustrated in Table 10-1 be added to the man-hole penetration of the tanks. Details of the tank modification are described in Section 9.1 and Figure 5 of this report. It is shown in this report that the reinforced tanks meet all the requirements of the GIP [17] except for the fact that water inside the tanks might slosh against the roof. However, the existing tank roof design was shown to be adequate to withstand the additional internal pressure caused by sloshing. Finally, a reconciliation study on the PPMSTs with the 1989 Edition of the ASME Code concludes that the existing PPMSTs may be classified as ASME Section III, Class 3 tanks, provided that (1) the Certified Material Test Reports (CMTRs) and original material examination records can be recovered, (2) the existing fillet welds (instead of full penetration welds required by the ASME Code) at tank shell to bottom plate junctions of the PPMSTs be accepted, (3) compliance with the roundness requirements per ND-4220 of the ASME Code can be assured, (4) the testing procedures provided by ASME Code ND-6000 are followed, and (5) the procedures specified in Appendix B of NBIC [21] are implemented.

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3.0 ASSUMPTIONS

The following assumptions were made in this evaluation:

(1) The maximum operating temperature of the PPMSTs is 120°F and the maximum ambient temperature is 110°F as required by [2].

(2) The tank foundation is uncracked and has a compressive strength (f_c') equal to or greater then 4,000 psi as required by [11].

(3) The tanks are constructed on a "thick" concrete foundation. Therefore, further soil-structure interaction effects (i.e., shear wave velocity of soil) will not have to be considered.

(4) Material properties of the additional anchor bolts will be the same or comparable to the existing anchor bolts from an evaluation standpoint, namely material ductility, ultimate strength, Young's modulus, and yield strength.

(5) The circularity tolerance requirements of ND-4220 of the ASME Code are satisfied. The tanks have to meet the circularity tolerance requirements to be qualified as ASME Code Tanks.

(6) One horizontal and one vertical earthquake need to be considered, with response combined by the Newmark procedure [25]. That is, 100% of the horizontal earthquake will be combined with 40% of the vertical earthquake [25].

(7) The existing bolts and the additional bolts share the loads according to the ratio of their sizes.

(8) Weight of the reinforcement stringers (see Section 9.1) is negligible compared with weight of the overall tank.

4.0 DESIGN INPUT

The following data were used as design input in the evaluation:

Name of the Tank	: Primary Plant Makeup Storage Tank
Original Constr. Code	: API-650, 5th Ed. + Supp. #1 [1]
Original Design Code	: API-620, 5th Ed. + Supp. #1 [1]
Applicable ASME Code	: Section III, Class 3, 1989 Ed. [19]
Tank Size	: 40 feet dia., 34 feet high [3 thru 9]
Roof Size	: R=48 feet, Self-Supported, Dome [4]
Capacity	: 300,000 Gallons [2]
Content Specific Gravity	: 1.0 [2]
Design Temperature*	: 180°F [2]
Maximum External Temp.	: 110°F [2]
Maximum Operating Temp.	: 120°F [2]
Design Pressure	: Atmospheric [2]
Tank Material	: SA-240, Type 304 [3] ICCN F 565 . P 95 of 27
Chair Material	: A-36 [3]
Anchor Bolt Material	: A-7 (A-307) [10]
Joint Efficiency	: 0.85 [1, 19]
Original Stress Report	: [1]
Original Tank Spec.	: [2]
Original Design Drawings	: [3 thru 12]
Response Spectra Curves	: [13 thru 16] and Figures 2 and 3
Tank Schematics	: Figure 1

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* Actual design temperature per FCN F-7519M for P&ID 40133 is 104°F. However, in this calculation, a design temperature of 120°F is conservatively used. See Appendix D, Sheet 229

5.0 METHODOLOGY

The evaluation procedures contained in Chapters 4, 5, and 7 and Appendix C of the GIP [17] were used to assess seismic design of the existing PPMSTs. The GIP is developed by SQUG (Seismic Qualification User's Group) based on EPRI's reports [25] for resolving the Unresolved Safety Issue A-46. There are twenty-one (21) steps in the GIP procedures, including capacity checks of tank shells, anchor bolts, top plates and stiffener plates of anchor chairs, and sloshing height. Since the tanks have to be modified and the GIP procedures are not directly applicable to reinforced tanks, alternate but compatible methods were used to evaluate the reinforced tanks. In evaluating the lower portion of the tanks, the additional stringers were smeared into the tank shell and an equivalent thickness was used in the evaluation. Methods specified in ASME Code Case N-284 [18] and two books by Baker, et al [22,23] were used to check seismic design of the higher elevations of the reinforced tanks. Evaluation of the higher elevations of the tank is not required by the GIP. The analysis method developed by Haroun [20] for seismic evaluation of flexible tanks was used to confirm the overturning moment and shear at the bottom of the tank calculated per the GIP [17] method, and to calculate overturning moments and shears at higher elevations of the tank. Haroun's paper [20] is the basis of overturning moment and shear force calculations in the GIP [17].

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6.0 REFERENCES

1. "Design Calculations for Primary Plant Make-Up Tank", Brown-Minneapolis Tank and Fabricating Co., January 1975, SO23-407-3-97-0.

2. "Quality Class III, IV Specification for Atmospheric Storage Tanks for the San Onofre Nuclear Generating Station, Units 2 & 3", SO23-407-3, February 22, 1974, including Addendum No. 1 dated May 30, 1974, Addendum No. 2 dated December 16, 1974, Addendum No. 3 dated April 16, 1975, Addendum No. 4 dated October 13, 1975, Addendum No. 5 dated March 11, 1976, Addendum No. 6 dated March 3, 1977, and Addendum No. 7 dated July 16, 1981.

3. Tank Drawing, SO23-407-3-61-2, Rev. 3, 1975.

4. Tank Drawing, SO23-407-3-62-3, Rev. 2, 1975.

5. Tank Drawing, SO23-407-3-63-3, Rev. 3, 1975.

6. Tank Drawing, SO23-407-3-64-1, Rev. 1, 1975.

7. Tank Drawing, SO23-407-3-65-1, Rev. 0, 1975.

8. Tank Drawing, SO23-407-3-66-1, Rev. 0, 1975.

9. Tank Drawing, SO23-407-3-67-1, Rev. 1, 1975.

10. Anchor Bolt Schedule, Drawing No. 20009, Rev. 2, 1976.

11. Auxiliary Building Plan, Drawing No. 25000, Rev. 17, 1983.

12. Auxiliary Building Plan, Drawing No. 25170, Rev. 10, 1978.

13. SONGS 2 & 3 DBE Horizontal Response Spectra, SO23-SK-S-689, Rev. 0, 1973. Also in SCE Calc. C-281-1, Rev. 1, "SONGS-2/3 Seismic Structural Response Sepctra."

14. SONGS 2 & 3 DBE Vertical Response Spectra, SO23-SK-S-690, Rev. 0, 1973. Also in SCE Calc. C-281-1, Rev. 1, "SONGS-2/3 Seismic Structural Response Sepctra."

15. SONGS 2 & 3 OBE Horizontal Response Spectra, SO23-SK-S-713, Rev. 0, 1973. Also in SCE Calc. C-281-1, Rev. 1, "SONGS-2/3 Seismic Structural Response Sepctra."

16. SONGS 2 & 3 OBE Vertical Response Spectra, SO23-SK-S-714, Rev. 0, 1973. Also in SCE Calc. C-281-1, Rev. 1, "SONGS-2/3 Seismic Structural Response Sepctra."

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

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18. ASME Code Case N-284, "Metal Containment Shell Buckling Design Methods", Reaffirmed July 30, 1989.

19. ASME Boiler and Pressure Vessel Code, Section III, 1989 Edition.

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

21. National Board Inspection Code, ANSI-NB-23, Revision 7, 1989.

22. E. H. Baker, L. Kovalevsky, and F. L. Rish, Structural Analysis of Shells, McGraw Hill Book Company, 1972.

23. E. H. Baker, et al, Shell Analysis Manual, NASA CR-912, 1967.

24. ANSI/AWWA D100-84, AWWA Standard for Welded Steel Tanks for Water Storage, American Water Works Association, 1985.

25. EPRI NP-5228-SL, Revision 1, "Seismic Verification of Nuclear Plant Equipment Anchorage, Vol 4: Guidelines on Tanks and Heat Exchangers", June, 1991.

26. "Manual of Steel Construction", American Institute of Steel Construction, Inc., 9th Edition, 1970.

27. E. H. Gaylord and C. N. Gaylord, "Structural Engineering Handbook", 2nd Edition, McGraw-Hill Book Co., 1979.

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7.0 NOMENCLATURE

7.1 From Reference 17:

A_b - Cross-sectional area of embedded anchor bolt [in.^{2}]

a - Width of chair top plate parallel to shell (see Figure 4) [in.]

b - Depth of chair top plate perpendicular to shell (see Figure 4) [in.]

c - Thickness of chair top plate (see Figure 4) [in.]

c' - Coefficient of tank wall thicknesses and lengths under stress [dimensionless]

d - Diameter of anchor bolt [in.]

E_s - Elastic modulus of tank shell material [psi]

E_b - Elastic modulus of anchor bolt material [psi]

e - Eccentricity of anchor bolt with respect to shell outside surface (see Figure 4) [in.]

F - Frequency [Hz]

F_b - Allowable tensile stress of bolt [psi]

F_f - Frequency of fluid-structure interaction mode [Hz]

F_r - Reduced allowable tensile stress of bolt [psi]

F_s - Sloshing mode frequency [Hz]

f - Distance from outside edge of chair top plate to edge of hole (see Figure 4) [in.]

f_y - Minimum specified yield strength of shell, chair, saddle, or base plate material [psi]

G - Acceleration of gravity [386.4 in/sec^2]

g - Distance between vertical plates of chair (see Figure 4) [in.]

H - Height of fluid at the maximum level to which the tank will be filled (see Figure 1) [in.]

H' - Height of tank shell (see Figure 1) [in.]

h - Height of chair (see Figure 4) [in.]

h_b - Effective length of anchor bolt being stretched (usually from top of chair to embedded anchor plate) (see Figure 1) [in.]

h_c - Height of shell compression zone at base of tank (usually height of chair) (see Figure 1) [in.]

h_f - Height of freeboard above fluid surface at the maximum level to which the tank will be filled (see Figure 1) [in.]

h_s - Slosh height of fluid in tank [in.]

h_s' - Slosh height of fluid for a ZPA of 1g applied at tank base [in.]

j - Thickness of chair vertical plate (see Figure 4) [in.]

k - Width of chair vertical plate (see Figure 4). Use average width for tapered plates [in.].

M - Overturning moment at base of tank [in-lbf]

M' - Base overturning moment coefficient [dimensionless]

M_{cap} - Overturning moment capacity of tank [in-lbf]

M'_{cap} - Base overturning moment capacity coefficient [dimensionless]

N - Number of anchor bolts [dimensionless]

P_e - Fluid pressure at base of tank for elephant-foot buckling of tank shell [psi]

P_e' - Pressure coefficient for elephant-foot buckling [dimensionless]

P_d - Fluid pressure at base of tank for diamond-shape buckling of tank shell [psi]

P_d' - Pressure coefficient for diamond-shape buckling [dimensionless]

P_u - Allowable tensile load of anchor bolt [lbf]

Q - Shear load at base of tank [lbf]

Q' - Base shear load coefficient [dimensionless]

Q_{cap} - Base shear load capacity of tank [lbf]

R - Nominal radius of tank [in.] (see Figure 1)

r - Least radius of gyration of vertical stiffener plate cross-sectional area about a centroidal axis [in.]

S_1 - Coefficient of tank radius to shell thickness $\left(\frac{R}{400\ t_s}\right)$ [dimensionless]

Sa - Spectral acceleration of ground or floor [g]

Sa_f - Spectral acceleration (4% damping) of the ground or floor on which the tank is mounted at the frequency of the fluid-structure interaction mode (F_f) [g]

Sa_s - Spectral acceleration (1/2% damping) of the ground or floor on which the tank is mounted at the frequency of the sloshing mode (F_s) [g]

t_{av} - Thickness of the tank shell averaged over the linear height of the tank shell (H') [in.]

t_b - Thickness of bottom or base plate of tank (see Figure 4) [in.]

t_{ef} - Effective thickness of tank shell based on the mean of the average thickness (t_{av}) and the minimum thickness (t_{min}) [in.]

t_{min} - Minimum shell thickness anywhere along the height of the tank shell (H'), usually at the top of the tank [in.]

t_s - Minimum thickness of the tank shell in the lowest 10% of the shell height (H') [in.]

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t_w - Thickness of leg of weld [in.]

t' - Equivalent shell thickness having the same cross-sectional area as the anchor bolts [in.]

V_s - Average shear wave velocity of soil for tanks founded at grade [ft/sec]

W - Weight of fluid contained in tank [lbf]

W_t - Weight of tank without fluid [lbf]

W_w - Average shear load on weld connecting anchor bolt chair to tank shell per unit length of weld (i.e., total shear load on chair divided by total length of chair/shell weld) [lbf/in. of weld]

Z - Tank shell stress reduction factor [dimensionless]

ZPA - Zero period acceleration [g]

β - Percentage damping [%]

γ - Buckling coefficient $[1 - 0.73 (1 - e^{-\phi})]$ [dimensionless]

γ_f - Weight density of fluid in tank [lbf/in^3]

$\Delta\gamma$ - Increase factor for internal pressure

σ - Stress at a point [psi]

σ_c - Stress at which shell buckles [psi]

σ_{pe} - Stress at which shell buckles in elephant-foot pattern [psi]

σ_{pd} - Stress at which shell buckles in diamond-shape pattern [psi]

σ_y - Yield strength of tank shell material [psi]

ϕ - Buckling coefficient $[(1/16)(R/t_s)^{1/2}]$ [dimensionless]

7.2 From Reference 18:

i = ϕ, θ, or $\phi\theta$ corresponding to meridional direction or stress component, circumferential direction or stress component, and in-plane shear stress component, respectively.

i = 1 or 2 corresponding to ϕ to θ above where 1 corresponds to the larger value and 2 corresponds to the smaller value.

j = L, S, G corresponding to local buckling (buckling of shell plate between stiffeners or boundaries), stringer buckling (buckling between rings of the shell plate and attached meridional stiffeners, and general instability (overall collapse), respectively.

A_i = cross-sectional area of stiffener (no effective shell included), sq in.

C_i = elastic buckling coefficients.

$= \dfrac{\sigma_{ieL} R}{E t}$

$C_{\theta r}$, $C_{\theta h}$ = elastic buckling coefficients in hoop direction for cylinders under uniform ex-

ternal pressure. $\sigma_\phi = 0$ and $\sigma_\phi = 0.5\sigma_\theta$, respectively.

E = modulus of elasticity of the material at Design Temperature, psi.

FS = Factor of safety.

$G = \dfrac{E}{2(1+\mu)}$

I_i = moment of inertia of stiffener in the i direction, about its centroidal axis, in.[4]

I_{Ei} = moment of inertia of stiffener plus effective width of shell ℓ_{ei} about centroidal axis of combined section, in the i direction, in.

$$= I_i + A_i z_i^2 \frac{\ell_{ei} t}{A_i + \ell_{ei} t} + \frac{\ell_{ei} t^3}{12}$$

J_i = torsional constant of stiffener, in.[4]

L = overall length of cylinder, in.

L_B = length of cylinder between bulkheads or lines of support with sufficient stiffness to act as bulkheads, in. Lines of support which act as bulkheads include end stiffeners, a circumferential line on an unstiffened head at one-third the depth of the head from the head tangent line, a circumferential line at point of embedment in or anchorage to a concrete foundation, and the cylinder to head junction when the head is designed in accordance with this Case for stiffened heads.

L_s = one-half of the sum of the distances L_B on either side of an end stiffener, in.

ℓ_i = distance in i direction between lines of support, in. A line of support includes any intermediate size stiffening ring which satisfies the requirements of this Case in addition to the lines of support included in the definition for L_B.

ℓ_s = one-half of the sum of the distances ℓ_i on either side of an intermediate size stiffener, in.

ℓ_{ei} = effective width of shell acting with the stiffener in the i direction, in.[4]

$= 1.56\sqrt{Rt}$ unless otherwise noted.

$M_i = \ell_i/\sqrt{Rt}$

$M_s = \ell_s/\sqrt{Rt}$

M = smaller of M_ϕ and M_θ

m = number of half waves into which shell will buckle in the meridional direction.

n = number of waves into which shell will buckle in the circumferential direction.

R = shell radius, in.

R_c = radius to centroidal axis of the combined stiffener and effective width of shell, in.

R_1, R_2 = effective stress radius for toroidal and ellipsoidal shells in the ϕ and θ directions, respectively, in.

t = shell thickness, in.

$t_\phi, t_\theta, t_{\phi\theta} = \dfrac{A_\phi}{\ell_\phi} + t, \dfrac{A_\theta}{\ell_\theta} + t, 0.5\,(t_\phi + t_\theta)$

z_i = distance from centerline of shell to centroid of stiffener (positive when stiffeners are on outside), in.

α_{ij} = capacity reduction factors to account for the difference between classical theory and predicted instability stresses for fabricated shells ($\alpha_{iS} = \alpha_{iG}$).

η_i = plasticity reduction factor.

$\lambda, \bar{\lambda} = \dfrac{\pi R}{\ell_\phi}, \dfrac{\pi R}{L_B}$

λ_c = the lowest multiples of the prebuckling stress states σ_{ie} and σ_{ip} which cause linear bifurcation buckling.

μ = Poisson's ratio.

σ_i = calculated membrane stress components due to applied loads, psi.

σ_{iej} = theoretical elastic instability stresses, psi.

σ_{ie} = amplified stress components to be used for elastic buckling stress evaluation, psi.

$= \sigma_i \cdot FS/\alpha_i$

σ_{ip} = amplified stress components to be used for inelastic buckling stress evaluations, psi.

$= \sigma_{ie}/\eta_i$

$\sigma_{\theta ep}, \sigma_{\theta ej}$ = theoretical elastic instability stresses in the hoop direction for cylinders under external pressure, $\sigma_\phi = 0$ and $\sigma_\phi = 0.5\,\sigma_\theta$, respectively, psi.

σ_y = tabulated yield stress of material at Design Temperature, psi.

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8.0 SEISMIC EVALUATION OF EXISTING TANKS

8.1 General Design Information on Existing Tanks

Design rules contained in ND-3800, "Design of Atmospheric Storage Tanks", of Section III of the ASME Code [19] were used to requalify the PPMSTs. The input parameters are listed in Section 4.0 of this report. A schematic of the PPMST with key dimensions is illustrated in Figure 1.

8.2 Weight Calculations

(a) Roof (W_r)

$$\theta = Sin^{-1}\frac{20}{48} = 24.6243° \text{ (see Figure 1)}$$

$$A_f = 2\pi\int_0^{\theta} R_f^2 Sin\Phi \, d\Phi = 189{,}576 \; inch^2 \quad (R_f\text{=Roof Radius=48}')$$

$$W_r = \rho_s A_f t_r = 0.283 * 189{,}576 * 0.25 = 13{,}413 \text{ Lbf}$$

where ϕ is the angle measured from the top of the roof, A_f is the total area of the roof plate, ρ_s is the weight density of steel, and t_r is the roof thickness.

(b) Tank (W_t)

$$t_{ave} = \frac{0.1875*240.75+0.25*71.625+0.3125*95.625}{408} = 0.2278 \; inch$$

$$W_t = \rho_s 2\pi R_c H' t_{ave} = 0.283*2\pi*240*408*0.2278 = 39{,}664 \text{ Lbf}$$

where R_c is the radius of the tank, H' is the height of the cylindrical part of the tank, and t_{ave} is the average plate thickness of the tank wall.

(c) Product (W_p)

$$W_p = \gamma_f \pi R_c^2 H = 0.0361*\pi*240^2*384 = 2{,}508{,}481 \text{ Lbf}$$

where γ_f is the weight density of the content of the tank, and H=384 inches [2] is the maximum fluid level of the tank.

8.3 Seismic Evaluation of the Existing Tank Design

Effects due to both the OBE and DBE need to be addressed. Design procedures provided by the Generic Implementation Procedure (GIP) [17] for the DBE will be used to perform the earthquake evaluation of the PPMST. Terminology used in the following evaluation steps are all according to the GIP [17].

[Step 1] Input Data

From Design Input specified in Section 4.0 of this report,

$R = 240$ inches

$H' = 408$ inches

$t_{min} = 0.1875$ inches

$t_s = 0.3125$ inches

$\sigma_y = 29{,}000$ psi (SA-240, Type 304 at 120 °F [19])

$h_c = 12.75$ inches

$E_s = 28.03 \times 10^6$ psi (Table I-6.0, Austenitic, 120°F [19])

V_s = average shear wave velocity

The maximum operating temperature of 120°F [2] was used as the metal temperature of the tanks. The soil shear wave velocity is intended for evaluating soil structure interaction (SSI). However, the PPMSTs are inside a building on a thick concrete foundation. Therefore, V_s will not be considered further (see Section 3.0).

$\gamma_f = 0.0361$ Lbf/in^3

$H = 384$ inches [1,2]

$h_f = 34.15$ inches (see Figure 1)

$N = 36$

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$d = 1.5$ inches [10]

$h_b = 40.75$ inches [10]

$E_b = 29.28 \times 10^6$ psi (Table I-6.0, Carbon Steel, 110°F)

The maximum environment temperature of 110°F was used as the bolt temperature.

[Step 2] Parameters

$H/R = 384/240 = 1.6$

$t_s/R = 0.3125/240 = 0.0013$

$$t_{av} = \frac{0.3125*95.625+0.25*71.625+0.1875*240.75}{408} = 0.2278 \text{ inches}$$

$$t_{ef} = \frac{t_{av}+t_{min}}{2} = \frac{0.2278+0.1875}{2} = 0.2077 \text{ inches}$$

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$t_{ef}/R = 0.2077/240 = 0.000865$

$$A_b = \frac{\pi d^2}{4} = \frac{\pi*1.5^2}{4} = 1.7671 \text{ inch}^2$$

$$t' = \frac{NA_bE_b}{2\pi RE_s} = \frac{36*1.7671*29.28}{2\pi*240*28.03} = 0.044 \text{ inches}$$

$$c' = \frac{t'h_c}{t_sh_b} = \frac{0.044*12.75}{0.3125*40.75} = 0.0441$$

$$W = \pi R^2 H\gamma_f = \pi*240^2*384*0.0361 = 2,508,481 \text{ Lbf}$$

The applicable ranges of parameters specified in Table 7-1 of the GIP [17] are satisfied, except for the t_{ef}/R ratio, which falls below the 0.001 to 0.01 applicable range. However, it is judged, based on the trend from 0.01 to 0.001, to be conservative to use the curves for t_{ef}/R=0.001 for the present evaluation.

[Step 3] Tank Frequency

From Table 7-3 of the GIP [17] for R = 240" and H/R = 1.6, $F_f = 7.58$ Hz

$F_f(s,f) = 7.58*(28.03/30)^{0.5} = 7.33$ Hz
Period = $1/F_f$ = 0.136 seconds

[Step 4] Spectra Acceleration

From the SONGS 2 & 3 seismic loading spectra (see Figures 2 and 3), it is found that, at 4% damping for DBE and 2% damping for OBE,

S_{af} = 1.15 g (DBE)
S_{af} = 0.75 g (OBE)

Thus, the DBE evaluation will be bounding, because the DBE load is 1.53 times (1.15/0.75 per [18]) the OBE load, but the OBE buckling factor-of-safety is only 1.49 times (2/1.34 per [18]) the DBE factor-of-safety.

[Step 5] Base Shear Load

From Figure 7-3 of the GIP [17], corresponding to H/R=1.6 and t_{af}/R=0.001,

Q'=0.71
$Q = Q' W S_{af}$ = 0.71*2,508,481*1.15 = 2,048,175 Lbf

[Step 6] Base Overturning Moment

From Figure 7-4 of the GIP [17], at H/R = 1.6,

M' = 0.345
$M = M' W H S_{af}$ = 0.345*2,508,481*384*1.15 = 382,172,097 in-Lbf

[Step 7] Bolt Tensile Capacity

L = 27.5 inches [11]
D = 1.5 inches [11]
From Table C.3-1 of the GIP [17],
$P_{nom} = 50.4*(1.5/1.375)^2$ = 59.98 kips
$V_{nom} = 25.25*(1.5/1.375)^2$ = 30.05 kips
S_{min} = 17.375*(1.5/1.375) = 19 inches
L_{min} = 13.75*(1.5/1.375) = 15 inches
E_{min} = 12.125*(1.5/1.375) = 13.25 inches

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$$S = \frac{2\pi R_{BC}}{N} = \frac{2\pi * 243}{36} = 42.4 \text{ inches} > S_{min}$$

R_{bc} = Radius of Bolt Circle = 243 inches

E = 22'6"-20'3"= 27" inches > E_{min} [12]

$L > L_{min}$

per [11], f'_c = 4000 psi > 3500 psi

$P_{all} = P_{nom}$ = 59.98 kips (No reduction factor is required for f'_c=4,000 psi per [11] and Assumption (2) in Section 3.0 of this report)

$V_{all} = V_{nom}$ = 30.05 kips

$P_u = P_{all}$ = 59,980 lbf

$F_b = P_u/A_b$ = 59,980/1.7671 = 33,943 psi

Since, in the GIP [17], the base shear is assumed to be taken by the friction force between the tank bottom and the foundation [25], the bolts are under pure tension. Thus, there is no need to check the shear-tension interaction limits.

[Step 8] Top Plate (see Figure 4)

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

$$= \frac{(0.375*2.5-0.22*1.5)*59,980}{0.9375*0.875^2}$$

$$= 50,765 \; psi$$

$\sigma > f_y$ = 35,680 psi (SA-36 material at 110°F [19]

Thus, the design of the top plate of the anchor chair is not adequate, and

$$F_z = F_b\left(\frac{f_y}{\sigma}\right) = 23,857 \text{ psi}$$

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[Step 9] Tank Shell Stress

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$$z = \frac{1}{\frac{0.177at_b}{\sqrt{Rt_s}}(\frac{t_b}{t_s})^2+1}$$

$$= \frac{1}{\frac{0.177*6.5*0.25}{\sqrt{240*0.3125}}(\frac{0.25}{0.3125})^2+1}$$

$$= 0.979$$

$$\sigma = \frac{P_u e}{t_s^2}[\frac{1.32z}{\frac{1.43ah^2}{Rt_s}+(4ah^2)^{1/3}}+\frac{0.031}{\sqrt{Rt_s}}]$$

$$= \frac{59,980*2.6875}{0.3125^2}[\frac{1.32*0.979}{\frac{1.43*6.5*12.75^2}{240*0.3125}+(4*6.5*12.75^2)^{1/3}}+\frac{0.031}{\sqrt{240*0.3125}}]$$

$$= 64,647\ psi$$

$\sigma > f_y$

$F_r = F_b\ (f_y/\sigma) = 33,943*(29,000/64,647) = 15,227$ psi

[Step 10] Vertical Stiffener Plate

$k = (4.5+1.25)/2 = 2.875$ inches

$$\frac{k}{j} = \frac{2.875}{0.5} = 5.75$$

$$\frac{95}{\sqrt{f_y/1000}} = \frac{95}{\sqrt{\frac{35,680}{1,000}}} = 15.90$$

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

$0.04(h-c) = 0.04*(12.75-0.875) = 0.475$ inches

$j > 0.04(h-c)$

$$\frac{P_u}{2kj} = \frac{59{,}980}{2*3.375*0.5} = 17{,}772 \text{ psi} < 21{,}000 \text{ psi}$$

The vertical stiffener plate design is adequate.

[Step 11] Chair-to-Tank Weld (see Figure 4)

$$W_w = P_u\sqrt{\left(\frac{1}{a+2h}\right)^2+\left(\frac{e}{ah+0.667h^2}\right)^2}$$

$$=59{,}980*\sqrt{\left(\frac{1}{6.5+2*12.75}\right)^2+\left(\frac{2.6875}{6.5*12.75+0.667*12.75^2}\right)^2}$$

$= 2{,}055$ *Lbf/inch*

$$30600\frac{t_w}{\sqrt{2}} = 30600*\frac{0.25}{\sqrt{2}} = 5409 > W_w$$

Therefore, the design of the chair-to-tank weld is adequate.

[Step 12] Elephant Foot Buckling Pressure

From Figure 7-7 of the GIP [17], at $S_{af} = 1.15g$ and $H/R = 1.6$,

$P'_e = 2.836$

$P_e = P'_e \gamma_f R = 2.836*0.0361*240 = 24.57$ psi

The above P_e value can also be derived by Eq. (2-20) of Reference 25.

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[Step 13] Elephant Foot Buckling Stress

$$S_1 = \frac{R}{400t_s} = \frac{240}{400*0.3125} = 1.92$$

$$\sigma_{pe} = \frac{0.6E_s}{R/t_s}[1-(\frac{P_eR}{\sigma_y t_s})^2][1-\frac{1}{1.12+S_1^{1.5}}][\frac{S_1+\sigma_y/36000}{S_1+1}]$$

$$= \frac{0.6*28.03*10^6}{240/0.3125}[1-(\frac{24.57*240}{29000*0.3125})^2][1-\frac{1}{1.12+1.92^{1.5}}][\frac{1.92+\frac{29}{36}}{1.92+1}]$$
$= 8,668\ psi$

[Step 14] Diamond-Shape Buckling Pressure

From Figure 7-9 of the GIP [17], corresponding to H/R=1.6 and S_{sf}=1.15,

$P'_d = 2.063$

$P_d = P'_d \gamma_f R = 2.063*0.0361*240 = 17.87$ psi

Similarly, the P_d value can also be obtained with Eq (2-20) of [25].

[Step 15] Diamond-Shape Buckling Stress

$$\phi = \frac{1}{16}\sqrt{\frac{R}{t_s}} = \frac{1}{16}\sqrt{\frac{240}{0.3125}} = 1.732$$

$\gamma = 1 - 0.73(1-e^{-\phi}) = 1 - 0.73(1-e^{-1.732}) = 0.399$

From Figure 7-11 of the GIP [17],

$\Delta\gamma = 0.15$

$$\sigma_{pd} = (0.6\gamma+\Delta\gamma)\frac{E_s}{R/t_s}$$
$$= (0.6*0.399+0.15)\frac{28.03*10^6}{240/0.3125}$$
$= 14,212\ psi$

[Step 16] Allowable Buckling Stress

σ_c = 0.72 [Min (σ_{pe} , σ_{pd})] = 0.72*8,668 = 6,241 psi

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[Step 17] Bending Moment Capacity

The weak link is in ductile failure.

$$(\frac{\sigma_c}{F_r})(\frac{h_c}{h_b}) = (\frac{6,241}{15,227})(\frac{12.75}{40.75}) = 0.13$$

From Figure 7-12 of the GIP [17], corresponding to c'=0.0458, M'_{CAP} = 0.1

Therefore,

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

= 0.1*2*15,227*240^2*0.3125*(40.75/12.75)

= 175,200,071 in-Lbf

[Step 18] Check Buckling Moment

M > M_{CAP}

Therefore, the tank is an outlier per the GIP [17].

[Step 19] Shear Load Capacity

Q_{CAP} = 0.55 (1-0.21S_{af}) W

= 0.55*(1-0.21*1.15)*2,508,481

= 1,046,476 lbf

[Step 20] Check Shear Load

Q > Q_{CAP}

Therefore, the tank is an outlier per the GIP [17].

[Step 21] Slosh Height

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

$$= \frac{1}{2\pi}\sqrt{\frac{1.84*386.4}{240}\tanh\left(\frac{1.84*384}{240}\right)}$$

$$= 0.2732\ Hz$$

Sloshing Period = 1/0.2732 = 3.66 seconds

S_{as} = 1.5 g at 0.5% damping per Figure 2

h_s = 0.837 R S_{as} = 0.837*240*1.5 = 301.32 inches

[Step 22] Check Sloshing Height

$h_s > h_f$ (= 34.15 inches)

Therefore, the tank is an outlier per the GIP [17].

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9.0 Evaluation of Modified Tanks

9.1 Proposed Modification to the Cylindrical Tank

The seismic evaluation presented in Section 8.3 of this report indicates that the PPMSTs in SONGS-2&3 do not meet the GIP [17] seismic requirements. As shown in Steps 18, 20, and 22 of Section 8.3, the existing PPMST design does not provide enough resistance in bending buckling, shear failure, and water sloshing. As illustrated in Figure 5, it is proposed that (1) the existing PPMST be reinforced with thirty-six equally spaced vertical stringers of either the same material as the shell (SA-240, Type 304) or SA-36 carbon steel, (2) a circumferential ring (SA-240, Type 304 or SA-36) be added to cap the tops of the vertical stringers, (3) thirty-four additional anchor bolts (A-307 or equivalent) of $1\frac{7}{8}$ inches or greater in diameter be added, and (4) the existing anchor chairs be removed and replaced with a ring-type chair around the circumference of the tank. It is recommended that the same material, SA-36, be used for the top plate and stiffener plates of the ring-type anchor chair, and the top plate thickness be increased from the existing 0.875 inches to at least 1.125 inches. It is also recommended that the thickness of the stiffener plates of the chair be increased from the existing 1/2 inch to 3/4 inches. The stringers should be 1.375 inches thick, 5 inches wide, and 58 inches high. To accommodate for the size of concrete drilling tools, it is recommended that the additional new bolts be placed at 3.6875 inches radially from the tank shell outer surface, which is 1 inch farther out radially than the existing bolts. The design for the welds between the tank shell and the chair top-plate, the chair top-plate and the vertical stiffener plates, and the stiffener plate to tank bottom should be the same as the existing welds. The details of other components and associated welding are shown in Figure 5. In addition, it is also recommended per Section 10.4 that a pad plate of the dimensions shown in Table 10-1 be

added to the man-hole penetration to meet the ASME Code ND-3332.2 requirements (see Section 10.4 of this report for details).

9.2 Seismic Evaluation of the Reinforced Tank

Except for Steps 14 and 15, which are not directly applicable to tanks with reinforcement stringers, the evaluation procedures provided by the GIP [17] will be used to evaluate the reinforced tanks. The reinforcement stringers were smeared into an equivalent shell thickness and the evaluation of Steps 14 and 15 of the GIP was performed on the smeared tank shell.

[Step 1] Input Data

The cross-sectional area of the stringers (6.875 $inches^2$) has to be considered and smeared into an equivalent shell thickness. The effective increase in shell thickness is 0.1639 inches ($\frac{36*5*1.375}{2*\pi*240.4764} = 0.1639$) from a tension stress point of view or 0.1676 inches from a bending stress point of view

$$\left(\frac{\sum_{i=0}^{35} 5*1.375[242.5*Sin(5°+10°*i)]^2}{\pi*240^3} = 0.1676\right).$$

Conservatively, smaller smeared thickness of 0.1194, corresponding to stringer size of 5"x1", is used in the analysis.

From the Design Input specified in Section 4.0 of this report,

R = 240 inches

H' = 408 inches

t_{min} = 0.1875 inches

t_s = 0.3125 inches

t_{se} = Adjusted Tank Shell Thickness

= (0.3125+0.1639) = 0.4764 inches

σ_y = 29,000 psi

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h_c = 12.75 inches

$E_s = 28.03 \times 10^6$ psi

V_s = average shear wave velocity of soil (will not be used)

γ_f = 0.0361 Lbf/in^3

H = 384 inches

h_f = 34.15 inches (see Figure 1)

N = 70

d = 1.5 inches (existing bolts)

d = 1.875 inches (new bolts)

h_b = 40.75 inches

$E_b = 29.28 \times 10^6$ psi (also assumed for new anchor bolts)

[Step 2] Parameters

H/R = 384/240 = 1.6

t_{se}/R = 0.4764/240 = 0.0020

$$t_{av}=\frac{0.3125*95.625+0.25*71.625+0.1875*240.75+0.1194*72}{408}=0.2488\ inch$$

$$t_{ef} = \frac{t_{av}+t_{min}}{2} = \frac{0.2488+0.1875}{2} = 0.2182 \text{ inches}$$

t_{ef}/R = 0.2182/240 = 0.00091

$$A_b' = \frac{\pi d^2}{4} = \frac{\pi*1.5^2}{4} = 1.7671 \text{ inch}^2$$

$$A_b'' = \frac{\pi*1.875^2}{4} = 2.7612\ in^2\ (new\ bolts)$$

$$A_b = \frac{36A_b' + 34A_b''}{70} = 2.250\ in^2$$

$$t' = \frac{NA_bE_b}{2\pi RE_s} = \frac{70*2.250*29.28}{2\pi*240*28.03} = 0.109 \text{ inches}$$

$$c' = \frac{t'h_c}{t_s h_b} = \frac{0.109*12.75}{0.3125*40.75} = 0.1091$$

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$W = \pi R^2 H \gamma_\ell = \pi * 240^2 * 384 * 0.0361 = 2,508,481$ Lbf

The applicable ranges of parameters specified in Table 7-1 of the GIP [17] are satisfied, except for the t_{ef}/R ratio, which falls below the 0.001 to 0.01 applicable range. However, it is conservative to use the curves for $t_{ef}/R=0.001$ for the present evaluation.

[Step 3] Tank Frequency

From Table 7-3 of the GIP [17], for R=240" and H/R = 1.6,

$F_f = 7.58$ Hz

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

Period = $1/F_f$ = 0.136 seconds

The additional stringers will likely increase the tank stiffness and thus its natural frequency. But, using the lower frequency of the existing tank will result in a higher spectrum acceleration and, thus, a higher and more conservative overturning moment and shear load.

[Step 4] Spectra Acceleration

From the SONGS 2 & 3 seismic loading spectra (see Figures 2 and 3), it is found that, at 4% damping,

$S_{af} = 1.15$ g (DBE)

$S_{af} = 0.75$ g (OBE)

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[Step 5] Base Shear Load

From Figure 7-3 of the GIP [17],

Q'=0.71

$Q = Q' W S_{af} = 0.71*2,508,481*1.15 = 2,048,175$ Lbf

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[Step 6] Overturning Moment and Shear at Different Levels

From Attachment A of this report:

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$$M = W\,H\,S_{af}\sqrt{0.119-0.482\frac{Y}{H}+0.498\left(\frac{Y}{H}\right)^2}$$

$$Q = W\,S_{af}\,\left(0.7048 - 0.87\frac{Y}{H}\right)$$

where y is the vertical distance from the bottom of the tank as illustrated in Figure 1.

Thus, the bending moments and shear at levels A, A′, B, and C (Figure 1) are as follows:

Level	y (in)	y/H	M (in-Lbf)	Q (Lbf)
A	0.000	0.000	382,172,097*	2,048,175*
A′#	72.000	0.1875	237,927,613	1,562,599
B	95.625	0.249	191,414,070	1,408,191
C	167.250	0.436	65,682,921	938,929

* Set to previous value for consistency. Percentage of the difference is negligible (<0.01%)

\# A′ is at the end of the vertical stringers.

[Step 7] Bolt Tensile Capacity

L = 27.5 inches (same as the Section 8.3 value)

D = 1.5 inches (existing bolts)

D = 1.875 inches (new bolts)

From Table C.3-1 of the GIP [17],

P''_{nom} = 50.4*(1.875/1.375)^2 = 93.72 kips (new bolts)

P'_{nom} = 50.4*(1.5/1.375)^2 = 59.98 kips (existing bolts)

$$P_{nom} = \frac{36\,P'_{nom} + 34\,P''_{nom}}{70} = 76.368\ kips$$

V''_{nom} = 25.25*(1.875/1.375)^2 = 46.95 kips (new bolts)

V'_{nom} = 25.25*(1.5/1.375)^2 = 30.05 kips (existing bolts)

V_{nom} = Average Nominal Shear Strength of the Bolts

$$= \frac{36\,V'_{nom} + 34\,V''_{nom}}{70} = 38.259\ kips$$

S_{min} = 17.375*[(1.875+1.5)/2]/1.375 = 21 inches

L_{min} = 13.75*[(1.875+1.5)/2]/1.375 = 17 inches

E_{min} = 12.125*[(1.875+1.5)/2]/1.375 = 15 inches

$S = \frac{2\pi R_{BC}}{N} = \frac{2\pi * 243.5}{72}$ = 21.2 inches > S_{min} (72 is used for the spacing of most bolts. The total number of bolts is only 70.)

E = 22'6"-20'4"= 26" inches > E_{min} [12]

$L > L_{min}$

f'_c = 4,000 psi > 3,500 psi

$P_{all} = P_{nom}$ = 76.368 kips

$V_{all} = V_{nom}$ = 38.259 kips

$P_u = P_{all}$ = 76,368 Lbf

$F_b = P_u/A_b$ = 76,368/2.25 = 33,941 psi

For new expansion anchor bolts, capabilities must equal the values shown above.

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[Step 8] Top Plate (see Figures 4 and 5)

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

$$= \frac{(0.375*2.5 - 0.22*1.5)*76,368}{0.9375*1.125^2}$$

$$= 39,100\ psi$$

$\sigma > f_y$ = 35,680 psi (SA-36 material at 110°F)

$F_r = F_b\ (\frac{f_y}{\sigma})$ = 33,491*(35,680/39,100) = 30,562 *psi*

[Step 9] Tank Shell Stress

For the ring-type chair, the equivalent dimension for "a" is 20.94 inches($\frac{2*\pi*240}{72}$).

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t_b = 0.25 inches [3]

$$z=\frac{1}{\frac{0.177at_b}{\sqrt{Rt_s}}(\frac{t_b}{t_s})^2+1}$$

$$=\frac{1}{\frac{0.177*20.94*0.25}{\sqrt{240*0.3125}}(\frac{0.25}{0.3125})^2+1}$$

$$=0.936$$

$$\sigma=\frac{P_u e}{t_s^2}[\frac{1.32z}{\frac{1.43ah^2}{Rt_s}+(4ah^2)^{1/3}}+\frac{0.031}{\sqrt{Rt_s}}]$$

$$=\frac{76368*2.6875}{0.3125^2}[\frac{1.32*0.936}{\frac{1.43*20.94*12.75^2}{240*0.3125}+(4*20.94*12.75^2)^{1/3}}+\frac{0.031}{\sqrt{240*0.3125}}]$$

= 36,770 *psi* (*at existing bolts*)

$$\sigma=\frac{P_u e}{t_s^2}[\frac{1.32z}{\frac{1.43ah^2}{Rt_s}+(4ah^2)^{1/3}}+\frac{0.031}{\sqrt{Rt_s}}]$$

$$=\frac{76368*3.6875}{0.3125^2}[\frac{1.32*0.936}{\frac{1.43*20.94*12.75^2}{240*0.3125}+(4*20.94*12.75^2)^{1/3}}+\frac{0.031}{\sqrt{240*0.3125}}]$$

= 50,452 *psi* (*at new bolts*)

Both σ are calculated conservatively based on the original shell thickness in lieu of the smeared shell thickness.

$\sigma > f_y$=29,000 psi

$F_r = F_b (f_y/\sigma)$ = 33,941*(29,000/50,646) = 19,509 psi

[Step 10] Vertical Stiffener Plate (see Figure 4)

$$\frac{k}{j}=\frac{(5.5+1.25)/2}{0.75}=4.5$$

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$$\frac{95}{\sqrt{f_y/1000}} = \frac{95}{\sqrt{\frac{35,680}{1,000}}} = 15.90$$

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

0.04(h-c) = 0.04*(12.75-1.125) = 0.465 inches

j > 0.04(h-c)

$$\frac{P_u}{2kj} = \frac{76,368}{2*3.375*0.75} = 15,085 \text{ psi} < 21,000 \text{ psi}$$

Thus, the vertical stiffener plate design is adequate.

[Step 11] Chair-to-Tank Weld

$$W_w = P_u\sqrt{(\frac{1}{a+2h})^2+(\frac{e}{ah+0.667h^2})^2}$$

$$=76,368*\sqrt{(\frac{1}{20.94+2*12.75})^2+(\frac{2.6875}{20.94*12.75+0.667*12.75^2})^2}$$

$$= 1,733 \; Lbf/in \quad (at\ existing\ bolts)$$

$$W_w = P_u\sqrt{(\frac{1}{a+2h})^2+(\frac{e}{ah+0.667h^2})^2}$$

$$=76,368*\sqrt{(\frac{1}{20.94+2*12.75})^2+(\frac{3.6875}{20.94*12.75+0.667*12.75^2})^2}$$

$$= 1,807 \; Lbf/in \quad (at\ new\ bolts)$$

$$30,600\frac{t_w}{\sqrt{2}} = 30,600*\frac{0.25}{\sqrt{2}} = 5,409 \; Lbf/in > W_w$$

Thus, the chair-to-tank weld design is adequate.

[Step 12] Elephant Foot Buckling Pressure

From Figure 7-7 of the GIP [17], at S_{af} = 1.15g and H/R = 1.6, P'_e = 2.8 (calculated per Eq. (2-20) of [25])

$P_e = P'_e \gamma_f R = 2.8*0.0361*240 = 24.26$ psi

Similarly, the elephant foot buckling pressure for higher elevations of the tank can be calculated by subtracting the hydrostatic head from the above pressure:

Level	y (in)	y/H	P_e (psi)
A	0.000	0.000	24.26
A'	72.000	0.1875	21.66
B	95.625	0.249	20.81
C	167.250	0.436	18.22

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[Step 13] Elephant Foot Buckling Stress

$$S_1 = \frac{R}{400 t_{se}} = \frac{240}{400*0.4764} = 1.26$$

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

$$= \frac{0.6*28.03*10^6}{240/0.4764}\left[1-\left(\frac{24.26*240}{29000*0.4764}\right)^2\right]\left[1-\frac{1}{1.12+1.26^{1.5}}\right]\left[\frac{1.26+\frac{29}{36}}{1.26+1}\right]$$

$= 15,191$ *psi*

The adjusted shell thickness of 0.4764 inches is used in the above calculations. Similarly, the elephant-foot buckling stresses at higher elevations are as follows:

Level	y (in)	t_s (in)	S_1	σ_{pe} (psi)
A	0.000	0.4764	1.26	15,191(a)
A'	72.000	0.3125	1.92	9,944(b)
B	95.625	0.2500	2.40	6,885(b)
C	167.250	0.1875	3.20	3,543(b)

(a) smeared thickness was used
(b) actual shell thickness were used

[Step 14] Diamond-Shape Buckling Pressure

From Figure 7-9 of the GIP [17], corresponding to H/R=1.6 and S_{ef}=1.15,

$P'_d = 2.063$

$P_d = P'_d \gamma_f R = 2.063 * 0.0361 * 240 = 17.87$ psi

Similarly, the diamond-shape buckling pressure at higher elevations are as follows:

Level	y (in)	y/H	P_d (psi)
A	0.000	0.000	17.87
A'	72.000	0.1875	15.27
B	95.625	0.249	14.42
C	167.250	0.436	11.83

[Step 15] Diamond-Shape Buckling Stress

The GIP procedure along with the equivalent thick t_{se} was used for the evaluation of fluid level A, while Code Case N-284 was used for evaluating higher elevations.

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

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

From Figure 7-11 of the GIP [17],

$\Delta\gamma = 0.12$

$$\sigma_{pd} = (0.6\gamma + \Delta\gamma)\ \frac{E_s}{R/t_{se}} = 21{,}680 \text{ psi (Level A)}$$

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This number is less than the 35,110 psi solution obtained according to Code Case N-284 (See Attachment B). From Attachment B, σ_{pd} is 13,548 psi at Level B and 12,328 at Level C.

[Step 16] Allowable Buckling Stress

σ_c = 0.72 [Min (σ_{pe} , σ_{pd})] = 0.72*15,191 = 10,938 psi

Similarly, the allowable buckling stresses at higher elevations are as follows:

Level	y (in)	y/H	σ_c (psi)
A	0.000	0.000	10,938
A'	72.000	0.1875	7,160
B	95.625	0.249	4,957
C	167.250	0.436	2,551

[Step 17] Buckling Bending Moment Capacity

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The weak link is in ductile failure.

$$\left(\frac{\sigma_c}{F_r}\right)\left(\frac{h_c}{h_b}\right) = \left(\frac{10,938}{19,509}\right)\left(\frac{12.75}{40.75}\right) = 0.175$$

From Figure 7-12 of the GIP [17],

M'_{CAP} = 0.13

Therefore,

M_{CAP} = M'_{CAP} $(2F_r)(R^2t_{se})(h_b/h_c)$

= 0.13*2*19,509*240^2*0.4764*(40.75/12.75)

= 444,856,583 in-Lbf

capacities at higher elevations are simply $M_{CAP} = \sigma_c * \pi * R^2 * t$ and are tabulated as follows

Level	Y (in)	Y/H	M_{CAP} (in-Lbf)
A	0.000	0.000	444,856,583
A'	72.000	0.1875	404,888,461
B	95.625	0.249	224,249,397
C	167.250	0.436	86,553,391

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[Step 18] Check Buckling Moment

$$\frac{M_{cap}}{M} > 1.17$$

where M is the overturing moment calculated in [Step 6] of this section. Therefore, the modified tank will not buckle in either elephant-foot mode or diamond-shape mode.

[Step 19] Shear Load Capacity

It is assumed that the anchor bolts also transfer shear:

$$Q_{CAP} = 0.55*(1-0.21*S_{af})*W + 70*V_{all}/2$$
$$= 0.55*(1-0.21*1.15)*2,508,481 + 35*38,259$$
$$= 2,385,541 \text{ lbf}$$

The number 35 (=70/2) is used in the above equation because the shear is distributed sinusoidally around the circumference of the tank and the total shear capacity of the bolts is the total number of bolts times bolt capacity V_{all} divided by two. V_{all} is calculated in [Step 7] of this section.

[Step 20] Check Shear Load

$$\frac{Q_{cap}}{Q} > 1.16$$

where Q is the shear force calculated in [Step 6] of this section. Therefore, the modified tank will not fail due to shear. Since part of the shear load is now taken by the bolts, it is necessary to check the shear-tension interaction limits per Figure C.3-2 of the GIP [17]. Both the tensile and shear loads distribute sinusoidally around the circumference of the tank. It is required by the GIP [17] that

$$\left(\frac{P}{P_{all}}\right) \le 1.0 \qquad ,if\ \frac{V}{V_{all}} \le 0.3$$

$$\left(\frac{P}{P_{all}}\right) + 1.43\left(\frac{V}{V_{all}}\right) \le 1.43 \qquad ,if\ 1 > \frac{V}{V_{all}} > 0.3$$

where $P = P_{max} Sin\theta$, $V = V_{max} Cos\theta$ and θ is the azimuth angle around the circumference of the tank. For the SONGS-2&3 PPMSTs,

$$P_{max} = \frac{2M}{NR} = \frac{2*382,172,097}{70*240} = 45,497\ LBf$$

$$V_{max} = \frac{Q-0.55*(1-0.21S_{af})W}{35} = 28,620\ Lbf$$

where the overturning moment M and the shear force Q are calculated in [Step 6] of this section. Therefore, as illustrated in Figure 14, the bolts satisfy the GIP shear-tension interaction limits (see C.3.7 of the GIP).

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[Step 21] Slosh Height

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

$$= \frac{1}{2\pi}\sqrt{\frac{1.84*386.4}{240}\tanh\left(\frac{1.84*384}{240}\right)}$$

$$= 0.2732\ Hz$$

Sloshing Period = 1/0.2732 = 3.66 seconds

S_{as} = 1.5 g at 0.5% damping per Figure 2

h_s = 0.837 R S_{as} = 0.837*240*1.5 = 301.32 inches

[Step 22] Check Sloshing Height

$h_s > h_f$

Therefore, during a DBE event, some of the water in the modified tank might slosh up and exert an additional uplift pressure on the roof. However, as shown in Section 10.0 of this report, the roof design as well as the tank-to-roof welds both meet ASME requirements to withstand the additional internal pressure. The shallower than required free board is likely to restrain the sloshing water from its first mode sloshing and reduce the overall overturning moment. The total uplift force due to the sloshing water is 560,144 Lbf, or 8,002 Lbf per bolt, according to the calculation described Section 10.3. As shown in Figure 14, bolts with the additional 8,002 Lbf tensile load will still satisfy the GIP shear-tension interaction limits calculated in Step 20.

10.0 Qualification to ASME Code Design Rules

In addition to the seismic requirements discussed in Section 9.0, the PPMSTs must also meet all ASME Code requirements.

10.1 Tank Shell Design

Per ND-3324.3(c), which is referred to by ND-3842, the minimum tank shell thickness should be determined by:

$$t_{min} = \frac{PR}{SE - 0.6P}$$

where P is the Design Pressure, R (240 inches) is the inside radius of the tank, S (18,000 psi) is the maximum allowable stress of the tank material at the Design Temperature per Code Table I-7.2, and E (0.85) is the joint efficiency. The joint efficiency is at 0.85 because the original API standards, API-620 and API-650, required only spot examination of the tank welds. Thus, according to ND-3352 of the ASME Code, the joint efficiency should be 0.85. Since P=0.0361*h psi, where h is the distance in inches from fluid surface as illustrated in Figure 1 minus 12" [ND-3841(a)], the minimum tank wall thickness at different levels of the tank can be calculated by:

$$t_{min} = \frac{0.0361 * h * 240}{18{,}000 * 0.85 - 0.6 * 0.0361 * h}$$

Thus, at levels A, B, and C (see Figure 1), the following minimum thicknesses are required:

Level	h (inch)	t_{min}(inch)	$t_{nominal}$(inch)
C	216.75	0.123	0.1875
B	288.375	0.1633	0.25
A	384.0	0.218	0.3125

Therefore, existing tank shell thicknesses of the PPMST at SONGS, Units 2 & 3 satisfy the ASME Code minimum wall thickness requirements.

10.2 Bottom Design

The existing bottom plate thickness of 0.25 inches satisfies the ND-3831 requirement. Since the PPMSTs were built to the standards of API-650, the existing foundation satisfies all the code requirements in ND-3831. The existing tank bottom design also satisfies the requirements on method of construction (ND-3832) but does <u>not</u> satisfy the shell-to-bottom attachment (ND-3833) requirements, as a full penetration weld is required.

10.3 Roof Design

Per ASME Section III, ND-3856.2, (i) the radius of curvature of the roof must be within the Code specified range, (ii) the roof plate thickness must be within the range specified by the Code, and (iii) the cross-sectional area of the top angle, in square inches must be greater than the Code minimum value calculated by the Code.

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R = Radius of Curvature of Roof = 48 feet

t = Plate Thickness = 0.25 inches

D = Tank Diameter = 40 Ft

$1.2D \geq R > 0.8D$

$0.5 \text{ inches} > t > (R/200) = (48/200) = 0.24$

$$A_{min} = \frac{DR}{1500} = \frac{40*48}{1500} = 1.28\ inch^2$$

A = cross-sectional area of the top angle
= $2.5^2 - (2.5-5/16)^2 = 1.46$ inches^2 [2]

Therefore, all the requirements specified in ND-3856, "Self-

Supported Dome and Umbrella Roofs", are satisfied.

In addition, the roof has to withstand the additional internal pressure caused by the water sloshing (see [step 22] of Section 9.2). The vertical force exerted by the sloshing water would be the sloshing mass (m_s in Attachment A) times the maximum vertical acceleration (0.77g for DBE per [14] and 0.5g for OBE per [16]). The horizontal force due to the sloshing water would be water density times the volume under the roof and above the vertical shell times the maximum horizontal acceleration (1.15g for DBE and 0.75g for OBE).

FV_{DBE} = 0.29*2,508,481*0.77 = 560,144 Lbf
FV_{OBE} = 0.29*2,508,481*0.50 = 363,730 Lbf
From Figure 1, the volume between the roof and the vertical shell can be calculated as

$$Volume = \int_{0}^{24.6243°} \pi R_f^3 Sin^3\phi d\phi$$

$$= \pi * 576^3 * (-0.75Cos\phi + \frac{0.25}{3}Cos3\phi)\Big|_0^{24.6243°}$$

$$= 4,814,637 \ inches^3$$

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FH_{DBE} = 0.0361*4,814,637*1.15 = 199,880 Lbf
FH_{OBE} = 0.0361*4,814,637*0.75 = 130,356 Lbf

The total force exerted on the roof is simply the SRSS of the horizontal and the vertical forces. Thus,

F_{DBE} = 594,738 Lbf
F_{OBE} = 386,383 Lbf

Stresses at the tank-to-roof weld is the above forces divided by $2\pi Rt_{throat}$ where t_{throat}=0.1326 inches [4]. That is,

$$\sigma_{weld}^{DBE} = \frac{594,738}{2*\pi*240*0.1326} = 2,974\ psi$$

$$\sigma_{weld}^{OBE} = \frac{386,383}{2*\pi*240*0.1326} = 1,932\ psi$$

Both stresses are much smaller than the allowable values (35,680 psi for DBE and 19,624 for OBE) per ND-3821.5 of the ASME Code.

The equivalent pressure due to the sloshing water is the total force divided by πR^2 where R is tank radius (3.29 psi for DBE and 2.14 psi for OBE), and the additional membrane stress caused by the pressure is simply $\frac{F}{2\pi Rt}$, where t is roof thickness (=0.25 inches). Thus, the additional membrane stresses due to the sloshing water are 7,580 psi for DBE and 4,931 psi for OBE, which are much smaller than the code allowable values of 35,680 psi for DBE and 19,624 psi for OBE per ND-3821.5.

Therefore, the existing roof design including the tank-to-roof junction weld is strong enough to withstand the additional pressure caused by the sloshing water.

10.4 Reinforcement of Shell Nozzles

As shown in Figure 6, the reinforcement requirements for the nozzles, including the manhole, per ASME Code ND-3332.2 are

d = Nozzle Inside Diameter

t_r = Minimum Tank Wall Thickness per Section 10.1

$$t_m = \frac{Pr_o}{SE+0.4P}$$

t_n = nominal nozzle wall thickness

$A_{req} = d\ t_r\ F$

F = 1.0

A = Area Available = $A_1 + A_2$

$A_1 = d(t-t_r)$

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$A_2 = d*t_n*(t_n-t_{rn})$

$A > A_{req}$

where all the quantities in the above calculation are according to those provided in ND-3335.1 of the ASME Code. The above reinforcement requirements for the PPMSTs were checked and is summarized in Table 10-1. As shown in Table 10-1, all nozzles except for the 24-inch manhole satisfy the ASME Code reinforcement requirements. It is recommended that, as illustrated in the last row of Table 10-1 and the figure below Table 10-1, a 1/4 inch thick annular pad plate be welded to the tank shell around the man hole. The recommended width of the annular pad plate is 6 inches or wider.

10.5 Code Stress Limits of Tank Shells

Per ND-3821.5, stresses in the PPMSTs under various loading conditions must satisfy different stress limits. Per Eq (2.13) of [25], the maximum equivalent pressure at different elevations can be calculated as follows:

Design Condition

Level	y (in)	P (psi)	σ_{hoop}* (psi)	σ_{allow}** (psi)
A	0.000	13.86	10,644	17,840
A'	72.000	11.26	8,648	17,840
B	95.625	10.41	9,994	17,840
C	167.250	7.82	10,010	17,840

* $\sigma_{hoop} = \frac{PR}{t}$, where R=240 inches is tank radius, and t is tank shell thickness given by [3].

** S=17,840 psi is the allowable general membrane stress for Design Condition loading at the design temperature of

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180°F per [19].

OBE

Level	y (in)	P_e (psi)	σ_{hoop}* (psi)	σ_{allow}** (psi)
A	0.000	20.84	16,005	19,624
A'	72.000	18.24	14,008	19,624
B	95.625	17.39	16,694	19,624
C	167.250	14.80	18,944	19,624

* $\sigma_{hoop} = \frac{P_e R}{t}$, where R and t are radius and thickness of the vessel, respectively.

** 1.1S=19,624 psi is the allowable membrane plus bending stress for Service Level B loading at the maximum operating temperature of 120°F.

DBE

Level	y (in)	P_e (psi)	σ_{hoop}* (psi)	σ_{allow}** (psi)
A	0.000	24.57	18,870	35,680
A'	72.000	21.97	16,873	35,680
B	95.625	21.12	20,361	35,680
C	167.250	18.53	23,718	35,680

* $\sigma_{hoop} = \frac{P_e R}{t}$, where R and t are radius and thickness of the vessel, respectively.

** 2S=35,680 psi is the allowable membrane plus bending stress for Service Level D loading at the maximum operating temperature of 120°F.

Therefore, the modified tank satisfies all the ASME Code stress limit requirements.

10.6 Strength of Bolts

The bolts have been shown to be adequate to withstand the DBE loading in Step 7 of the GIP [17] evaluation in Section 9.2. For OBE loading,

$$M_{OBE} = 0.345\ W\ H\ S_{af} = 0.345*2,508,481*384*0.75$$
$$= 249,242,672 \text{ in-Lbf}$$

$$V_{OBE} = 0.7048\ W\ S_{af} = 0.7048*2,508,481*0.75 = 1,325,983 \text{ Lbf}$$

The above two equations are identical to those for the overturing moment M and shear force Q at fluid level y=0 in Attachment A of this report. Thus, the maximum bolt tensile stress $\sigma_{t,max}$ due to the overturning bending moment is

$$\sigma_{t,max} = \frac{F_{max}}{A_b} = \frac{2\ M_{OBE}}{NRA_b} = \frac{2*249,242,672}{70*240*2.25} = 13,187\ psi$$

In the above equation, the maximum bolt force F_{max} is calculated based on Eq. (16) in page 23-7 of [27]. The above bolt tensile stress is less than the allowable value of 20,000 psi specified by the AISC [26]. The shear force is assumed to be taken by the frction force between the tank bottom and the concrete as well as the bolts. The maximum shear stress in the bolts is

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$$\tau_{max} = \frac{V_{OBE} - 0.55(1-0.21S_{af})W}{N A_b/2}$$
$$= \frac{1,325,983-0.55*(1-0.21*0.75)*2,508,481}{70*2.25/2}$$
$$= 2,078\ psi$$

The second term in the numerator of the above equation is the friction force between the tank bottom and the concrete per the GIP [17] and the factor od 1/2 in the denominator is to account for the sinusoidal shear stress distribution. The bolt shear stress is less than the allowable value of 10,000 psi specified by the AISC [26].

To check the tension/shear interaction limits, the following linear curve is checked

$$\frac{\sigma_t}{\sigma_{all}} + \frac{\tau}{\tau_{all}} \leq 1$$

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Since $\sigma_t = \sigma_{t,max}\ Sin\theta$ and $\tau = \tau_{max}\ Cos\theta$, where θ is the azimuth angle around the circumference of the tank, the above linear shear-tension interaction limits are satisfied.

10.7 Code Stress Limits of Ring-Type Anchor Chair

As shown in Step 8 and Step 10 in Section 9.2, the maximum stress in the top plate and stiffener plates of the ring-type anchor chair are, respectively, 39,100 psi and 15,085 psi under the DBE loading, which are less than the allowable value of 42,816 psi (= 2.4S = 2.4 * 17,840 at 120°F per [19]) for the Service Level D loading. Similarly, under OBE, the pulling force at the anchor bolts due to the overturning moment is simply 29,671 Lbf ($\sigma_{t,max}A_b = \sigma_{t,max} * A_b = 13,187$ psi*2.25 inches^2). With the same equation used in Step 8 of Section

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9.2,

$$\sigma = \frac{(0.375g - 0.22d)P}{fc^2}$$

$$= \frac{(0.375*2.5 - 0.22*1.5)*29{,}671}{0.9375*1.05^2}$$

$$= 17{,}439\ psi$$

This stress is less than the allowable value of 29,436 psi (= 1.65S = 1.65*17,840 at the maximum operating temperature of 120°F) per ASME Code ND-3821.5.

Table 10-1 Reinforcement Requirement of Tank Nozzles

Table 10-1 Reinforcement Requirements of Tank Penetrations

Nozzle ID	d (inches)	tn (inches)	y (inches)	P (psi)	tr (inches)	trn (inches)	A1 in^2	A2 in^2	A in^2	Areq in^2	A>Areq
3-A	24.000	0.438	27.500	12.87	0.202	0.0106	2.66	0.93	3.59	4.85	No
3-C	3.826	0.337	9.000	13.54	0.212	0.0020	0.38	0.56	0.96	0.81	Yes
4-C	2.323	0.276	5.375	13.67	0.215	0.0013	0.23	0.36	0.61	0.50	Yes
4-E	1.939	0.218	6.000	13.65	0.214	0.0011	0.19	0.24	0.43	0.42	Yes
4-F	1.939	0.218	5.750	13.66	0.214	0.0011	0.19	0.24	0.43	0.42	Yes
4-G	3.826	0.337	5.875	13.65	0.214	0.0020	0.38	0.56	0.94	0.82	Yes
3-A *	24.000	0.438	27.500	12.87	0.202	0.0106	2.66	3.93	6.59	4.85	Yes

* See the recommended modification below.

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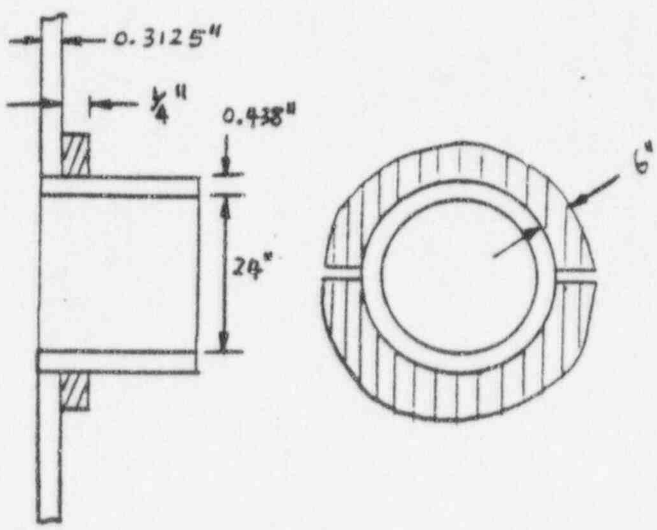

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11.0 Reconciliation with 1989 Edition ASME Code

11.1 Material

This section discusses ASME Code ND-2000 versus API-650, Section 2. These two codes are very similar in the material requirements except that the ASME ND-2000 calls for CMTR's. Since the PPMSTs were built with ASME materials (except for the anchor bolt chairs, which will be replaced with new anchor bolt chairs of an ASME material) and all the CMTR's are still recoverable, the ND-2000 requirements on materials can be considered satisfied.

11.2 Design

This section discusses the differences between ASME ND-3000 and API-650, Section 3. As discussed in Chapter 2 of this report, except for tank shell buckling and water sloshing height, the existing PPMS tank design meets all ND-3000 requirements. A tank design modification is described in Chapter 2 of this report, and it is shown in Chapter 4 that the modified PPMS tank meets the shell buckling requirement. It is also shown in Chapter 10 of this report that although water might slosh against the roof, the existing roof design is adequate to withstand the additional internal pressure caused by sloshing.

11.3 Fabrication and Installation

This section discusses the differences between ASME ND-4000 and API-650, Sections 4 and 5. The two Codes are quite compatible on fabrication and installation. One major difference is the roundness requirements specified in ND-4220. According to a roundness measurement recently performed by SCE, all PPMSTs at SONGS-2&3 are in full compliance with ~~NC~~ ND-4220.

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11.4 Examination

This section discusses the difference between the ASME Code, Subsection NB-5000 and API-650 Standard. API-650 requires that the tanks be inspected by spot radiography, which is consistent with ASME ND-5000 for welds with joint efficiency of 0.85, except for some differences as explained in Attachment D of Appendix A. Therefore, the PPMS tanks should be examined per ND-5000. This examination has been performed for T-056; results are documented in QC reports given in Appendix E.

11.5 Testing

The testing requirements specified in ASME, ND-6000 and API-650, Section 5.0 are very similar. Therefore, the requirements on testing the tanks can be viewed to be satisfied for the existing tank. However, after the recommended reinforcement of the tanks, the testing procedures provided by ASME ND-6000 must be followed before the tank is certified and used again.

11.6 Overpressure Protection

ASME Code ND-7000 discusses rules and requirements for overpressure protection, while the API-650 Code does not have any requirements in this area. Since the PPMST's are designed and operated at atmospheric pressure, no overpressure protection is required per ASME Code. The existing 1" vent (3-D in [3]) and 6" vent (4-H in [3] are adequate for maintaining the tanks at atmospheric pressure. Therefore, the PPMST's are in full compliance with ASME Code in this area.

11.7 Welding

According to Section 7.0 of the API-650 Code, all welding must be done according to ASME Code Section IX. Therefore, the PPMST's are in full compliance with the ASME Code requirements in this area. It is worth noting that, although the welding procedure and implementation satisfy the ASME Code requirements, the design of the welds may not, as pointed out in Section 10.2.

11.8 Stamping

Rules on stamping per ASME Code, ND-8000 and API-650, Section 8 are obviously not the same. It is recommended that SCE requalify its tanks as ASME Section III, Class 3 tanks by implementing the procedures specified in Appendix B of NBIC [21].

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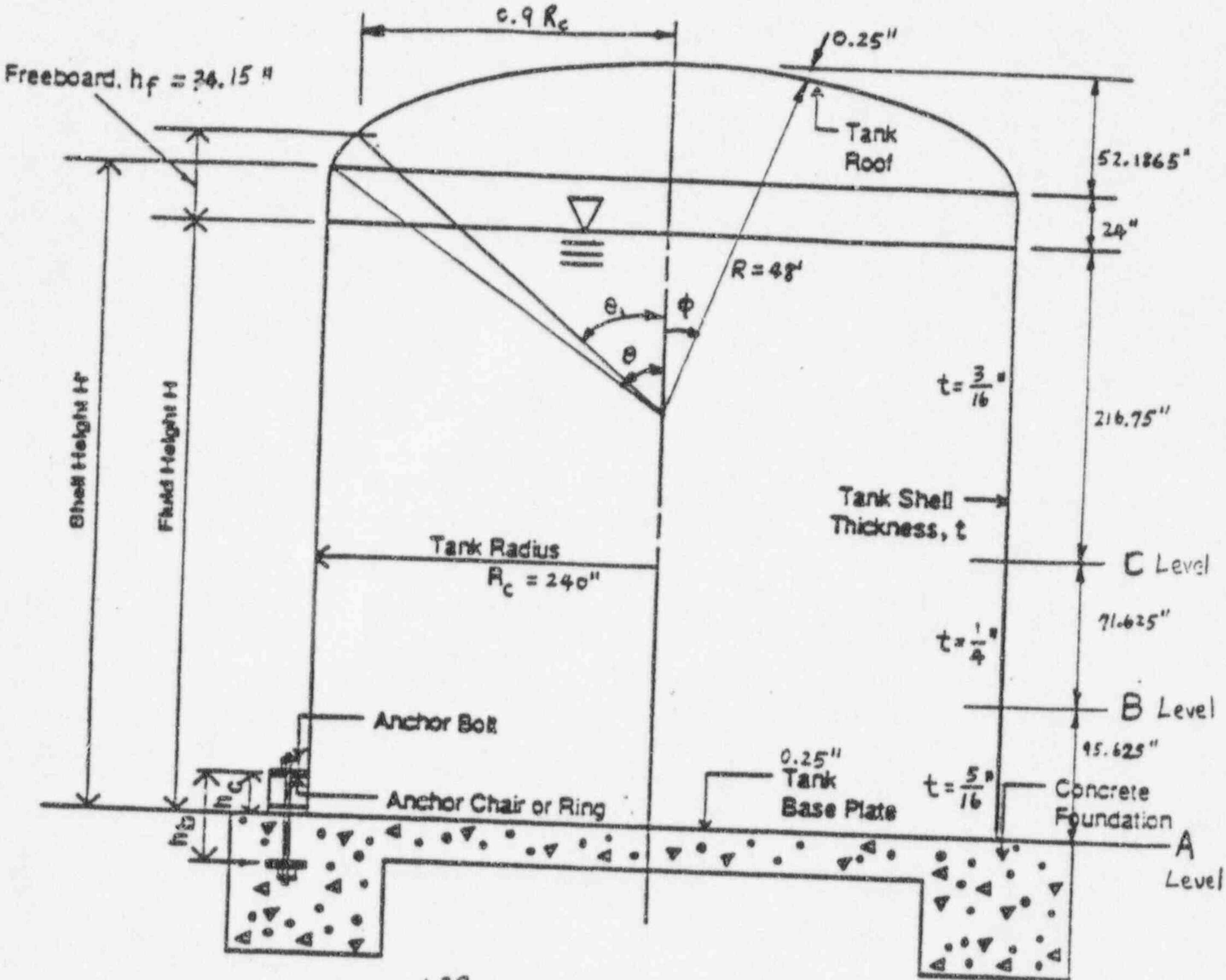
12.0 Figures



$$\theta = \sin^{-1}\frac{20}{48} = 24.6243^\circ \qquad 48 \times 12 \times (1 - \cos\theta) = 52.382"$$

$$\theta_1 = \sin^{-1}\frac{0.9 \times 20}{48} = 22.0243^\circ$$

$$h_f \approx 24" + 52.1865" - 48 \times 12 \times (1 - \cos\theta_1) = 34.15"$$

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Figure 1. Songs 2&3 Primary Make-up Tank

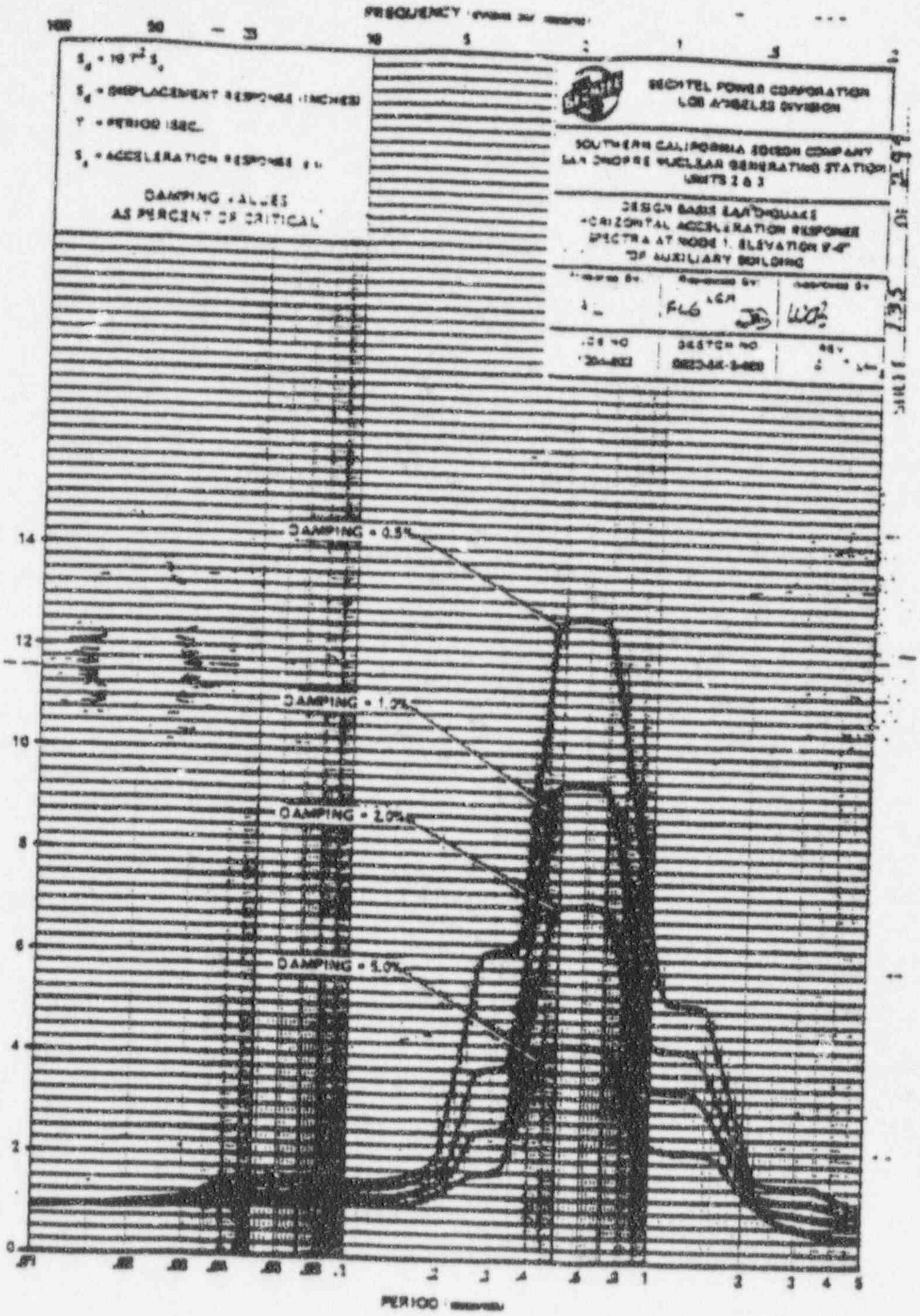

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Figure 2(a). Design Basis Earthquake Horizontal Acceleration Response Spectra at Node 1, Elevation 9'0" of Auxiliary Building [13]

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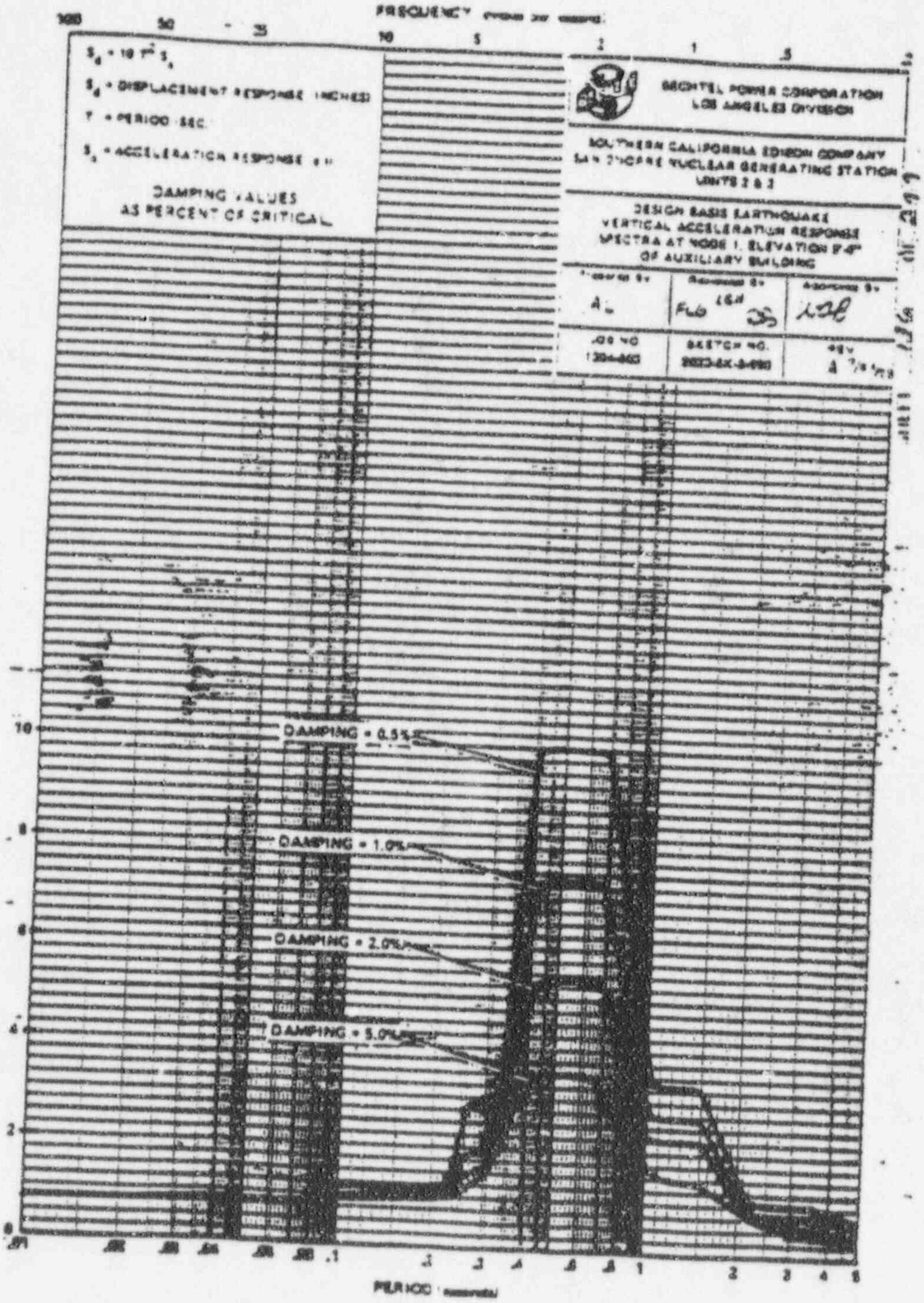

Figure 2(b). Design Basis Earthquake Vertical Acceleration Response Spectra at Node 1, Elevation 9'0" of Auxiliary Building [14]

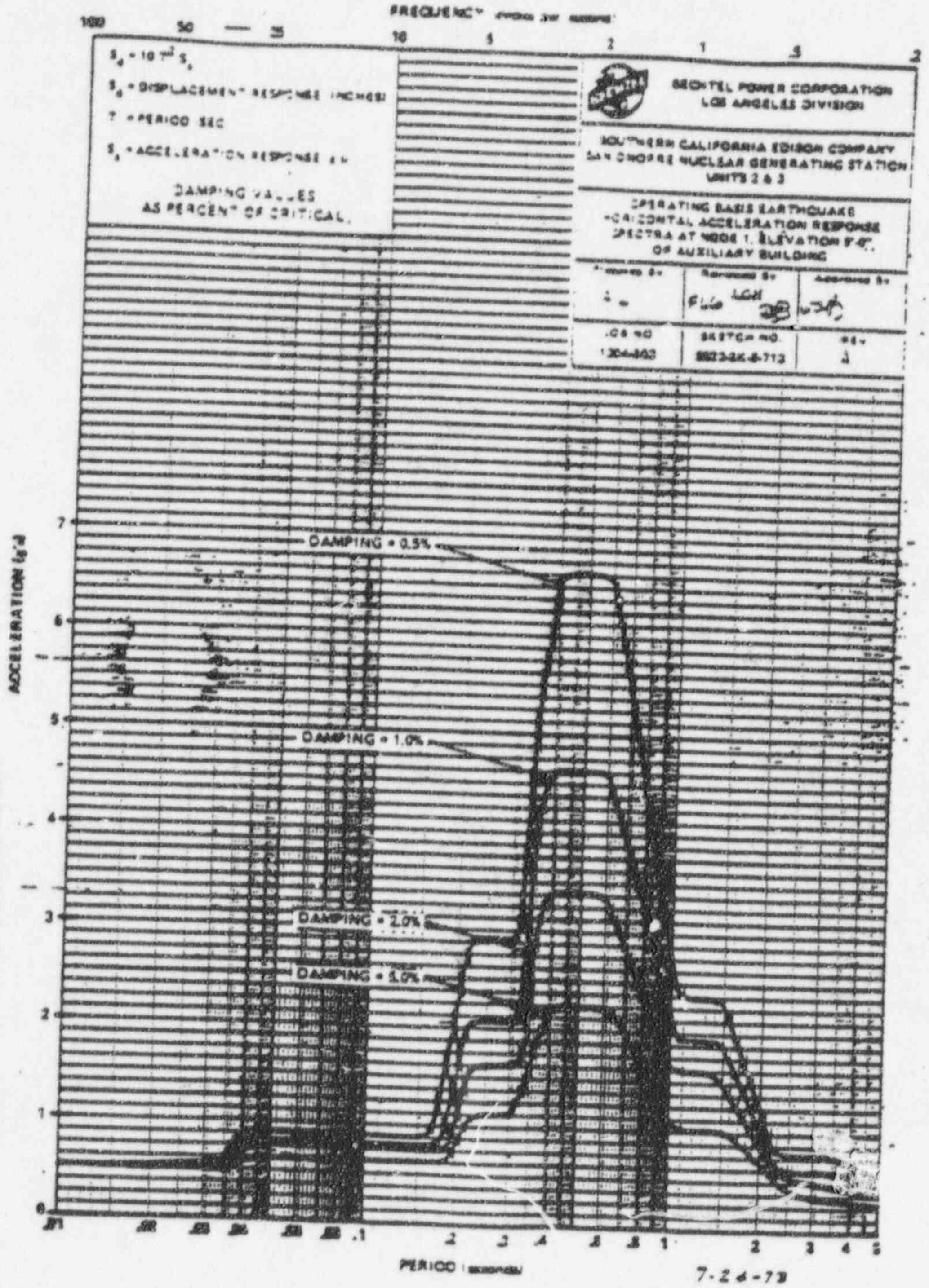

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Figure 3(a). Operating Basis Earthquake Horizontal Acceleration Response Spectra at Node 1, Elevation 9'0" of Auxiliary Building [15]

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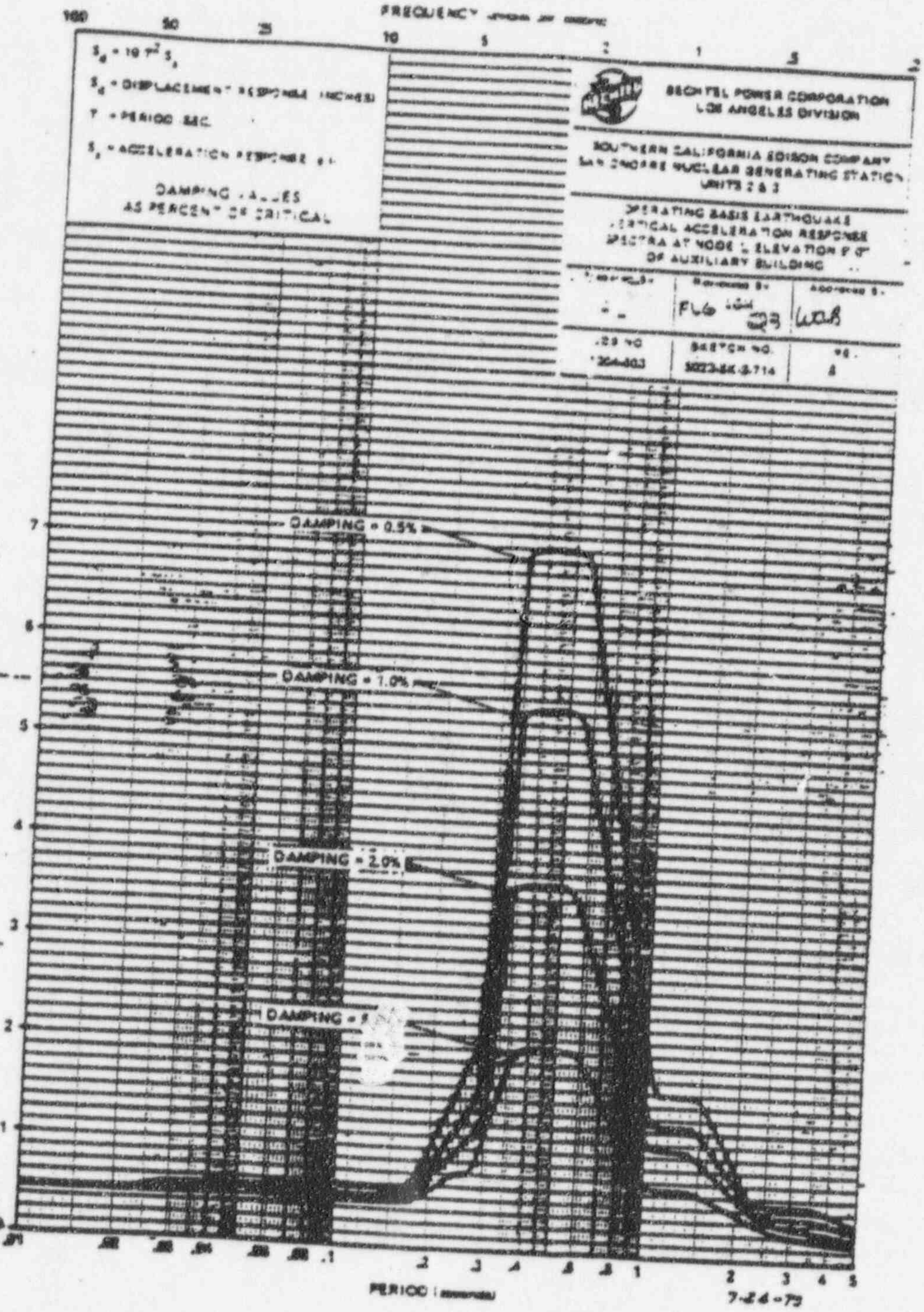

Figure 3(b). Operating Basis Earthquake Vertical Acceleration Response Spectra at Node 1, Elevation 9'0" of Auxiliary Building [16]

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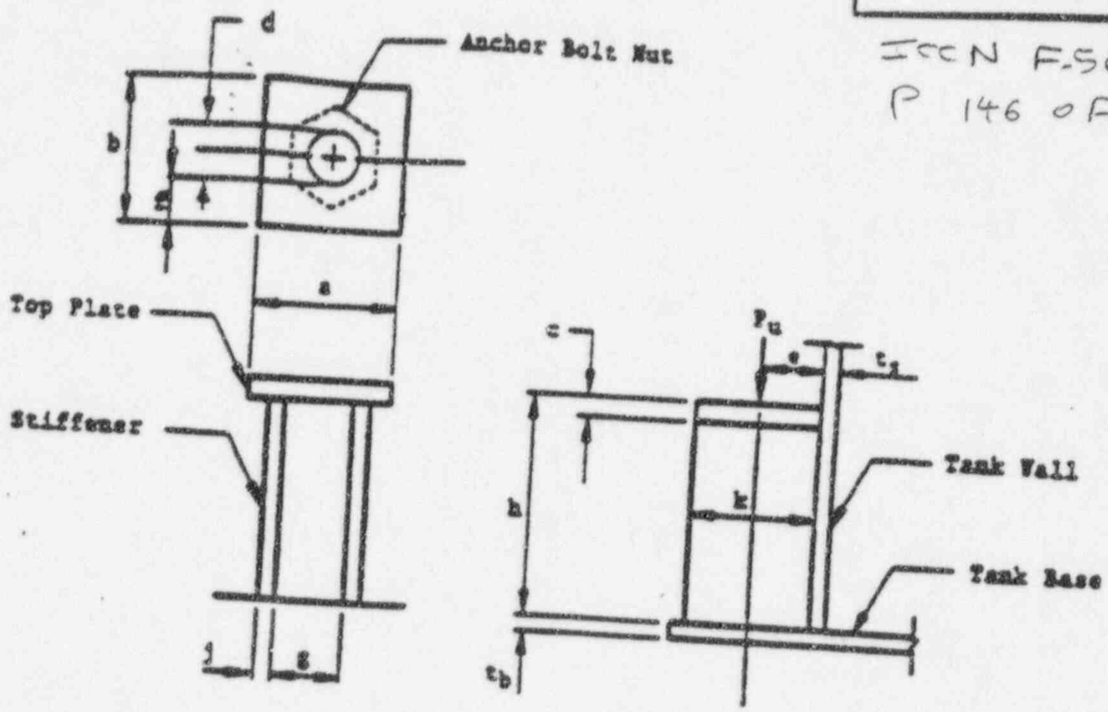

(a) Typical Plan and Outside Views

(b) Side View

Figure 4. Typical Anchor Bolt Chair

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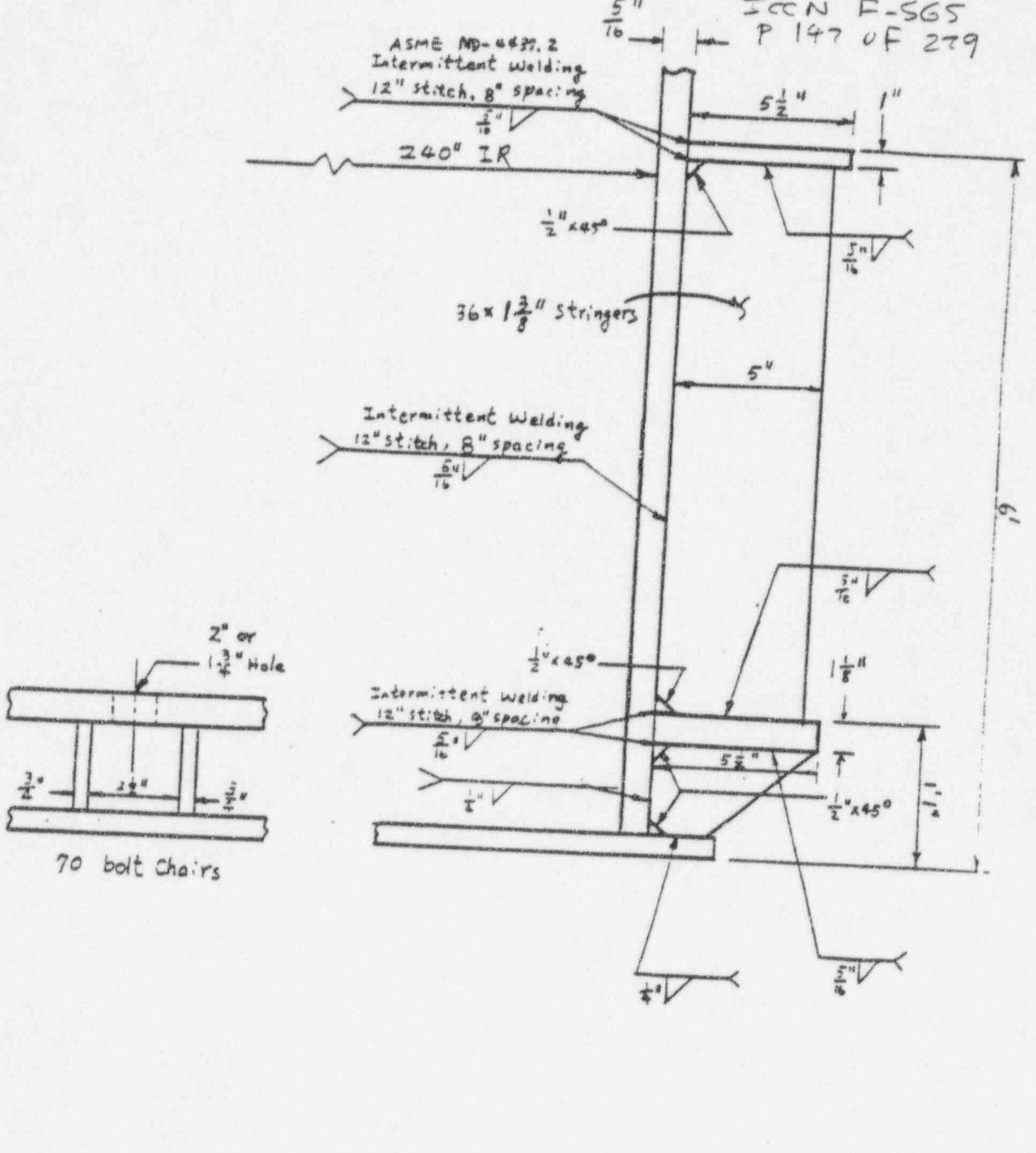

Figure 5. Reinforcement Design of PPMST

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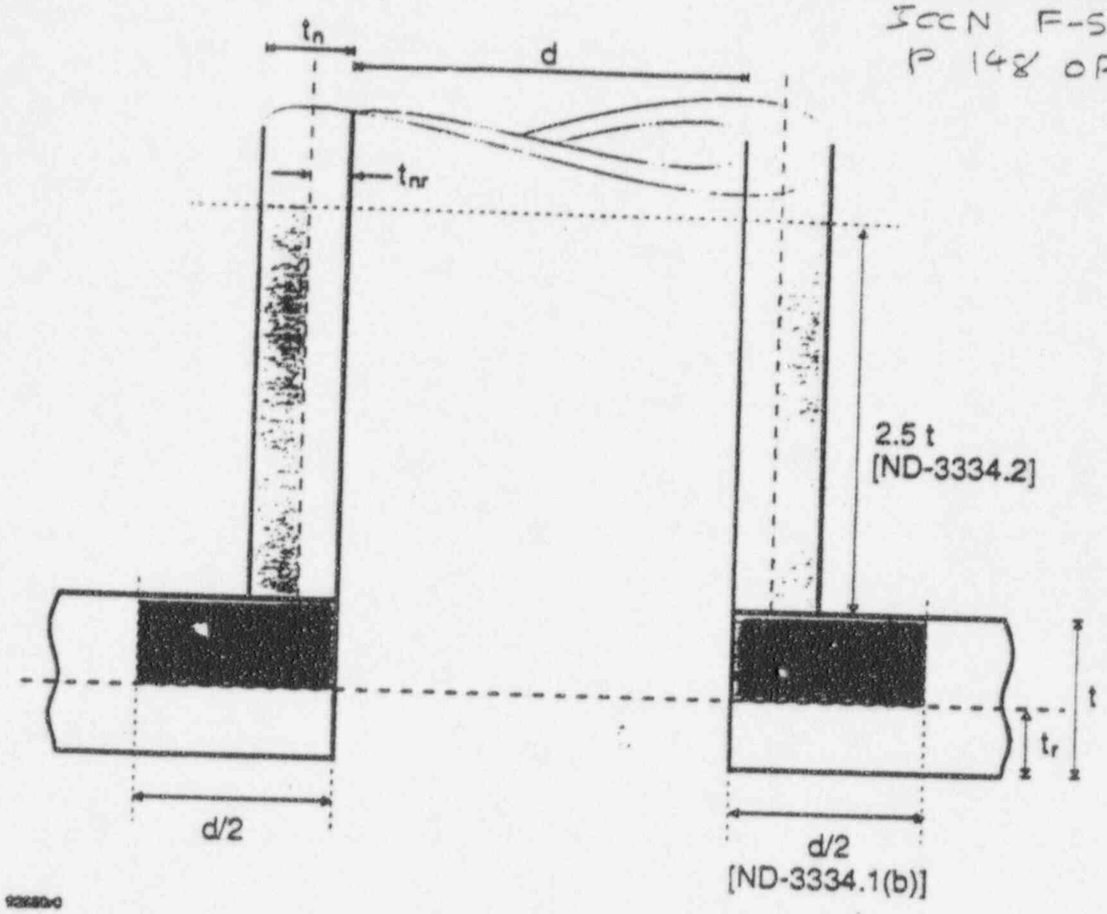

Figure 6. Reinforcement Requirement of Tank Opening

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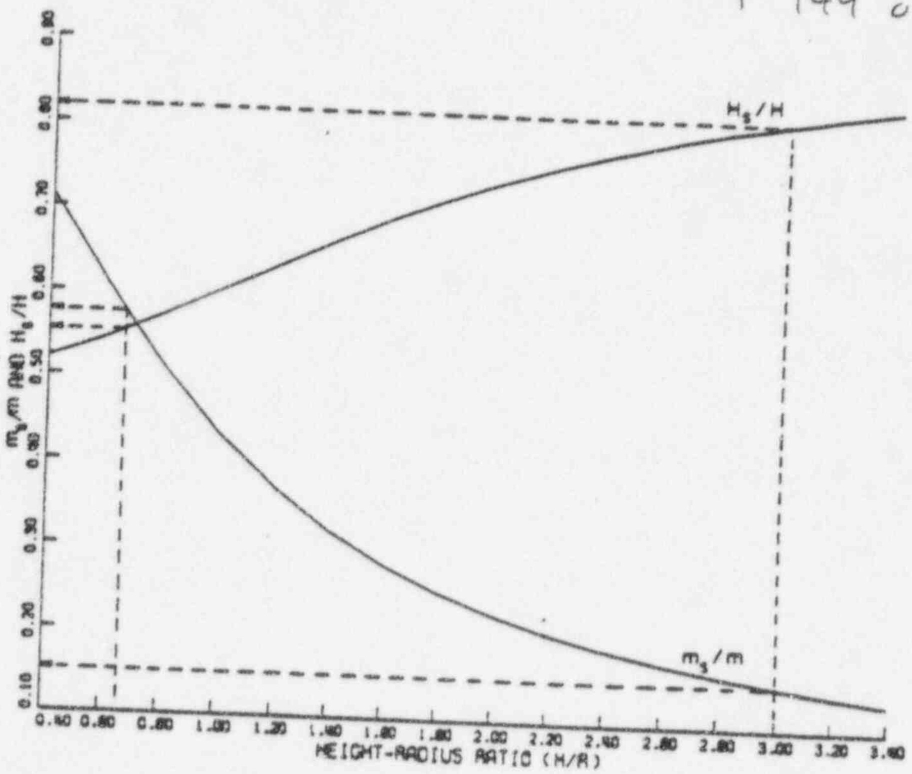

Figure 7. Convective Mass (m_s) and its Elevation (H_s) [20]

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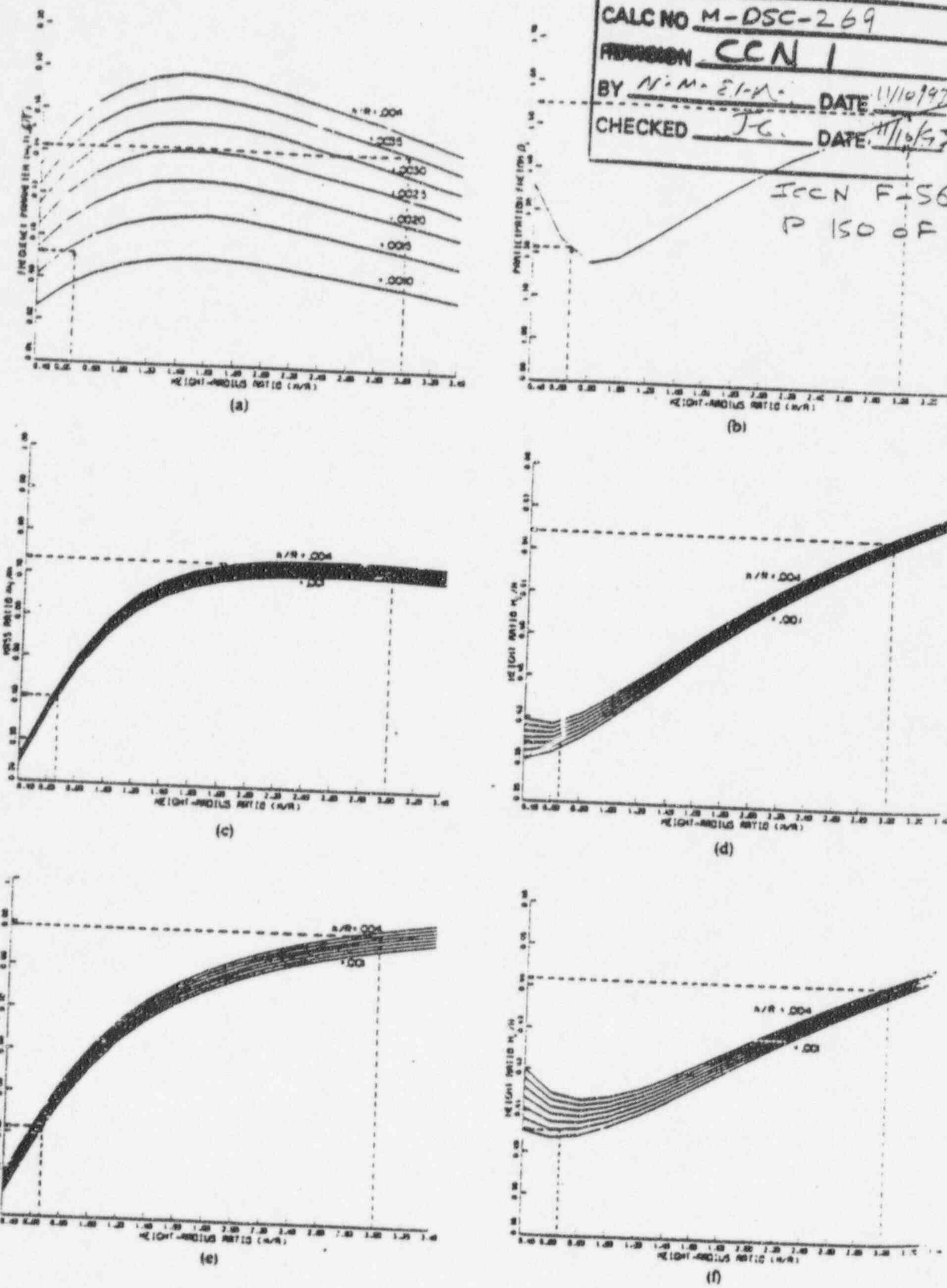

Figure 8. Parameters of the Mechanical Model [20]

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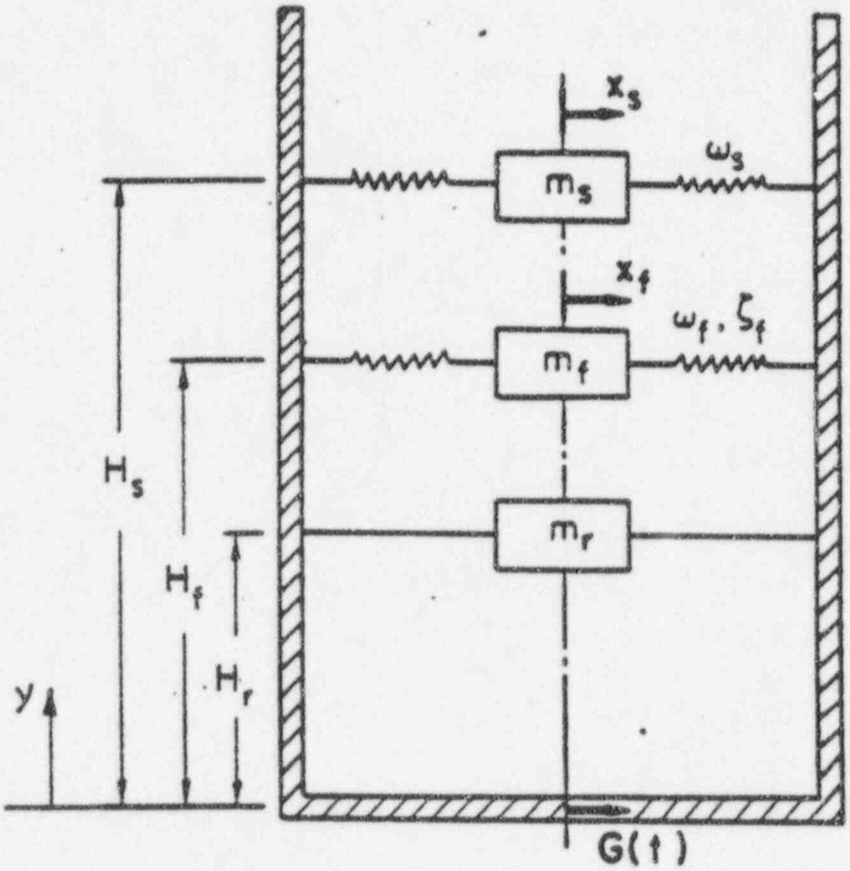

Figure 9. Mechanical Model of a Flexible Tank [20]

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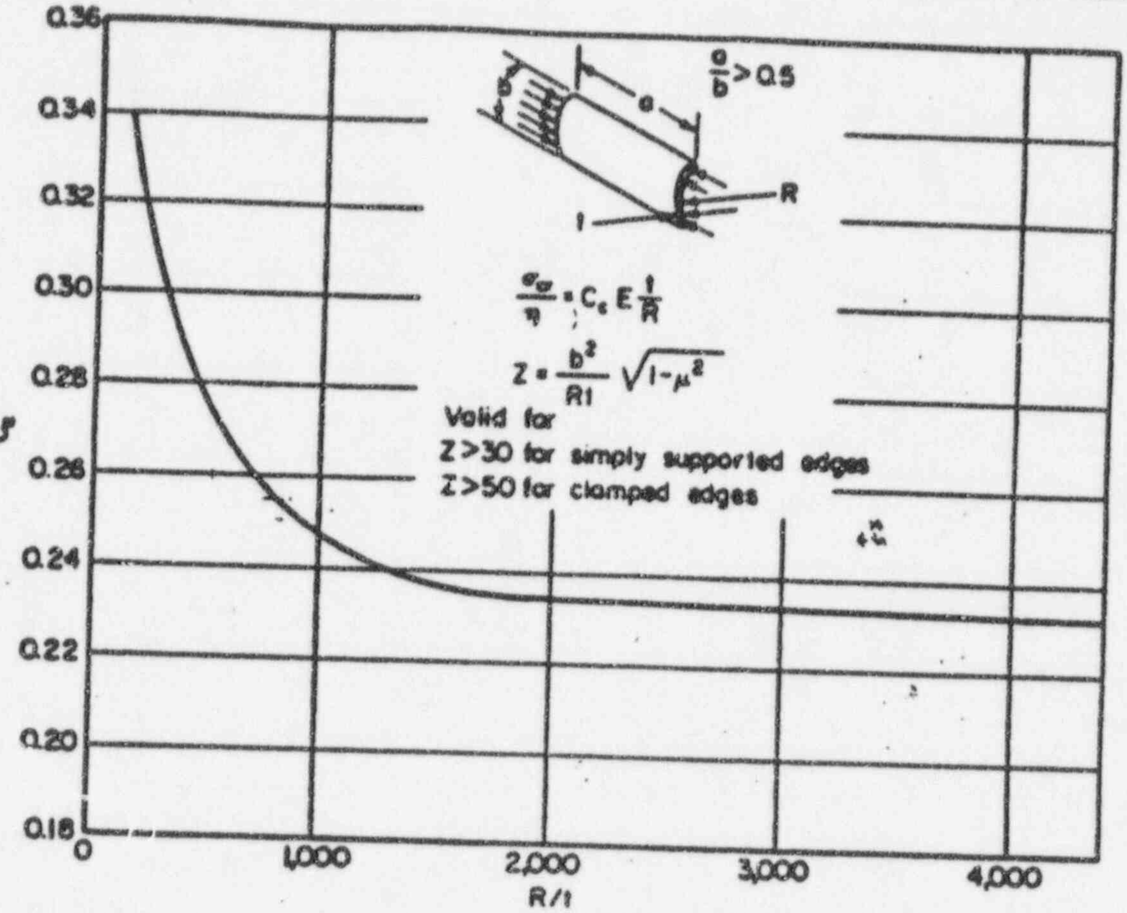

Figure 10. Buckling-stress Coefficient C_c for Unpressurized Curved Panels Subjected to Axial Compression [22]

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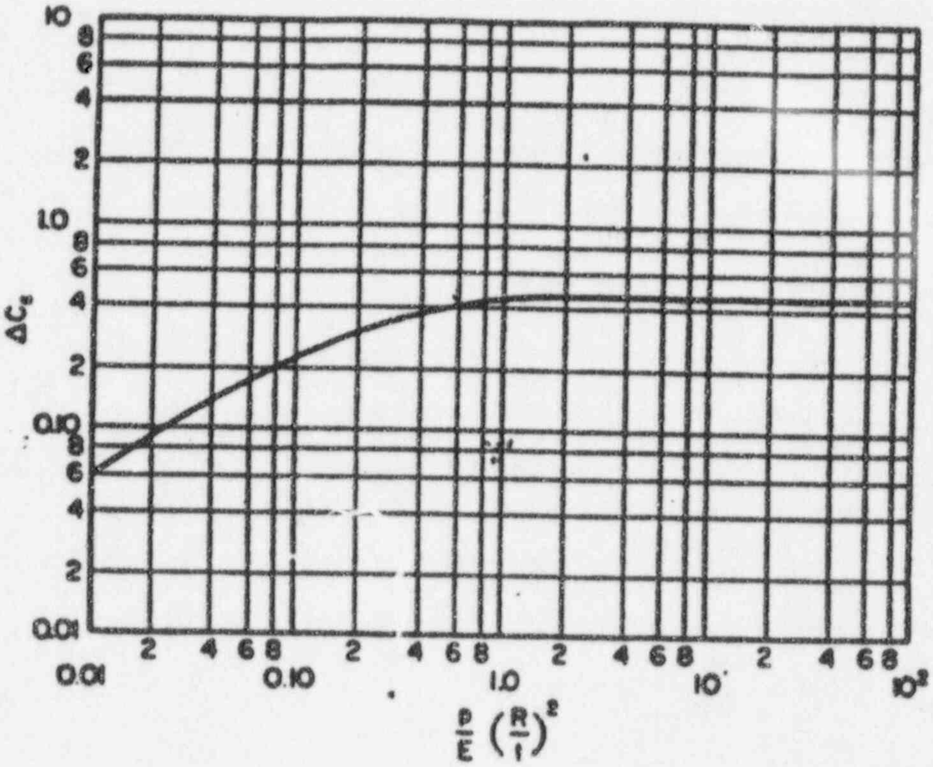

Figure 11. Increase in Axial-compressive Buckling-stress Coefficient for Curved Panels Due to Internal Pressure [22]

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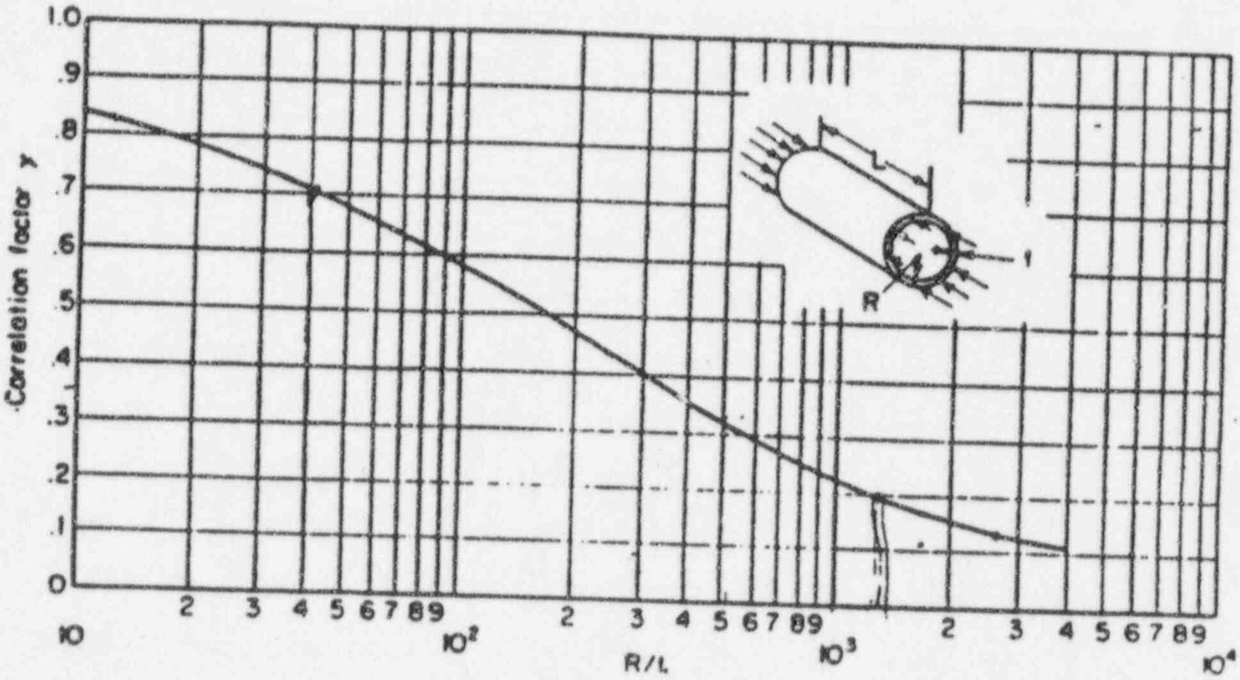

Figure 12. Correlation Factors for Unstiffened Unpressurized Circular Cylinders Subjected to Axial Compression [22]

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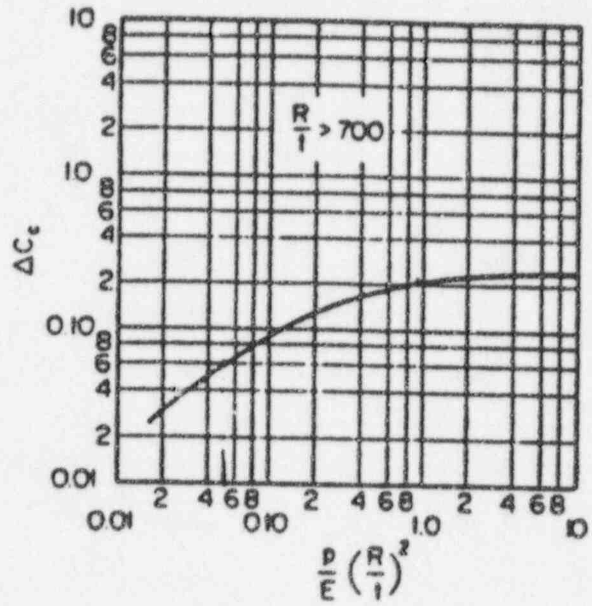

Figure 13. Increase in Axial-compressive Buckling-stress Coefficient for Cylinders Internal Pressure [22]

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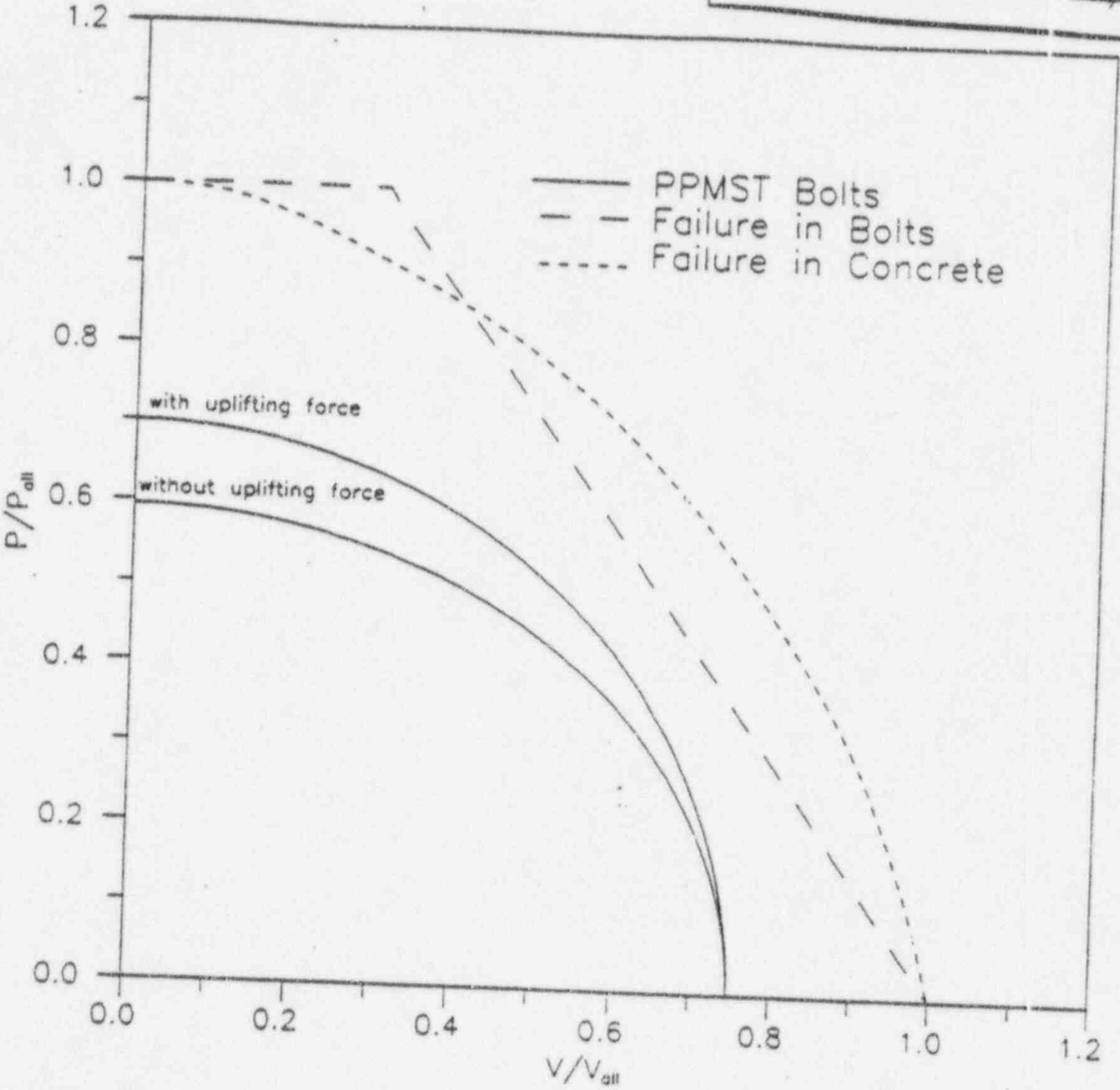

Figure 14. Shear-Tension Interaction Limits of Bolts in the Modified PPMSTs [17]

Attachment A

Overturning Moments and Shears at Various Liquid Levels

The overturning moment and shear calculated per the GIP [17] are the maximum values at the bottom of the tank. The analysis method developed by Haroun [20] was used to compute overturning moments and shears at higher elevations of the tank.

$H/R = 384/240 = 1.6$
$h = t_{ef} = 0.2077$ inches (see Step 2 of Section 8.3)
$h/R = 0.2077/240 = 0.000865$

From the referenced paper,

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$$\omega_s^2 = \frac{1.84g}{R}\tanh\frac{1.84H}{R}$$
$$= \frac{1.84*386.4}{240}\tanh\frac{1.84*384}{240}$$
$$= 2.946\ (rad/sec)^2$$

$$\omega_s = 1.716\ rad/sec, \quad T_s = \frac{2\pi}{\omega_s} = 3.66\ seconds$$

In addition, the following quantities can be obtained from Figures 7 and 8, which are extracted from Haroun's paper [20]:

$$\omega_f H \sqrt{\frac{\rho_s}{E}} = 0.09$$

$$\frac{m_\ell}{m} = 0.68$$

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$$\frac{m_r}{m} = 0.71$$

$$\frac{m_s}{m} = 0.29$$

$$\frac{H_\ell}{H} = 0.47$$

$$\frac{H_r}{H} = 0.414$$

$$\frac{H_s}{H} = 0.69$$

Thus,

$$\omega_\ell = \frac{0.09}{H}\sqrt{\frac{E}{\rho_s}}$$
$$= \frac{0.09}{384}\sqrt{\frac{28.03*10^6*386.4}{0.283}}$$
$$= 45.77\ rad/sec$$

$$T_\ell = \frac{2\pi}{\omega_\ell} = 0.137\ seconds$$

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From the DBE spectrum shown in Figure 2(a):

$S_{af} = 1.15\ g$

$S_{as} = 0.75\ g = 0.65\ S_{af}$ (set to achieve the GIP [17] moment)

$\ddot{G}_{max} = 1\ g = 0.87\ S_{af}$

From the model shown in Figure 9, it can be shown that, at a distance y from the tank bottom, the overturning moment and shear are:

$$M = \sqrt{[m_s (H_s - y) S_{as}]^2 + [m_f (H_f - y) S_{af}]^2 + \{[m_r (H_r - y) - m_f (H_f - y)]\ \ddot{G}_{max}\}^2}$$
$$= H\, m\, S_{af} \sqrt{0.119 - 0.482 \frac{y}{H} + 0.498 (\frac{y}{H})^2}$$

The above equation is the same as the first equation in page 205 of [20] by Haroun except that the moment arms H_s, H_f, and H_r are ajusted to reflect higher fluid levels.

Similarly,

$$V = \sqrt{(m_s S_{as})^2 + (m_f S_{af})^2 + [(m_r - m_f) \ddot{G}_{max}]^2} - m \frac{y}{H} \ddot{G}_{max}$$
$$= (0.7048 - 0.87 \frac{y}{H})\ m\, S_{af}$$

This equation is simply the last equation in page 203 of [20] less the product of the fluid mass between the bottom and the level and the acceration.

Attachment B

Diamond-Shape Buckling Stress Limits

B.1 Perform Stress Analysis (Step 1 of CC N-284)

$$\sigma_\phi = \textit{axial stress} = \frac{W_t}{2\pi Rt} + \frac{M}{\pi R^2 t}$$

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$$\sigma_\theta = \textit{Hoop Stress} = \frac{P_d R}{t}$$

$$\tau_{\phi\theta} = \textit{Shear Stress} = \frac{Q}{2\pi Rt}$$

Where P_d is the pressure calculated in Step 14 of Section 9.2.

B.2 Determine Stress Components σ_i (Step 2 of CC N-284)

(a) Level A (see Figure 1 for definition)

$$\sigma_\phi = \frac{39664}{2\pi*240*0.3125} + \frac{382,172,097}{\pi*240^2*0.3125} = 6,843 \text{ psi (compression)}$$

$$\sigma_\theta = \frac{17.87*240}{0.3125} = 13,724 \text{ psi (tension)}$$

$$\sigma_{\phi\theta} = \frac{2,048,175}{2\pi*240*0.3125} = 4,346 \text{ psi (shear)}$$

where 39,664 Lbs is the weight of the tank W_t calculated in Section 8.1 of this report, 382,172,097 in-Lbf is the overturing moment M calculated in [Step 6] of Section 9.2 of this report, 2,048,175 is the shear force Q calculated in [Step 6] of Section 9.2 of this

report, and 17.87 psi is the diamond shape buckling pressure calculated in [Step 13] of Section 9.2 of this report.

(b) Level B (see Figure 1 for definition)

$$\sigma_\phi = \frac{39664}{2\pi * 240 * 0.25} + \frac{191,639,921}{\pi * 240^2 * 0.25} = 4,342 \text{ psi (compression)}$$

$$\sigma_\theta = \frac{14.42 * 240}{0.25} = 13,843 \text{ psi (tension)}$$

$$\sigma_{\phi\theta} = \frac{1,408,191}{2\pi * 240 * 0.25} = 3,735 \text{ psi (shear)}$$

where definitions of the numbers in the above equations, namely 39,664, 191,639,921, 1,408,191, and 14.42, are similar to those for Level A.

(c) Level C (see Figure 1 for definition)

$$\sigma_\phi = \frac{39664}{2\pi * 240 * 0.1875} + \frac{65,682,921}{\pi * 240^2 * 0.1875} = 2,077 \text{ psi (compression)}$$

$$\sigma_\theta = \frac{11.83 * 240}{0.1875} = 15,142 \text{ psi (tension)}$$

$$\sigma_{\phi\theta} = \frac{940,067}{2\pi * 240 * 0.1875} = 3,325 \text{ psi (shear)}$$

where definitions of the numbers in the above equations, namely 39,664, 65,682,921, 940,067, and 11.83, are similar to those for Level A.

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B.3 Factor of Safety (Step 3 of CC N-284)

FS = 1.34 for DBE

FS = 2.0 for OBE

B.4 Capacity Reduction Factors (Step 4 of CC N-284)

(a) Level A

l_ϕ = 72 *inches*

$$l_\theta = \frac{2\pi * 240}{36} = 41.89 \textit{ inches}$$

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$$M_\phi = 72/\sqrt{240*0.3125} = 8.31$$

$$M_\theta = 41.89/\sqrt{240*0.3125} = 4.84$$

$$M = \text{Min}(M_\phi, M_\theta) = 4.84$$

$$\alpha_{\phi L} = \frac{0.826}{M^{0.6}} = 0.321$$

$$\alpha_{\theta L} = 0.8$$

$$l_{s\theta} t = \frac{41.89}{2} * 0.3125 = 6.54 \textit{ inch}^2$$

$$\alpha_{\phi\theta L} = 1.323 - 0.218 Log_{10}\frac{R}{t} = 1.323 - 0.218 Log_{10}\frac{240}{0.3125} = 0.694$$

Assume that the cross sectional area of the stringer is greater than or equal to 5 inch^2.

$$\bar{A} = \frac{A_\phi}{l_{s\theta} t} = \frac{5}{6.54} = 0.765$$

$$\alpha_{\phi G} = 0.72$$

$$\alpha_{\theta G} = 0.8$$

$$\alpha_{\phi\theta G} = 1.323 - 0.218 \; Log_{10}(R/t) = 0.694$$

(b) Level B

$$l_\phi = 408 \textit{ inches}$$

$$l_\theta = 2\pi * 240 = 1{,}508 \textit{ inches}$$

$$M_\phi = 408/\sqrt{240*0.25} = 52.7$$

$$M_\theta = 1508/\sqrt{240*0.25} = 195$$

$$M = \text{Min}(M_\phi, M_\theta) = 52.7$$

$$\alpha_{\phi L} = \alpha_{\phi G} = 0.207$$

$$\alpha_{\theta L} = \alpha_{\theta G} = 0.8$$

$$\alpha_{\phi\theta L} = 1.323 - 0.218 Log_{10}\frac{R}{t} = 1.323 - 0.218 Log_{10}\frac{240}{0.25} = 0.673$$

(c) Level C

$l_\phi = 408\ inches$

$l_\theta = 2\pi * 240 = 1,508\ inches$

$M_\phi = 408/\sqrt{240*0.1875} = 60.8$

$M_\theta = 1508/\sqrt{240*0.1875} = 225$

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$M = Min(M_\phi, M_\theta) = 60.8$

$\alpha_{\phi L} = \alpha_{\phi G} = 0.207$

$\alpha_{\theta L} = \alpha_{\theta G} = 0.8$

$$\alpha_{\phi\theta L} = 1.323 - 0.218 Log_{10}\frac{R}{t} = 1.323 - 0.218 Log_{10}\frac{240}{0.1875} = 0.646$$

It is worth noting that the roundness requirements on the tank shell, ND-4220 of the ASME Code are implicit in the calculations of all the above reduction factors. Since the PPMST's were built originally according to API-620 and API-650 rules which did not have such roundness requirements, checks on roundness of the tanks per ASME, Section III, ND-4220 might be necessary to justify accepting evaluation results by Code Case N-284.

B.5 Plasticity Reduction Factors (Step 5 of CC N-284)

Since DBE loading is a Level D service loading, the factor of safety FS is 1.34 per the Code Case N-284.

$$\frac{\sigma_\phi FS}{\sigma_y} = \frac{6843*1.34}{30,000} = 0.31 < 0.55$$

$\eta_\phi = 1$

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$$\frac{\sigma_\theta FS}{\sigma_y} = \frac{10646*1.34}{30,000} = 0.48 < 0.67$$

$$\eta_\theta = 1$$

B.6 Calculate Amplified Stresses (Step 6 of CC N-284)

(a) Level A

$$\sigma_{\phi e} = \sigma_\phi \frac{FS}{\alpha_{\phi L}} = 6843*\frac{1.34}{0.321} = 28,528 \text{ psi (in compression)}$$

$$\sigma_{\theta e} = \sigma_\theta \frac{FS}{\alpha_{\theta L}} = 13724*\frac{1.34}{0.8} = 22,988 \text{ psi (in tension)}$$

$$\tau_{\phi\theta e} = \tau_{\phi\theta} \frac{FS}{\alpha_{\phi\theta L}} = 4,346*\frac{1.34}{0.694} = 8,393 \text{ psi (in shear)}$$

(b) Level B

$$\sigma_{\phi e} = \sigma_\phi \frac{FS}{\alpha_{\phi L}} = 4342*\frac{1.34}{0.207} = 28,108 \text{ psi (in compression)}$$

$$\sigma_{\theta e} = \sigma_\theta \frac{FS}{\alpha_{\theta L}} = 13843*\frac{1.34}{0.8} = 23,187 \text{ psi (in tension)}$$

$$\tau_{\phi\theta e} = \tau_{\phi\theta} \frac{FS}{\alpha_{\phi\theta L}} = 3,735*\frac{1.34}{0.673} = 7,437 \text{ psi (in shear)}$$

(c) Level C

$$\sigma_{\phi e} = \sigma_\phi \frac{FS}{\alpha_{\phi L}} = 2077*\frac{1.34}{0.207} = 13,445 \text{ psi (in compression)}$$

$$\sigma_{\theta e} = \sigma_\theta \frac{FS}{\alpha_{\theta L}} = 15142*\frac{1.34}{0.8} = 25,363 \text{ psi (in tension)}$$

$$\tau_{\phi\theta e} = \tau_{\phi\theta} \frac{FS}{\alpha_{\phi\theta L}} = 3,325*\frac{1.34}{0.646} = 6,897 \text{ psi (in shear)}$$

B.7 Plasticity Effects (Step 7 of CC N-284)

$$\sigma_{\phi p} = \sigma_{\phi s}/\eta_\phi = \sigma_{\phi s}$$

$$\sigma_{\theta p} = \sigma_{\theta s}/\eta_\theta = \sigma_{\theta s}$$

$$\sigma_{\phi\theta p} = \sigma_{\phi\theta s}$$

B.8 Determine Evaluation Approach (Step 8 of CC N-284)

Article-1700, By Formula, of Code Case N-284 will be used to evaluate the reinforced PPMST. It is worth noting that the stresses calculated in Step 13 of this section are the maximum axial stress at a certain liquid level of the tank. Stresses at a higher elevations and other azimuth angles around the circumference are lower than the maximum values. However, the maximum stresses calculated in Step 13 are used conservatively for the evaluation in lieu of the average stresses within a meridional distance of $\sqrt{Rt}$ permitted by Article-1711 of the Code Case.

B.9 Determine Allowable (Step 9 of CC N-284)

$$\sigma_{\phi eL} = (C_\phi + \Delta C_\phi)\frac{Et}{R}$$

$$\sigma_{\phi\theta eL} = (C_{\phi\theta} + \Delta C_{\phi\theta})\frac{Et}{R}$$

ΔC_ϕ , $\Delta C_{\phi\theta}$ are included to adjust for internal pressure. It is specifically stated in Article-1500 of the Code Case that "The influence of internal pressure on a shell structure may reduce the initial imperfections and therefore higher values of capacity reduction factors may be acceptable." Similarly, the latest AWWA Standard for Welded Steel Tanks for Water Storage [24] also allows the

adjustment for internal pressure.

(a) Level A

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$$C_\phi = \frac{3.62}{M_\phi^2} + 0.0253 M_\phi^2$$
$$= \frac{3.62}{2.49^2} + 0.0253 * 2.49^2$$
$$= 0.74$$

$$\Delta C_\phi = \Delta C_c \frac{C_\phi}{C_c} = 0.35 * \frac{0.74}{0.255} = 1.02$$

$$C_{\phi\theta} = \frac{1}{M^2}[4.82(1+0.0239M^3)^{1/2} + 3.62(\frac{b}{a})^2]$$
$$= \frac{1}{2.49^2}[4.82(1+0.0239*2.49^3)^{1/2} + 3.62(\frac{21.54}{72})^2]$$
$$= 0.962$$

In the above equations, the coefficients C_c and ΔC_c are elastic buckling coefficient and buckling coefficient increment due to internal pressure defined by Baker, et al [22,23], and are calculated as follows

$$b = \frac{2\pi R}{36} = 41.9 \text{ inches}$$

a/b = 72/41.9 = 1.7 > 0.5

$$Z = \frac{b^2}{Rt}\sqrt{1-\mu^2} = \frac{41.9^2}{240*0.3125}\sqrt{1-0.3^2} = 22.3$$

$$\frac{P}{E}(\frac{R}{t})^2 = \frac{17.87}{28.03x10^6}(\frac{240}{0.3125})^2 = 0.376$$

From Figures 10 and 11, which are extracted from Figures 10-2 and 10-3 of Baker, et al, [22],

C_c = 0.255

ΔC_c = 0.35

It should be noted that the buckling coefficient C_c given by Baker, et al [22,23] is corresponding to a 90 percentile failure of the actual test data while the N-284 buckling coefficient C_ϕ is corresponding to a much higher theoretical buckling strength. The compound coefficient $C_\phi \alpha_{\phi L}$=0.125 is corresponding to the lower bound of test data and is certainly lower than the 90% failure coefficient (0.255). ΔC_c is the buckling coefficient increment due to internal pressure defined by Baker, et al [22,23].

$\sigma_{\phi\theta L}$ = (0.74+1.02)*28.3*10^6*0.3125/240 = 64,235 psi

$\sigma_{\phi a s}$ = 80,860 psi (see Appendix C for details)

$\sigma_{\phi\theta a L}$ = 0.962*28.03*10^6*0.3125/240 = 35,110 *psi* psi

Therefore,

$\sigma_{\phi s} < \sigma_{\phi a L}$

$\sigma_{\phi s} < \sigma_{\phi a S}$

$\sigma_{\phi\theta s} < \sigma_{\phi\theta a L}$

The reinforced PPMST will not buckle due to the DBE loads at level A.

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(b) Level B

C_ϕ = 0.605

$$\Delta C_\phi = \Delta C_c \frac{C_\phi}{C_c} = 0.16*\frac{0.605}{0.139} = 0.70$$

$$C_{\phi\theta} = \frac{0.746}{\sqrt{52.7}} = 0.103$$

$$\Delta C_{\phi\theta} = \frac{0.103}{0.077}*0.27 = 0.361$$ (from Figures 10-4 and 10-6 of [22])

In the above equations, the coefficients C_c and ΔC_c are calculated per Baker, et al, [22,33], as follows

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$b = 2\pi R = 1{,}508$ inches

$R/t = 240/0.25 = 960$

$$C_c = \frac{0.23}{\sqrt{3(1-0.3^2)}} = 0.139 \quad \text{(from Figure 12)}$$

$$\frac{P}{E}\left(\frac{R}{t}\right)^2 = \frac{14.42}{28.03x10^6}\left(\frac{240}{0.25}\right)^2 = 0.474$$

$\Delta C_c = 0.16$ (from Figure 13)

Again, the buckling coefficient C_c given by Baker, et al [12,13] is corresponding to a 90 percentile failure of the actual test data while the N-284 buckling coefficient C_ϕ is corresponding to a much higher theoretical buckling strength. The compound coefficient $C_\phi \alpha_{\phi L}$=0.125 is corresponding to the lower bound of test data and is certainly lower than the 90% failure coefficient (0.139). The ΔC_c factor is used to adjust for benefits due to internal pressure.

$$\sigma_{\phi eL} = (0.605+0.70)*28.14*10^6*0.25/240 = 38{,}620 \text{ psi}$$

$$\sigma_{\phi\theta eL} = (0.103+0.361)*28.03*10^6*0.25/240 = \underline{13{,}548} \text{ psi}$$

Therefore,

$$\sigma_{\phi s} < \sigma_{\phi eL}$$

$$\sigma_{\phi\theta s} < \sigma_{\phi\theta eL}$$

The reinforced PPMST will not buckle due to the DBE loads

at level B.

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(c) Level C

$C_\phi = 0.605$

$$\Delta C_\phi = \Delta C_c \frac{C_\phi}{C_c} = 0.18 * \frac{0.605}{0.121} = 0.90$$

$$C_{\phi\theta} = \frac{0.746}{\sqrt{60.8}} = 0.096$$

$$\Delta C_{\phi\theta} = \frac{0.096}{0.072} * 0.35 = 0.467$$ (from Figures 10-4 and 10-6 of [22])

In the above equations, the coefficients C_c and ΔC_c are calculated per Baker, et al, [12,13], as follows,

$b = 2\pi R = 1,508$ inches

$R/t = 240/0.1875 = 1280$

$$C_c = \frac{0.20}{\sqrt{3(1-0.3^2)}} = 0.121$$ (from Figure 12)

$$\frac{P}{E}\left(\frac{R}{t}\right)^2 = \frac{11.83}{28.03x10^6}\left(\frac{240}{0.1875}\right)^2 = 0.691$$

$\Delta C_c = 0.18$ (from Figure 13)

Again, the buckling coefficient C_c given by Baker, et al [12,13] is corresponding to a 90 percentile failure of the actual test data while the N-284 buckling coefficient C_ϕ is corresponding to a much higher theoretical buckling strength. The compound coefficient $C_\phi \alpha_{\phi L} = 0.125$ is corresponding to the lower bound of test data and is certainly lower than the 90% failure coefficient (0.139). The ΔC_c factor is used to adjust for benefits due to internal pressure.

$\sigma_{\phi eL} = (0.605+0.90)*28.03*10^6*0.1875/240 = 33,404$ psi

$\sigma_{\phi\theta eL} = (0.096+0.467)*28.03*10^6*0.1875/240 = \underline{12,328}$ psi

Therefore,

$\sigma_{\phi s} < \sigma_{\phi eL}$

$\sigma_{\phi\theta s} < \sigma_{\phi\theta eL}$

The reinforced PPMST will not buckle due to the DBE loads at level C.

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Attachment C

Calculation of Stringer Buckling Stress

Equations contained in Article-1712.2.2 of ASME Code Case N-284 were used to compute stringer buckling stress. A copy of the Code Case page is included in the next page for reference. After many iterations, it was found that the minimum stringer buckling stress

$$\sigma_{\phi e s} = 80,860\ psi$$

occur at m=1 and n=16. Computer outputs for the cases of (m,n)= (1,16), (1,15), (1,17), (2,15), and (2,16) are attached.

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-1712.2.2 Cylindrical Shells — Stringer Stiffened or Ring and Stringer Stiffened

The theoretical elastic buckling stresses for both stringer buckling and general instability are given by the equations which follow. Stringer buckling is defined as the buckling between rings of the stringer and attached plate and general instability is defined as the buckling mode in which the rings and attached plate deform radially.

The elastic buckling stress is denoted σ_{iej} where i is the stress direction and j is the buckling mode; $j = S$ for stringer buckling and $j = G$ for general instability. The stringer buckling stress is determined by letting the cylinder length equal the ring spacing, $L_j = \ell_\theta$, and the general instability stress by letting $L_j = L_B$.

The values of m and n to use in the following equations are those which minimize σ_{iej} where $m \geq 1$ and $n > 2$. The following values are to be used for ℓ_{se} and $\ell_{\theta e}$. When $\ell_{se} < \ell_s$ or $\ell_{\theta e} < \ell_\theta$, set $\mu = 0$.

(a) Axial Compression

$$\ell_{\theta e} = \ell_\theta$$

$$\ell_{se} = \ell_s \quad \text{if } \ell_s \leq 1.288tQ$$

$$\ell_{se} = 1.9tQ\left(1 - \frac{0.415tQ}{\ell_s}\right) \quad \text{if } \ell_s > 1.288tQ$$

where

$$Q = \sqrt{\frac{E}{\sigma_{xej}\,\alpha_{xG}}} \geq \sqrt{\frac{E}{\sigma_y}}$$

For stringer buckling:

$$j = S,\ A_\theta = I_\theta = J_\theta = 0,\ t_\theta = t,\ L_j = \ell_\theta$$

For general instability:

$$j = G,\ L_j = L_B$$

See -1521(a)(1) for α_{xG} and the equation below for σ_{xej}. When $\ell_{se} < \ell_s$, the values for σ_{xej} must be determined by iteration since the effective width is a function of the buckling stress.

$$\sigma_{xej} = \frac{A_{33} + \left(\dfrac{A_{12}A_{23} - A_{13}A_{22}}{A_{11}A_{22} - A^2_{12}}\right)A_{13} + \left(\dfrac{A_{12}A_{13} - A_{11}A_{23}}{A_{11}A_{22} - A^2_{12}}\right)A_{23}}{\left(\dfrac{m\pi}{L_j}\right)^2 t\phi}$$

where

$$A_{11} = E_s\left(\frac{m\pi}{L_j}\right)^2 + G_{s\theta}\left(\frac{n}{R}\right)^2$$

$$A_{22} = E_\theta\left(\frac{n}{R}\right)^2 + G_{s\theta}\left(\frac{m\pi}{L_j}\right)^2$$

$$A_{33} = D_s\left(\frac{m\pi}{L_j}\right)^4 + \overline{D}_{s\theta}\left(\frac{m\pi}{L_j}\right)^2\left(\frac{n}{R}\right)^2 + D_\theta\left(\frac{n}{R}\right)^4 + \frac{E_\theta}{R^2} + \frac{2C_\theta}{R}\left(\frac{n}{R}\right)^2$$

$$A_{12} = (E_{s\theta} + G_{s\theta})\left(\frac{m\pi}{L_j}\right)\left(\frac{n}{R}\right)$$

$$A_{23} = \frac{E_\theta}{R}\left(\frac{n}{R}\right) + C_\theta\left(\frac{n}{R}\right)^3$$

$$A_{13} = \frac{E_{s\theta}}{R}\left(\frac{m\pi}{L_j}\right) + C_s\left(\frac{m\pi}{L_j}\right)^3$$

$$E_s = \frac{Et}{1-\mu^2}\left(\frac{\ell_{se}}{\ell_s}\right) + \frac{EA_s}{\ell_s} \qquad E_{s\theta} = \frac{\mu Et}{1-\mu^2}$$

$$E_\theta = \frac{Et}{1-\mu^2}\left(\frac{\ell_{\theta e}}{\ell_\theta}\right) + \frac{EA_\theta}{\ell_\theta} \qquad G_{s\theta} = \frac{Gt}{2}\left(\frac{\ell_{\theta e}}{\ell_\theta} + \frac{\ell_{se}}{\ell_s}\right)$$

$$D_s = \frac{Et^3}{12(1-\mu^2)}\left(\frac{\ell_{se}}{\ell_s}\right) + \frac{EI_s}{\ell_s} + \frac{EA_s z^2_s}{\ell_s}$$

$$D_\theta = \frac{Et^3}{12(1-\mu^2)}\left(\frac{\ell_{\theta e}}{\ell_\theta}\right) + \frac{EI_\theta}{\ell_\theta} + \frac{EA_\theta z^2_\theta}{\ell_\theta}$$

$$\overline{D}_{s\theta} = \frac{\mu Et^3}{6(1-\mu^2)} + \frac{Gt^3}{6}\left(\frac{\ell_{\theta e}}{\ell_\theta} + \frac{\ell_{se}}{\ell_s}\right) + \frac{GJ_s}{\ell_s} + \frac{GJ_\theta}{\ell_\theta}$$

$$C_s = \frac{EA_s z_s}{\ell_s} \qquad C_\theta = \frac{EA_\theta z_\theta}{\ell_\theta}$$

(b) External Pressure

Stringer Buckling ($j = S$)

$$\ell_{se} = \sqrt{Rt} \text{ but not greater than } \ell_s$$

$$\ell_{\theta e} = \ell_\theta$$

$$A_\theta = I_\theta = J_\theta = 0,\ t_\theta = t,\ L_j = \ell_\theta$$

General Instability ($j = G$)

$$\ell_{se} = 1.56\sqrt{Rt} \text{ but not greater than } \ell_s$$

$$\ell_{\theta e} = \ell_\theta,\ L_j = L_B$$

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SUPPLEMENT —
CALC NO M-DSC-269
[redacted] SCN 1
BY N.M. S1-A — DATE 11/10/93
CHECKED J.F.G. DATE 11/10/93

STRUCTURAL INTEGRITY ASSOCIATES, INC.

m=	1
n=	16
alpha$G=	0.402
Sig-y=	30000
t=	0.3125
E=	28030000
L$=	408
Le$=	408
z$=	2.8125
A$=	6.875
I$=	10.417
J$=	20.834
t$=	0.353520
E$=	2128409.
E$Q=	2887706.
D$=	10845225
D$Q=	1447543.
C$=	3233808.
A11=	17243.41
A22=	44084.90
A33=	172.2593
A12=	3608.590
A23=	2673.801
A13=	246.8350

Sig$ej=	80860.38 ←
Q=	29.36504
sq(E/Sy)=	30.56686
1.288tQ=	11.81942
R=	240
Nu=	0.3
LQ=	167.6
LeQ=	17.03931
zQ=	1
AQ=	0
IQ=	0
JQ=	0
tQ=	0.3125
EQ=	9625686.
G$Q=	3711504.
DQ=	78334.03
CQ=	0

G=	10780769
Lj=	167.6
t$Q=	0.333010

$ → φ

Q → θ

SHT. 173

SUPPLEMENT —
CALC NO M-DSC-269
[illegible] CCN 1
BY N.M.El-Ar DATE 11/10/93
CHECKED J-G. DATE 11/10/93

ICCN F-565
P 173 OF 279

m=	1
n=	15
alpha$G=	0.402
Sig-y=	30000
t=	0.3125
E=	28030000
L$=	408
Le$=	408
z$=	2.8125
A$=	6.875
I$=	10.417
J$=	20.834
t$=	0.353520
E$=	2127346.
E$Q=	2887706.
D$=	10845216
D$Q=	1447537.
C$=	3233808.
A11=	15244.07
A22=	38904.28
A33=	171.6335
A12=	3383.053
A23=	2506.689
A13=	246.8350

Sig$ej=	81040.48
Q=	29.33239
sq(E/Sy)=	30.56686
1.288tQ=	11.80628
R=	240
Nu=	0.3
LQ=	167.6
LeQ=	17.02081
zQ=	1
AQ=	0
IQ=	0
JQ=	0
tQ=	0.3125
EQ=	9625686.
G$Q=	3711132.
DQ=	78334.03
CQ=	0

G=	10780769
Lj=	167.6
t$Q=	0.333010

SHT. 174

SUPPLEMENT —
CALC NO M-OSC-269
REVISION CCN 1
BY N.M. Fi-Dr DATE 11/10/93
CHECKED J-G. DATE 11/10/93

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m=	1
n=	17
alpha$G=	0.402
Sig-y=	30000
t=	0.3125
E=	28030000
L$=	408
Le$=	408
z$=	2.8125
A$=	6.875
I$=	10.417
J$=	20.834
t$=	0.353520
E$=	2120403.
E$Q=	2887706.
D$=	10845160
D$Q=	1447497.
C$=	3233808.
A11=	19352.92
A22=	49598.63
A33=	172.9752
A12=	3834.127
A23=	2840.914
A13=	246.8350

Sig$ej=	82231.83
Q=	29.11913
sq(E/Sy)=	30.56686
1.288tQ=	11.72045
R=	240
Nu=	0.3
LQ=	167.6
LeQ=	16.89991
zQ=	1
AQ=	0
IQ=	0
JQ=	0
tQ=	0.3125
EQ=	9625686.
G$Q=	3708702.
DQ=	78334.03
CQ=	0

G=	10780769
Lj=	167.6
t$Q=	0.333010

SHT. 175

SUPPLEMENT —
CALC NO M-DSC-269
REVISION CCN 1
BY N.M.EI-A. DATE 11/10/93
CHECKED J-G.. DATE 11/10/93

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m=	2	Sig$cj=	95424.60		
n=	16	Q=	27.03138		
alpha$G=	0.402	sq(E/Sy)=	30.56686		
Sig-y=	30000	1.288tQ=	10.88013		
t=	0.3125	R=	240		
E=	28030000	Nu=	0.3		
L$=	408	LQ=	167.6	G=	10780769
Le$=	408	LeQ=	15.71417	Lj=	167.6
z$=	2.8125	zQ=	1		
A$=	6.875	AQ=	0		
I$=	10.417	IQ=	0		
J$=	20.834	JQ=	0		
t$=	0.353520	tQ=	0.3125	t$Q=	0.333010
E$=	2052303.	EQ=	9625686.		
E$Q=	2887706.	G$Q=	3684866.		
D$=	10844606	DQ=	78334.03		
D$Q=	1447109.				
C$=	3233808.	CQ=	0		
A11=	19261.57				
A22=	47959.68				
A33=	199.1200				
A12=	7217.180				
A23=	2673.801				
A13=	621.4589				

SHT. 176

SUPPLEMENT —
CALC NO M-DSC-269
REVISION CCN 1
BY N.M.-ElAkl DATE 11/10/93
CHECKED J.G. DATE 11/10/93

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P 176 OF 279

STRUCTURAL INTEGRITY ASSOCIATES, INC.

m=	2
n=	15
alpha$G=	0.402
Sig-y=	30000
t=	0.3125
E=	28030000
L$=	408
Le$=	408
z$=	2.8125
A$=	6.875
I$=	10.417
J$=	20.834
t$=	0.353520
E$=	2049970.
E$Q=	2887706.
D$=	10844587
D$Q=	1447096.
C$=	3233808.
A11=	17271.92
A22=	42778.04
A33=	197.6732
A12=	6766.106
A23=	2506.689
A13=	621.4589

Sig$ej=	95930.68
Q=	26.95999
sq(E/Sy)=	30.56686
1.288tQ=	10.85139
R=	240
Nu=	0.3
LQ=	167.6
LeQ=	15.67355
zQ=	1
AQ=	0
IQ=	0
JQ=	0
tQ=	0.3125
EQ=	9625686.
G$Q=	3684050.
DQ=	78334.03
CQ=	0

G=	10780769
Lj=	167.6
t$Q=	0.333010

SHT. 177

SUPPLEMENT —
CALC NO M-DSC-269
~~REVISION~~ CCN 1
BY N.M.-El-A. DATE 11/10/93
CHECKED J-Z. DATE 11/10/93

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Attachment D Examination Reconciliation with the ASME Code

Examination of tank shell welding by spot radiography is acceptable by both the 1989 ASME Code, Section III, Subsection ND, and API Standard 650, 5th. Edition. Table 1 gives a comparison between the requirements of the Code and the Standard showing the areas of agreement between them and the main differences. These differences are pertain mainly to the number of spots for examination and the acceptability criteria for crowns and undercuts.

Table 1 Comparison Between API-650 ASME Code

		API-650	ASME Section ND
Cracks		Unacceptable.	Unacceptable.
Inclusion & Indications		<2/3T O.K. 3/4" Max. <1/4" O.K. Combined length of several inclusions <T in 6T length.	<2/3T O.K. 3/4" Max. <1/4" O.K. Same. Rounded indications are not a factor in the acceptability of welds not required to be fully radiographed.
Frequency of Spot Radiography	Vertical Joint	First 10 ft, 100 ft increments (25% at intersections).	First 50 ft, 50 ft increments.
	Horizontal Joint	First 10 ft, 200 ft increments.	

	AP-650	ASME
Crowns	≤1/16 " in the area where spot radiography is planned.	3/32" Max.
Undercut	No requirement.	1/32" Max.

SUPPLEMENT —
CALC NO M-DSC-269
REVISION CCN 1
BY N. M. El-A DATE 11/10/93
CHECKED J-C DATE 11/10/93
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REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	NABIL M. EL-AKILY	10/12/93	JUN GAOR J.G.	10/12/93					

APPENDIX - B

TANK STICK MODEL

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	S. PELLET SHP	11/10/93	JUN GAOR JG.	11/10/93					

DCP 2&3 - 6742.07-SM

"CCW SAFETY RELATED MAKEUP SYSTEM"

APPENDIX B

TABLE OF CONTENTS

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	S. PELLET SHP	11/10/93	JUN GAOR J.G.	11/10/93					

PURPOSE / OBJECTIVE

THE PURPOSE OF THIS CALCULATION IS TO DEVELOP PROPERTIES FOR A STICK MODEL OF THE PRIMARY PLANT MAKE-UP STORAGE TANKS T-055 AND T-056. THIS MODEL WILL BE INTEGRATED WITH THE MODELS FOR THE ATTACHED PIPING. THE PIPING MODELS WILL THEN EXHIBIT APPROPRIATE BEHAVIOR AT THE TANK CONNECTION POINTS (NOZZLES).

METHODOLOGY

THE TANK WILL BE MODELED WITH A MEMBER ELEMENT ORIENTED VERTICALLY AND LOCATED AT THE TANK CENTERLINE. HAND CALCULATIONS WILL BE PERFORMED TO DETERMINE APPROPRIATE MASSES AND TANK SECTION PROPERTIES. LOCAL SHELL STIFFNESSES WILL ALSO BE DEVELOPED USING GENERAL PLATE THEORY FORMULAS, (FOR INFORMATION ONLY).

J.G. 1/4/93

NES&L DEPARTMENT

CALCULATION SHEET

ICCN NO./ PRELIM. CCN NO. F-565 | PAGE 182 OF 27?

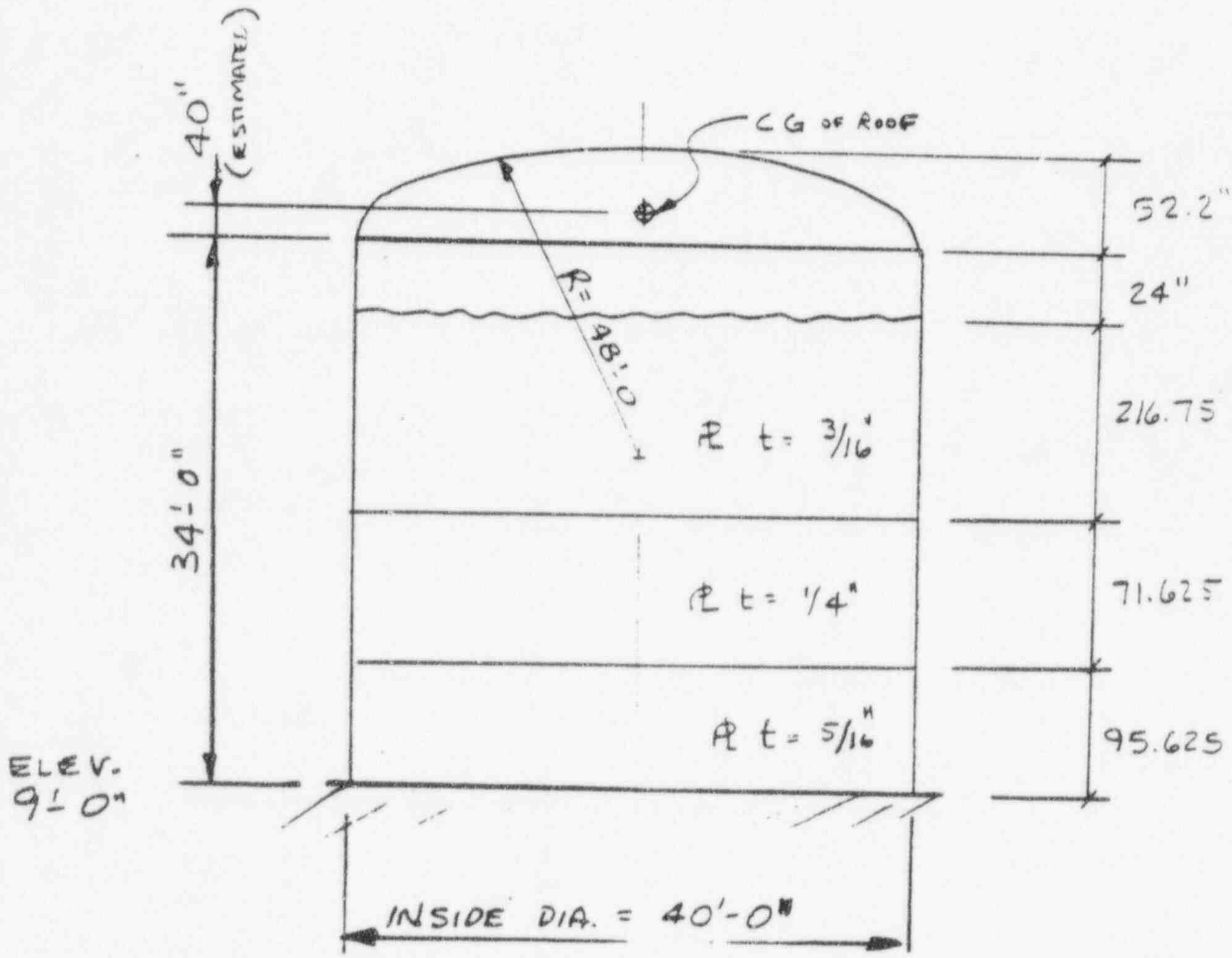
CCN CONVERSION CCN NO. CCN - 1

Project or DCP/MMP SONGS 3 Calc No. M-DSC-269

Subject See Title Sheet Sheet No. 182

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	S. PELLET SHP	11/10/93	JUN GAOR JG	11/10/93					

T-055 AND T056 DIMENSIONS



ELEVATION VIEW

SCE 26-426 NEW 4/90

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	S. PELLET SHP	11/10/93	JUN GAOR J.G.	11/10/93					

ASSUMPTIONS:

1. THE TANK BASE IS FIXED TO CONCRETE SLAB BOTH IN TRANSLATION AND ROTATION.
2. THE L 2½ x 2½ CONNECTING THE ROOF TO SIDE WALL WILL BE NEGLECTED.
3. THE MASS OF ATTACHED LADDER AND PIPING WILL BE NEGLECTED.
4. THE SHELL IS RIGID IN THE VERTICAL, AXIAL AND TANGENTIAL REACTION.
5. THE ROOF IS RIGID IN THE HORIZONTAL DIRECTION.
6. NOT USED
7. THE TANK IS FULL (32'-0) OF WATER, REF [5]

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Project or DCP/MMP SONGS 3 Calc No. M-DSC-269

CCN CONVERSION
CCN NO. CCN - 1

Subject See Title Sheet Sheet No. 184

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	S. PELLET SHP	11/10/93	JUN GAOR JG	11/10/93					

REFERENCES

1. "DESIGN OF WELDED STRUCTURES", BLODGETT, LINCOLN ARC WELDING FOUNDATION, 1972

2. "SEISMIC DESIGN OF LIQUID STORAGE TANKS", HAROUN & HOUSNER, ASCE JOURNAL, APRIL 1981

3. "STRESS AND STRAIN DATA HANDBOOK", HSU, GULF PUBLISHING, 1986

4. "FORMULAS FOR STRESS AND STRAIN", ROARK & YOUNG, M^cGRAW HILL, 1975

5. STRUCTURAL INTEGRITY REPORT SIR-92-063, DRAFT "RECONCILIATION OF PRIMARY PLANT MAKEUP STORAGE TANKS", SEPTEMBER 1992

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	S. PELLET SHP	11/10/93	JUN GAOR JG	11/10/93					

DETERMINE MASSES OF FLUID & SHELL

THE TANK MASSES WILL BE CONSIDERED IN FOUR PARTS AS OUTLINED IN REF [2] THE MASSES AND LOCATIONS WILL BE DETERMINED BASED ON THE FOLLOWING PARAMETERS

$H = 32'\text{-}0 \quad R = 20' \quad H/R = 1.6$

FOR THE PURPOSE OF THE CALCULATIONS MASSES WILL BE EXPRESSED IN UNITS OF $\frac{\text{lbf} \cdot \text{SEC}^2}{\text{IN}}$

THE DENSITY OF WATER IS GIVEN AS

$$\rho_\ell = \frac{(62.4)\ \frac{\text{lbm}}{\text{FT}^3}}{(32.174)\ \frac{\text{lbm} \cdot \text{FT}}{\text{lbf SEC}^2}} = 1.94\ \frac{\text{lbf SEC}^2}{\text{FT}^4}$$

THE MASS OF ALL OF THE WATER IS GIVEN BY

$$M = \rho_\ell \pi R^2 H$$

$$= (1.94)\ \frac{\text{lbf} \cdot \text{SEC}^2}{\text{FT}^4}\ \pi (20)^2\ \text{FT}^2 (32)\ \text{FT} \left(\frac{1}{12}\right) \frac{\text{FT}}{\text{IN}}$$

$$= 6500\ \frac{\text{lbf} \cdot \text{SEC}^2}{\text{IN.}}$$

CHECK THIS VALUE AGAINST 7-2 OF REF [5]

$$W_p = \frac{(2{,}508{,}431)\ \text{lbm}}{32.174\ \frac{\text{lbm} \cdot \text{FT}}{\text{lbf} \cdot \text{SEC}^2}} \cdot \frac{1\ \text{FT}}{12\ \text{IN}} = 6498\ \checkmark\ \text{OK}$$

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	S. PELLET SHP	11/10/93	JUN GAOR J-G	11/10/93					

I FOR THE SLOSHING MASS , EQ'N 10, REF[2]

$$M_s = 0.455 \pi \rho_\ell R^3 \tanh\left(\frac{1.84 H}{R}\right)$$

$$= 0.455 \pi (1.94) \frac{lbf \cdot sec^2}{ft^4} (20)^3 ft^3 \left(\frac{1}{12}\right)\frac{ft}{in} \tanh\left[1.84\left(\frac{32}{20}\right)\right]$$

$$= 1838 \frac{lbf\ sec^2}{in}$$

CHECKING THIS AGAINST FIG 4, REF[2] $H/R = 1.6 \Rightarrow M_s/m = 0.28$

GIVING $M_s = 0.28(6500)\frac{lbf\ sec^2}{in} = 1820 \frac{lb\ sec^2}{in}$ ∴ OK

USE $M_s = 1830 \frac{lbf\ sec^2}{in}$

OR $M_s = 1830 \frac{lbf \cdot sec^2}{in} (12)\frac{in}{ft} (32.2) \frac{lbm\ ft}{lbf\ sec^2} =$ **707,000 lbm**

$$H_s = \left[1 - \left(\frac{20}{1.84(32)}\right)\tanh\left(\frac{0.92(32)}{20}\right)\right] 32 ft = 22.22 ft$$

ABOVE BASE

OR **ELEV.** $22.2 + 9.0 =$ **31.22 FT**

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	S. PELLET SHP	11/10/93	JUN GAOR JG	11/10/93					

II FOR THE MASS OF THE DEFORMABLE LIQUID FILLED SHELL FROM FIG. 7, REF [2], $H/R = 1.6$ $h = 1/4''$, $h/R = 0.001$ & FIG. 8

GRAPH YIELDS $M_f/m = 0.68$ $H_f/H = 0.465$

$$M_f = 0.68(6500)\ \frac{lbf \cdot sec^2}{in} = 4420\ \frac{lbf \cdot sec^2}{in}$$

or M_f = **1,708,000 lbm**

AND

$$H_f = 0.465(32) = 14.9 \text{ FT ABOVE BASE}$$

or $H_f = 14.9 + 9 =$ **23.9' ELEV**

III FOR THE MASS ASSOCIATED WITH RIGID GROUND MOTION FROM FIG. 9 & FIG 10, REF [2]

GRAPHS YIELD $M_r/m = 0.71$; $H_r/H = 0.417$

$$M_r = 0.71(6500) = 4615\ \frac{lbf \cdot sec^2}{in}$$

or M_r = **1,783,000 lbm**

AND

$$H_r = 0.417(32) = 13.34 \text{ FT ABOVE BASE}$$

or $H_r = 13.3 + 9 =$ **22.3' ELEV.**

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	S. PELLET SHP	11/10/93	JUN GAOR JG.	11/10/93					

IV FOR THE MASS OF THE ROOF $R = 48', t = 1/4''$

$$M_{ROOF} = \rho_S \cdot S_{URFACE\ AREA} \cdot t_{HICKNESS}$$

$$S = 2\pi R h = 2\pi (48)(12)(52.2) = 189{,}000 \text{ IN}^2$$

$$M_{ROOF} = 500 \frac{\text{lbm}}{\text{FT}^3} \frac{(189000)\text{IN}^2 (0.25)\text{IN}}{(12)^3 \frac{\text{IN}^3}{\text{FT}^3}} = 13{,}700 \text{ lbm}$$

WHICH AGREES CLOSELY WITH REF [5]

THE HEIGHT OF THE CENTER OF GRAVITY OF THIS MASS MAY BE ESTIMATED AT 40" ABOVE THE TOP OF THE SHELL. THE DIMENSION IS NOT CRITICAL SINCE THIS MASS IS SMALL COMPARED TO OTHERS CALCULATED PREVIOUSLY.

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	S. PELLET SHP	11/10/93	JUN GAOR JG.	11/10/93					

DETERMINE TANK SHELL AND ROOF LATERAL STIFFNESSES. THE FLEXURAL RIGIDITY EQUATION FOR GENERAL PLATE THEORY IS GIVEN BY

$$D = \frac{E t^3}{12(1-\nu^2)}$$ REF [3] PAGE 160, REF [4] PAGE 326

$$= \frac{29\times10^6 \frac{lbs}{in^2} (t)^3 \ in^3}{12(1-(0.3)^2)}$$

SUBSTITUTING THE VARIOUS TANK SHELL AND ROOF THICKNESS WE OBTAIN:

t (in)	D (lbs/in)
3/16	17,500
1/4	41,500
5/16	81,050

THE SHELL MAY BE CONSIDERED RIGID IN THE PLANE TANGENT TO THE CURVATURE.

ROTATIONAL STIFFNESS IS DETERMINED BY REF [4] PAGE 351 AND CASE 5c PAGE 352 ASSUME a=1 b=6

$b/a = 0.16\bar{6}$ INTERPOLATING $\frac{0.1-0.3}{-0.1073-(-0.1626)} = \frac{0.1-1/6}{-0.1073-(K_{\theta_b})}$

$K_{\theta_b} = -0.126$ PLUGGING INTO EQUATION

$$\frac{M_o}{\theta} = \frac{D}{K_\theta a} = \frac{D}{-0.126(1)}$$ GIVING

t (in)	$\frac{M_o}{\theta}$ (in lb / RAD)
3/16	138,900
1/4	329,400
5/16	643,300

NES&L DEPARTMENT
CALCULATION SHEET

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	CCN CONVERSION CCN NO. CCN - 1

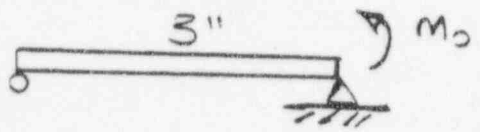
Project or DCP/MMP SONGS 3 Calc No. M-DSC-269

Subject See Title Sheet Sheet No. 190

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	S. PELLET SHP	11/10/93	JUN GAOR JG.	11/10/93					

A QUICK CHECK MAY SHOW THE VALIDITY OF THESE ROTATIONAL STIFFNESS.

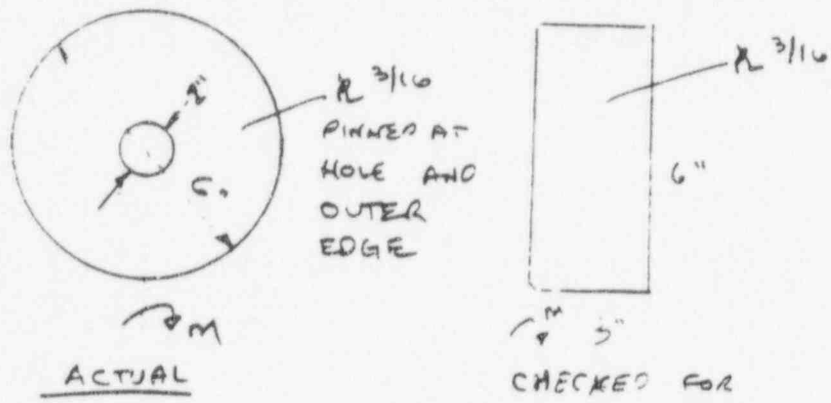
TAKE A SIMPLY SUPPORTED BEAM 3/16" DEEP BY 6" WIDE AND 3" LONG



$$\theta_0 = -\frac{M_0 L}{3EI} \quad \text{REF [1]}$$

$$\frac{M}{\Theta} = \frac{3EI}{L} = \frac{3(29\times10^6)\left(\frac{6(\frac{3}{16})^3}{12}\right)}{3}$$

$= 95,600 \ \frac{\text{IN LBS}}{\text{RAD}}$ WHICH IS ON THE SAME MAGNITUDE AS 138,900 FOUND FOR A 3/16" CIRCULAR PLATE. ∴ OK



ACTUAL

CHECKED FOR VALIDITY

STIFFNESS CALCULATED FOR BENDING ABOUT ℄

STIFFNESS CALCULATED FOR BENDING ABOUT LEFT EDGE.

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	S. PELLET SHP	11/10/93	JUN GAOR JC.	11/10/93					

TANK SHELL SECTION PROPERTIES

FOR $t = 5/16''$ $\qquad I_x = t \pi R^3$ REF [1]

$$I_x = (5/16)\,\pi\,[(20)(12)]^3 = 13{,}572{,}000 \text{ IN}^4$$

$$S_x = \frac{I_x}{R} = \frac{13\,572\,000}{(20)(12)} = 56{,}550 \text{ IN}^3$$

$$A = \pi(R_o^2 - R_i^2) = \pi\left[(240.3125)^2 - (240)^2\right]$$

$$= 471.5 \text{ IN}^2$$

FOR $t = 1/4''$

$$I_x = (1/4)\,\pi\,[(20)(12)]^3 = 10{,}857{,}000 \text{ IN}^4$$

$$S_x = \frac{I_x}{R} = \frac{10\,857\,000}{(20)(12)} = 45{,}238 \text{ IN}^3$$

$$A = \pi\left[(240 + 1/4)^2 - (240)^2\right] = 377 \text{ IN}^2$$

NES&L DEPARTMENT
CALCULATION SHEET

ICCN NO./ PRELIM. CCN NO. F-565	PAGE 193 OF 279
	CCN CONVERSION CCN NO. CCN - 1

Project or DCP/MMP SONGS 3 Calc No. M-DSC-269

Subject See Title Sheet Sheet No. 192

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	S. PILLET SHP	11/10/93	JUN GAOR J.C.	11/10/93					

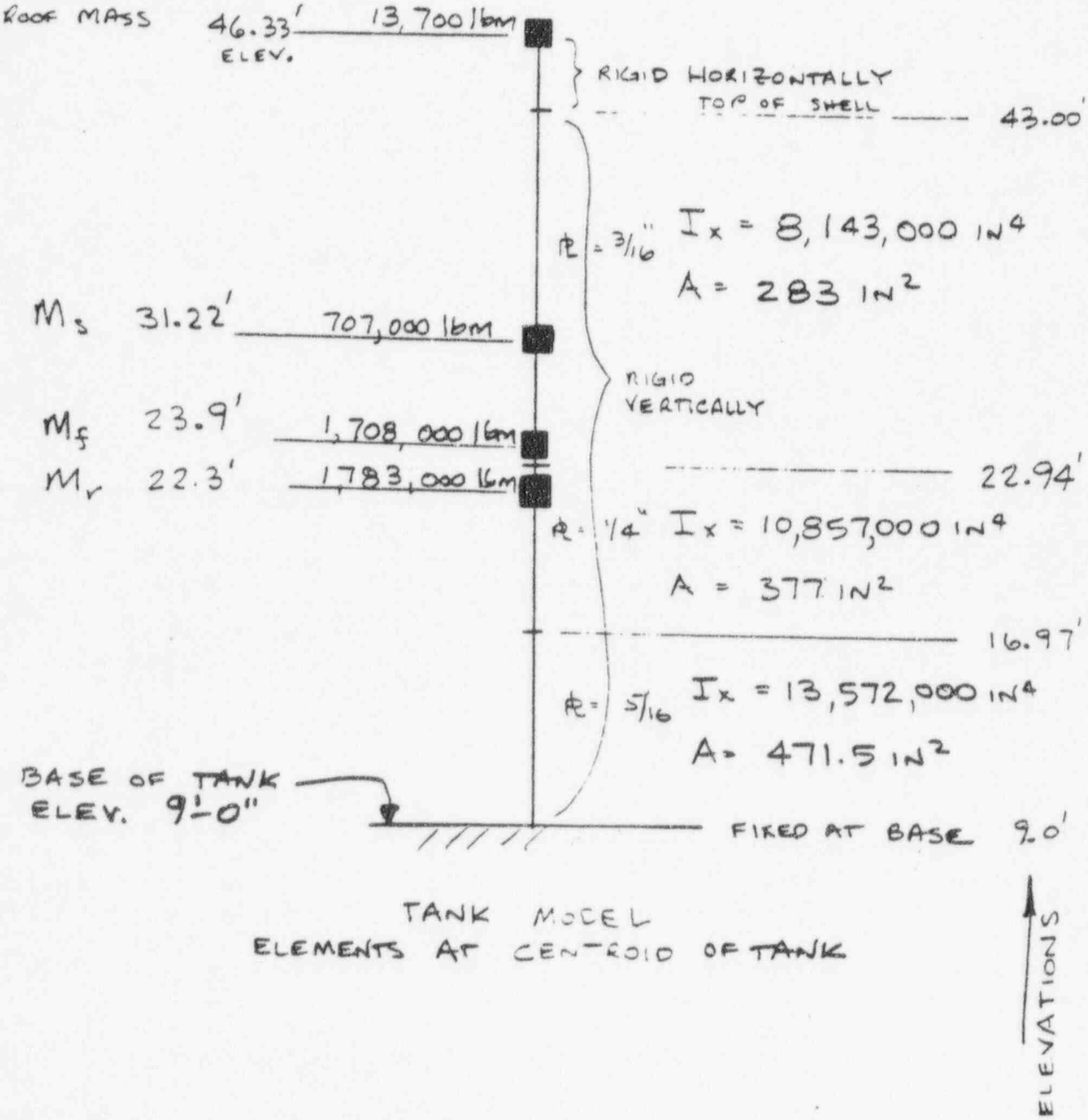
FOR $t = 3/16$

$$I_x = (3/16)\,\pi\,[(20)(12)]^3 = 8,143,000 \text{ IN}^4$$

$$S_x = \frac{8\,143\,000}{(20)(12)} = 33,930 \text{ IN}^3$$

$$A = \pi\,(240 + 3/16)^2 - (240)^2 = 283 \text{ IN}^2$$

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	S. PELLET SHP	11/10/93	JUN GAOR J-G.	11/10/93					



TANK MODEL
ELEMENTS AT CENTROID OF TANK

NES&L DEPARTMENT

CALCULATION SHEET

ICCN NO./ PRELIM. CCN NO. F-565	PAGE 196 OF 2??
	CCN CONVERSION CCN NO. CCN - 1

Project or DCP/MMP SONGS 3 Calc No. M-DSC-269

Subject See Title Sheet Sheet No. 194

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	NABIL M. EL-AKILY	10/12/93	JUN GAOR JG.	10/12/93					

APPENDIX - C

ANSYS AND ME101LS INPUT FILES

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	NABIL M. EL-AKILY	10/12/93	JUN GAOR J-G.	10/12/93					

List of ANSYS Input Files

File Name	Description	Sheet
PPMS1	Tank model with concentrated force of 1,000,000 lb applied near the top of the shell.	196
PPMS4	Tank model with forces applied at each shell node. Each force is 1,000 lb in magnitude.	201

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	NABIL M. EL-AKILY	10/12/93	JUN GAOR J.G.	10/12/93					

```
/PREP7
/TITLE,PRIMARY PLANT MAKE-UP TANK
C***FILE NAME: PPMS1.
C***
C***    FORCE APPLIED NEAR THE TOP
C***
KAN,0
C***
C***            ELEMENT TYPE: ELASTIC SHELL
ET,1,63
ET,2,8
C***
C***            MATERIAL PROPERTIES
EX,1,28.3E6                    * TANK SHELL (TYPE 304 SS)
NUXY,1,0.3                     *
EX,2,30.0E9
NUXY,2,0.3
C***
C***            REAL CONSTANTS
R,1,0.25                       * BOTTOM
R,2,0.3125                     * FIRST TIER
R,3,0.25                       * SECOND TIER
R,4,0.1875                     * THIRD TIER
R,5,0.25                       * ROOF
R,6,1.0                        * SPOKES
C***
C***            GEOMETRY
RT=240.0                       * TANK RADIUS
H1=95.625                      * HEIGHT TO TOP OF FIRST TIER
H2=167.25                      * HEIGHT TO TOP OF SECOND TIER
HT=408.0                       * TANK HEIGHT
RBL=243.0                      * BOLT CIRCLE RADIUS
RBT=246.0                      * OUTSIDE RADIUS OF THE BOTTOM
RR=576.0                       * ROOF RADIUS
A1=SQRT(RR*RR-RT*RT)
A2=HT-A1                       * CENTER OF COORDINATE SYSTEM 11
A3=A2+576.0
C***
C***            NODE DEFINITION
N,1,1.0                        * CENTER OF THE TANK
N,7,RT                         * TANK RADIUS
FILL,1,7                       *
N,9,RT,H1
FILL,7,9
```

NES&L DEPARTMENT

CALCULATION SHEET

ICCN NO./ F-565
PRELIM. CCN NO.

CCN CONVERSION
CCN NO. CCN - 1

Project or DCP/MMP SONGS 3 Calc No. M-DSC-269

Subject See Title Sheet Sheet No. 197

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	NABIL M. EL-AKILY	10/12/93	JUN GAOR JG.	10/12/93					

```
N,11,RT,H2
FILL,9,11
N,17,RT,HT
FILL,11,17
C***
N,23,1.0,A3
N,9000,0.,A2
NGEN,2,1,9000,,,1.0
NGEN,2,1,9001,,,,1.0
CS,11,1,9000,9001,9002
CSYS,11
FILL,17,23
C***
CSYS,0
N,24,RBL
N,25,RBT
C***
N,9003,0.,0.,0.
N,9004,1.0,,-1.0
CS,12,1,9003,7,9004
CSYS,12
NGEN,72,25,1,25,,,5.0
NDEL,9000,9004
C***
CSYS,0
N,1801,,367.875
C***
C***          ELEMENT DEFINITION
MAT,1
TYPE,1
REAL,1                        * BOTTOM
E,1,2,27,26
EGEN,6,1,1
E,7,24,49,32
E,24,25,50,49
EGEN,71,25,1,8
E,1776,1777,2,1
EGEN,6,1,569
E,1782,1799,24,7
E,1799,1800,25,24
C***
REAL,2                        * FIRST TIER
E,7,8,33,32
EGEN,71,25,577
```

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	NABIL M. EL-AKILY	10/12/93	JUN GAOR J.G.	10/12/93					

```
E,1782,7,8,1783
EGEN,2,1,577,648
C***
REAL,3                         * SECOND TIER
E,9,34,35,10
EGEN,71,25,721
E,1784,9,10,1785
EGEN,2,1,721,792
C***
REAL,4                         * THIRD TIER
E,11,36,37,12
EGEN,71,25,865
E,1786,11,12,1787
EGEN,6,1,865,936
C***
REAL,5                         * ROOF
E,17,42,43,18
EGEN,71,25,1297
E,1792,17,18,1793
EGEN,6,1,1297,1368
C***
MAT,2
TYPE,2
REAL,6                         * SPOKES
E,1801,16
E,1801,41
E,1801,66
E,1801,91
E,1801,116
E,1801,141
E,1801,166
E,1801,191
E,1801,216
E,1801,241
E,1801,266
E,1801,291
E,1801,316
E,1801,341
E,1801,366
E,1801,391
E,1801,416
E,1801,441
E,1801,466
E,1801,491
```

NES&L DEPARTMENT

CALCULATION SHEET

ICCN NO./ PRELIM. CCN NO. F 565	PAGE 199 OF 211
CCN CONVERSION CCN NO. CCN - 1	

Project or DCP/MMP SONGS 3 Calc No. M-DSC-269

Subject See Title Sheet Sheet No. 199

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	NABIL M. EL-AKILY	10/12/93	JUN GAOR J.G.	10/12/93					

E,1801,516
E,1801,541
E,1801,566
E,1801,591
E,1801,616
E,1801,641
E,1801,666
E,1801,691
E,1801,716
E,1801,741
E,1801,766
E,1801,791
E,1801,816
E,1801,841
E,1801,866
E,1801,891
E,1801,916
E,1801,941
E,1801,966
E,1801,991
E,1801,1016
E,1801,1041
E,1801,1066
E,1801,1091
E,1801,1116
E,1801,1141
E,1801,1166
E,1801,1191
E,1801,1216
E,1801,1241
E,1801,1266
E,1801,1291
E,1801,1316
E,1801,1341
E,1801,1366
E,1801,1391
E,1801,1416
E,1801,1441
E,1801,1466
E,1801,1491
E,1801,1516
E,1801,1541
E,1801,1566
E,1801,1591

NES&L DEPARTMENT

CALCULATION SHEET

ICCN NO./ F.565
PRELIM. CCN NO.

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CCN CONVERSION
CCN NO. CCN - 1

Project or DCP/MMP SONGS 3 Calc No. M-DSC-269

Subject See Title Sheet Sheet No. 200

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	NABIL M. EL-AKILY	10/12/93	JUN GAOR J.G.	10/12/93					

```
E,1801,1616
E,1801,1641
E,1801,1666
E,1801,1691
E,1801,1716
E,1801,1741
E,1801,1766
E,1801,1791
C***
C***           LOADING AND BOUNDARY CONDITIONS
WSORT,ALL
NSEL,,24,1799,25              * FIXED NODES ALONG THE BOLT CIRCLE
D,ALL,ALL                     *
NALL                          *
C***
ITER,-10000,10000,1
F,1801,FX,1000000.0            * FORCE APPLIED AT THE CENTER
C***
AFWRITE
FINISH
/INPUT,27
FINISH
```

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	NABIL M. EL-AKILY	10/12/93	JUN GAOR JG.	10/12/93					

```
/PREP7
/TITLE,PRIMARY PLANT MAKE-UP TANK
C***FILE NAME: PPMS4
C***
C***      UNIFORMLY DISTRIBUTED FORCE ABOVE BOTTOM
C***
KAN,0
C***
C***          ELEMENT TYPE: ELASTIC SHELL
ET,1,63
ET,2,8
C***
C***          MATERIAL PROPERTIES
EX,1,28.3E6                  * TANK SHELL (TYPE 304 SS)
NUXY,1,0.3                   *
C***
C***          REAL CONSTANTS
R,1,0.25,0.25,0.25,0.25,30000.0      * BOTTOM
R,2,0.3125                           * FIRST TIER
R,3,0.25                             * SECOND TIER
R,4,0.1875                           * THIRD TIER
R,5,0.25                             * ROOF
C***
C***          GEOMETRY
RT=240.0                     * TANK RADIUS
H1=95.625                    * HEIGHT TO TOP OF FIRST TIER
H2=167.25                    * HEIGHT TO TOP OF SECOND TIER
HT=408.0                     * TANK HEIGHT
RBL=243.0                    * BOLT CIRCLE RADIUS
RBT=246.0                    * OUTSIDE RADIUS OF THE BOTTOM
RR=576.0                     * ROOF RADIUS
A1=SQRT(RR*RR-RT*RT)
A2=HT-A1                     * CENTER OF COORDINATE SYSTEM 11
A3=A2+576.0
C***
C***          NODE DEFINITION
N,1,1.0                      * CENTER OF THE TANK
N,7,RT                       * TANK RADIUS
FILL,1,7                     *
N,9,RT,H1
FILL,7,9
N,11,RT,H2
FILL,9,11
N,17,RT,HT
```

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	NABIL M. EL-AKILY	10/12/93	JUN GAOR J.G.	10/12/93					

```
FILL,11,17
C***
N,23,1.0,A3
N,9000,0.,A2
NGEN,2,1,9000,,,1.0
NGEN,2,1,9001,,,,1.0
CS,11,1,9000,9001,9002
CSYS,11
FILL,17,23
C***
CSYS,0
N,24,RBL
N,25,RBT
C***
N,9003,0.,0.,0.
N,9004,1.0,,-1.0
CS,12,1,9003,7,9004
CSYS,12
NGEN,72,25,1,25,,,5.0
NDEL,9000,9004
C***
CSYS,0
C***
C***          ELEMENT DEFINITION
MAT,1
TYPE,1
REAL,1                    * BOTTOM
E,1,2,27,26
EGEN,6,1,1
E,7,24,49,32
E,24,25,50,49
EGEN,71,25,1,8
E,1776,1777,2,1
EGEN,6,1,569
E,1782,1799,24,7
E,1799,1800,25,24
C***
REAL,2                    * FIRST TIER
E,7,8,33,32
EGEN,71,25,577
E,1782,7,8,1783
EGEN,2,1,577,648
C***
REAL,3                    * SECOND TIER
```

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	NABIL M. EL-AKILY	10/12/93	JUN GAOR J.G.	10/12/93					

```
E,9,34,35,10
EGEN,71,25,721
E,1784,9,10,1785
EGEN,2,1,721,792
C***
REAL,4                        * THIRD TIER
E,11,36,37,12
EGEN,71,25,865
E,1786,11,12,1787
EGEN,6,1,865,936
C***
REAL,5                        * ROOF
E,17,42,43,18
EGEN,71,25,1297
E,1792,17,18,1793
EGEN,6,1,1297,1368
C***
C***           LOADING AND BOUNDARY CONDITIONS
WSORT,ALL
NSEL,,24,1799,25              * FIXED NODES ALONG THE BOLT CIRCLE
D,ALL,ALL                     *
NALL                          *
C***
ITER,-10000,10000,1
NSEL,Y,2.0,500.0
F,ALL,FX,1000.0               * FORCE APPLIED
NALL
C***
AFWRITE
FINISH
/INPUT,27
FINISH
```

APPENDIX - D

REFERENCE DOCUMENTS

Primary Plant Makeup Storage Tank (PPMST) Nozzles

NOZZLE	SIZE	QUANTITY	ELEVATION	DESCRIPTIONS/REMARKS
A	3"	1	10'-7"	CCW Safety Related Makeup Pumps Suction
B	1"	1	16'-0"	CCW Safety Related Makeup Pumps Miniflow Back to the PPMST
[redacted]				
F	2½"	1	31'-0"	Existing Fill Line for the PPMST (Relocated)
G	2"	1	31'-0"	Existing PPMST Pumps Recirc to the PPMST (Relocated)
H	4"	1	31'-0"	Existing Suction Line for the PPMST Pumps (Relocated)
J	4"	1	9'-9 13/16"	Existing PPMST Overflow Line
K	3"	1	8'-5"	Existing PPMST Drain Line
L	2"	2	9'-6" 42'-0"	Existing Level Transmitter Taps
M	2"	1	9'-8"	Existing PPMST Pumps Recirc to the PPMST (to be capped)
N	2½"	1	9'-7 11/16"	Existing Fill Line for the PPMST Pumps (to be capped)
P	4"	1	9'-6 13/16"	Existing Suction Line for the PPMST Pumps (to be capped)

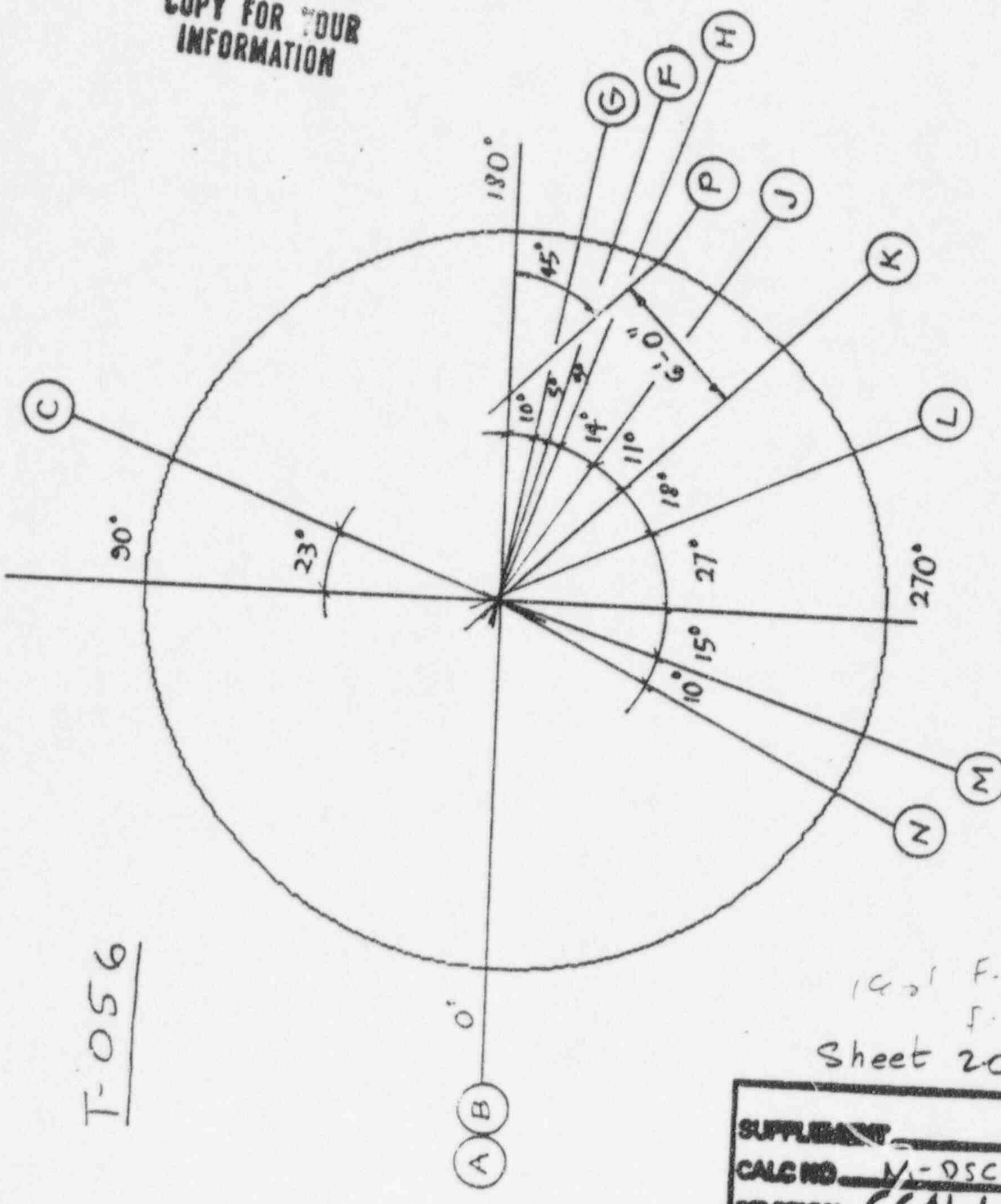
NOTE: All elevations are pipe centerline elevations.

COPY FOR YOUR INFORMATION

F-565 p.205

SHT. 205

SUPPLEMENT
CALC NO M-DSC-269
REVISION CCN 1
BY — DATE —
CHECKED — DATE —



UNIT 2

T-056

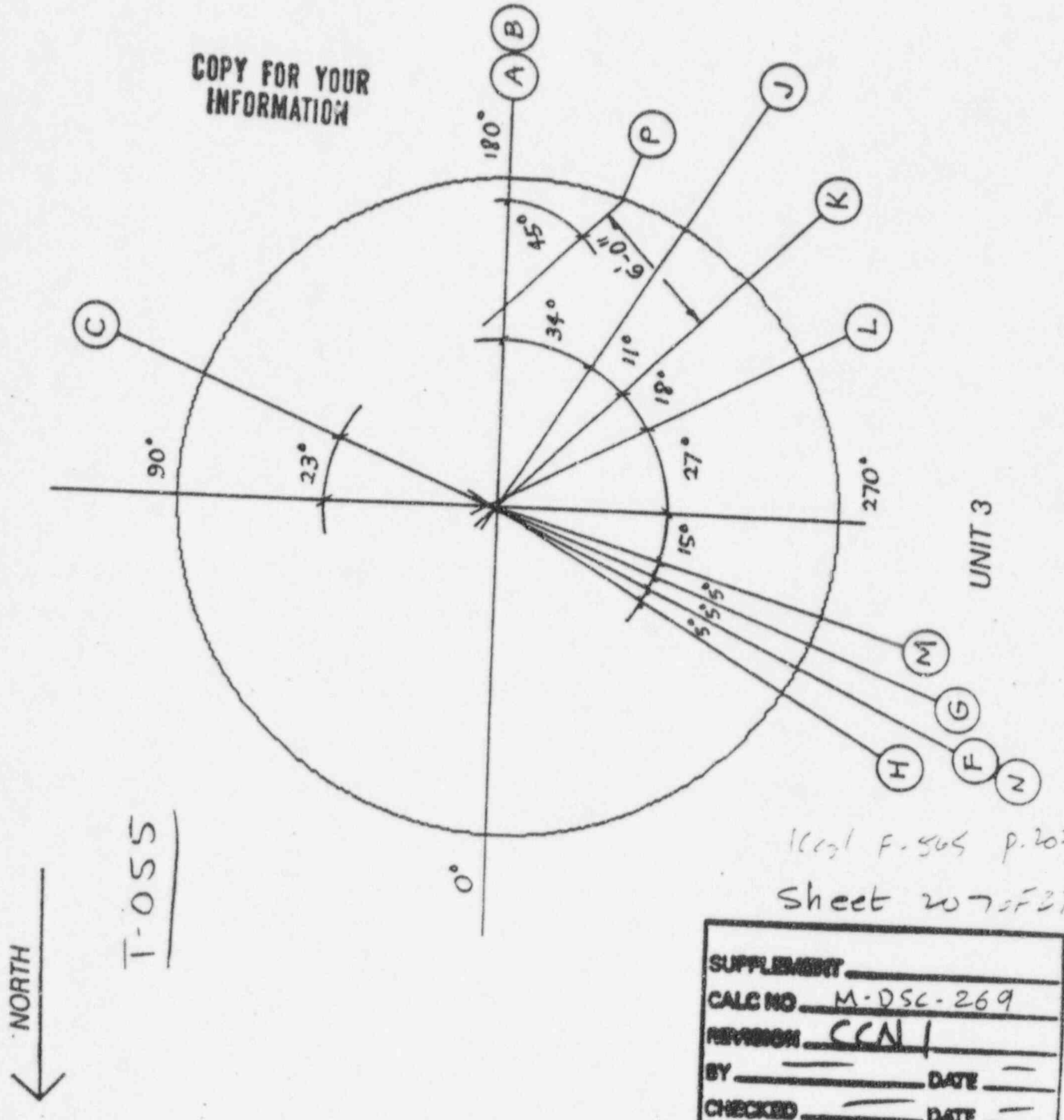
NORTH

14.21 F.565
F.206

Sheet 206 of 279

SUPPLEMENT
CALC NO. N-DSC-269
REVISION CCN 1
BY ______ DATE ______
CHECKED ______ DATE ______

COPY FOR YOUR INFORMATION



Sheet 207 of 277

SUPPLEMENT ______
CALC NO. M-DSC-269
REVISION CCN 1
BY — DATE —
CHECKED — DATE —

CALCULATION SHEET

ICCN NO./ PRELIM. CCN NO.	PAGE OF

Project or DCP/MMP 2 & 3 - 6742.07 SM Calc No. M-1203-476-2A

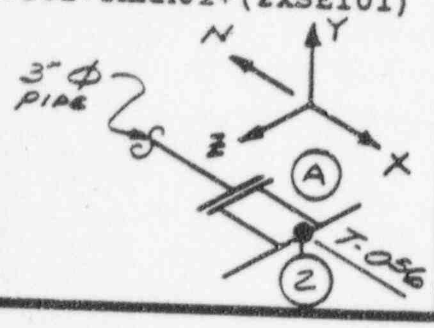
CCN CONVERSION
CCN NO. CCN -

Subject SEE TITLE SHEET

Sheet No. ______

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
0	P. DE ALDAY	02-23-93	[signature]	2/23/93					

8.6 EQUIPMENT NOZZLE LOADS EVALUATIONS (CONT'D)

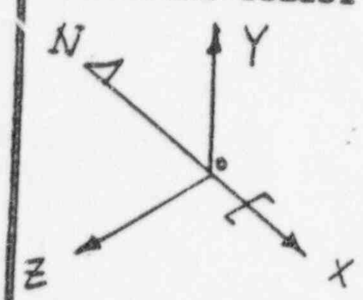
EQUIPMENT I.D./ DATA POINT	FORCE (LBS) MOMENT (FT-LBS)	ALLOWABLE (*) (LBS & FT-LBS)	REMARK
Tank - T056 Nozzle A / 2 / WT01	Fx = 0 / Fy = + 58 / Fz = 0 / Mx = - 67 / My = 0 / Mz = -130 /	- COPY FOR YOUR INFORMATION	
THRM01	Fx = -755 / Fy = + 12 / Fz = -287 / Mx = + 10 / My = -237 / Mz = - 38 /	-	
SEIS01	Fx = 86 / Fy = 28 / Fz = 37 / Mx = 45 / My = 47 / Mz = 115 /	-	Seismic loads are +/-
TOTAL LOADS: WT01+THRM01+(2xSEI01) 	Fx = +172 / -927 / Fy = +126 / 0 / Fz = + 74 / -361 / Mx = + 33 / -157 / My = + 94 / -331 / Mz = +100 / -398 /	ICCN F-565 P.208 - SHT. 208 OF 279 SUPPLEMENT ____ CALC NO. M-DSC-269 REVISION CCN 1 BY ____ DATE ____ CHECKED ____ DATE ____	See note (1)

Notes : (1) Tank nozzle loads are evaluated in calculation M-DSC-269 Rev. 0

SCE 26-426 NEW 4/90

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
0	TAO VAN NGUYEN	12-09-92	[signature]	12/10/92					

8.6 EQUIPMENT NOZZLE LOADS EVALUATIONS (Cont'd.)

EQUIPMENT I.D./ DATA POINT/ LDCASE	FORCE (LBS) MOMENT (FT-LBS)	ALLOWABLE (LBS & FT-LBS)	REMARK
Tank -T056 Nozzle B / 2A / WT1	FX = + 3 / FY = - 15 / FZ = + 2 / MX = - 2 / MY = + 5 MZ = - 2 /		
THRM1	FX = + 3 / FY = - 3 / FZ = + 3 / MX = + 2 / MY = + 5 / MZ = + 12 /	-	
SEIS1	FX = 30 / FY = 7 / FZ = 25 / MX = 2 / MY = 60 / MZ = 6	-	Seismic loads are +/-
TOTAL LOADS: WT1+THRM1+2SEIS1 	FX = + 66 / - 66 FY = + 32 / = - 32 FZ = + 55 / = - 55 MX = + 6 / = - 6 MY = +130 / = -130 MZ = + 22 / = - 22	-	SAM Loads are negligible See note (1)

Notes : (1) Tank nozzle loads are evaluated in calculation M-DSC-269 Rev.0

ICCN F-565 P. 209

SHT 209

SUPPLEMENT
CALC NO. M-DSC-269
REVISION CCN 1
BY — DATE —
CHECKED — DATE —

NES&L DEPARTMENT

CALCULATION SHEET

SUPPLEMENT "A"

ICCN NO./ C-1 F-565
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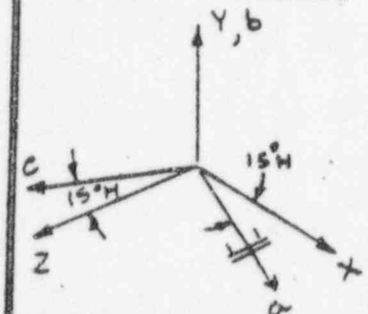
CCN CONVERSION
CCN NO. CCN -

Subject SEE TITLE SHEET   Sheet No. A - 28

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
0	S.BISWAS	12-23-92	TVN	12-30-92					

8.6 EQUIPMENT NOZZLE LOADS EVALUATIONS

EQUIPMENT I.D./ DATA POINT/ LDCASE	FORCE (LBS) MOMENT (FT-LBS)	ALLOWABLE (LBS & FT-LBS)	REMARK
Tank -T056 Nozzle ØF / 5 / WT1	FA = + 3 FB = - 67 FC = - 1 MA = + 1 MB = + 1 MC = - 60	-	
THRM1	FA = - 62 FB = + 43 FC = - 9 MA = + 6 MB = + 12 MC = - 79	-	
SEIS1	FA = 36 FB = 152 FC = 44 MA = 32 MB = 46 MC = 189	-	Seismic loads are +/-
TOTAL LOADS: WT1+THRM1+2SEIS1 	FA = + 131 / - 131 FB = + 371 / = - 371 FC = + 98 / = - 98 MA = + 71 / = - 71 MB = + 105 / = - 105 MC = + 517 / = - 517	-	See note (1)

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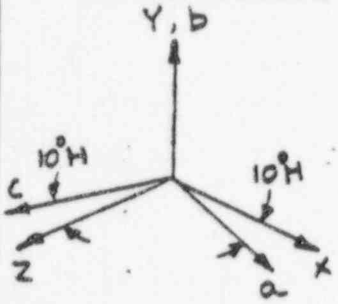
ICCN F-565
SHT 210 of 279

SUPPLEMENT ___
CALC NO. M-DSC-269
REVISION CCN 1
BY ___ DATE ___
CHECKED ___ DATE ___

Notes : (1) Tank nozzle loads are evaluated in calculation M-DSC-269 Rev.0

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
0	S.BISWAS	01-04-93	[signature]	1-6-93					

8.6 EQUIPMENT NOZZLE LOADS EVALUATIONS

EQUIPMENT I.D./ DATA POINT/ LDCASE	FORCE (LBS) MOMENT (FT-LBS)	ALLOWABLE (LBS & FT-LBS)	REMARK
Tank -T056 Nozzle G / 5 / WT1	FA = + 6 FB = - 84 FC = + 2 MA = - 2 MB = - 4 MC = - 85	-	-
THRM1	FA = - 28 FB = + 11 FC = - 1 MA = + 1 MB = + 2 MC = - 62	-	
SEIS1	FA = 50 FB = 502 FC = 62 MA = 34 MB = 85 MC = 587	-	Seismic loads are +/-
TOTAL LOADS: WT1+THRM1+2SEIS1 	FA = + 106 / - 122 FB = + 931 / = -1088 FC = + 126 / = - 123 MA = + 67 / = - 70 MB = + 168 / = - 174 MC = +1089 / = -1321	-	See note (1)

Notes : (1) Tank nozzle loads are evaluated in calculation M-DSC-269 Rev.0

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Iccn F.565
SHT. 211 of 279

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SUPPLEMENT ___
CALC NO M-DSC-269
REVISION CCN 1
BY ___ DATE ___
CHECKED ___ DATE ___

CALCULATION SHEET

SUPPLEMENT "A"

CCN NO./ C-1 F-565 PRELIM. CCN NO.	PAGE 27 of 61
	CCN CONVERSION CCN NO. CCN -

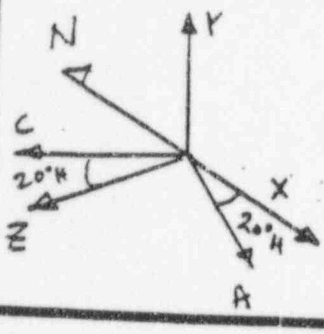
Project or DCP/MMP 2 & 3 - 6742.07 SM Calc No. S-1415-06

Subject SEE TITLE SHEET

Sheet No. A - 26

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
0	TAO VAN NGUYEN	12-17-92	[signature]	12-22-92					

8.6 EQUIPMENT NOZZLE LOADS EVALUATIONS

EQUIPMENT I.D./ DATA POINT/ LDCASE	FORCE (LBS) MOMENT (FT-LBS)	ALLOWABLE (LBS & FT-LBS)	REMARK
Tank -T056 Nozzle H / 3C1 / WT1	FA = 13 FB = - 137 FC = 19 MA = - 17 MB = - 46 MC = - 180	-	
THRM1	FA = - 68 FB = 8 FC = + 14 MA = - 14 MB = - 33 MC = - 208	-	
SEIS1	FA = 116 FB = 258 FC = 119 MA = 42 MB = 181 MC = 512	-	Seismic loads are +/-
TOTAL LOADS: WT1+THRM1+2SEIS1 	FA = + 245 / - 287 FB = + 387 / = - 653 FC = + 271 / = - 219 MA = + 67 / = - 115 MB = + 316 / = - 441 MC = + 844 / = -1412	-	See note (1)

CCN INFORMATION (stamp, partial)

p. 217 (test p. 567)

SHT 212 of 27

SUPPLEMENT ______
CALC NO. M-DSC-269
REVISION CCN 1
BY ______ DATE ______
CHECKED ______ DATE ______

Notes : (1) Tank nozzle loads are evaluated in calculation M-DSC-269 Rev.0

NES&L DEPARTMENT

CALCULATION SHEET

Supplement "A"

ICCN NO./ PRELIM. CCN NO. C-1 F-565 | PAGE 213 OF 279

Project or DCP/MMP 2&3 - 6742.07 SM | Calc No. S-1415-37 | CCN CONVERSION CCN NO.

Subject See Title Sheet | Sheet No. A -

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
0	LI-FENG YANG	2-17-93	sml	2/19/93					

8.6 Equipment Nozzle Loads Evaluation :

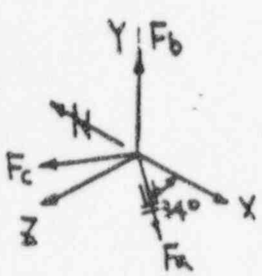
COPY FOR YOUR INFORMATION

ICCN F-565 p.213

SHT. 213

SUPPLEMENT
CALC NO M-DSC-269
REVISION CCN1
BY ___ DATE ___
CHECKED ___ DATE ___

Equipment I.D. / Data Point / Loadcase	Force (Lbs) Moment (Ft-lbs)		Remark
Tank T-056 and T-055 Nozzle J / D.P. A1 / Dead Weight	Fa = - 6 Fb = - 564 Fc = + 0	Ma = - 1 Mb = + 0 Mc = - 356	
Thermal	Fa = - 1 Fb = + 0 Fc = + 0	Ma = + 0 Mb = - 1 Mc = + 4	
SAM (DBE)	Fa = 1 Fb = 103 Fc = 5	Ma = 35 Mb = 4 Mc = 71	SAM loads are +/-
Seismic (DBE)	Fa = 87 Fb = 610 Fc = 90	Ma = 166 Mb = 102 Mc = 385	Seismic loads are +/-
Total Design Load	Fa = + 81 - 93 Fb = + 54 - 1183 Fc = + 90 - 90 Ma = + 169 - 170 Mb = + 102 - 103 Mc = + 39 - 748		See Note (1)



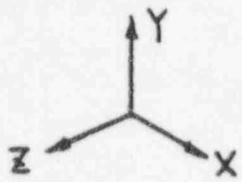
Note : 1) Nozzle loads are qualified by calc. M-DSC-269 Rev. 0

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
0	LI-FENG YANG	2-19-93	Bmf	2-19-93					

SUPPLE... CALC M-DSC-269 CCN 1 BY ... DATE ... CHK ... DATE

8.6 Equipment Nozzle Loads Evaluation :

SHT. 214

Equipment I.D. / Data Point / Loadcase	Force (Lbs) Moment (Ft-lbs)	Remark
Tank T-056 and T-055 Nozzle K / D.P. 5 / Dead Weight	Fx = + 0 Fy = - 188 Fz = + 0 Mx = + 287 My = + 0 Mz = - 287	COPY FOR YOUR INFORMATION
Seismic (OBE)	Fx = 182 Fy = 146 Fz = 182 Mx = 244 My = 512 Mz = 244	Seismic loads are +/-
Total Design Load Dead weight + 2(Seismic) 	Fx = + 182 - 182 Fy = + 0 - 334 Fz = + 182 - 182 Mx = + 531 - 0 My = + 512 - 512 Mz = + 0 - 531	See Note (1)

ICN 1 F-565 p. 214

Note : 1) Nozzle loads are qualified by calc. M-DSC-269 Rev. 0

NES&L DEPARTMENT

CALCULATION SHEET

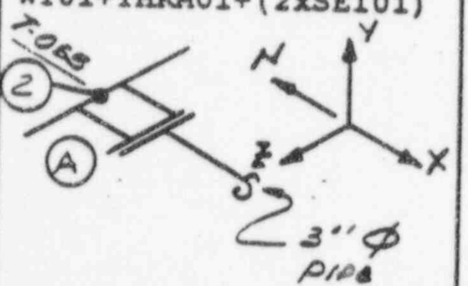
ICCN NO./ PRELIM. CCN NO. F-565	PAGE 215 OF 279
	CCN CONVERSION CCN NO. CCN -

Project or DCP/MMP 2 & 3 - 6742.07 SM Calc No. M-1203-476-3A

Subject SEE TITLE SHEET Sheet No. ______

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
0	P. DE ALDAY	02-23-93	[signature]	3/24/93					

8.6 **EQUIPMENT NOZZLE LOADS EVALUATIONS (CONT'D)**

EQUIPMENT I.D./ DATA POINT	FORCE (LBS) MOMENT (FT-LBS)	ALLOWABLE (*) (LBS & FT-LBS)	REMARK
Tank - T055 Nozzle A / 2 / WT01	Fx = 0 / Fy = + 58 / Fz = 0 / Mx = - 67 / My = 0 / Mz = +130 /	-	
THRM01	Fx = +755 / Fy = + 12 / Fz = -287 / Mx = + 10 / My = +237 / Mz = + 38 /	-	
SEIS01	Fx = 86 / Fy = 28 / Fz = 37 / Mx = 45 / My = 47 / Mz = 115 /	-	Seismic loads are +/-
TOTAL LOADS: WT01+THRM01+(2xSEI01)  	Fx = +927 / -172 / Fy = +126 / - 0 / Fz = + 74 / -361 / Mx = + 33 / -157 / My = +331 / - 94 / Mz = +398 / -100 /	-	See note (1)

COPY FOR YOUR INFORMATION

T-755 ICCN F-565 SHT. 215

SUPPLEMENT ______
CALC NO M-DSC-269
REVISION CCN 1
BY ______ DATE ______
CHECKED ______ DATE ______

Notes : (1) Tank nozzle loads are evaluated in calculation M-DSC-269 Rev. 0

NES&L DEPARTMENT

CALCULATION SHEET

ICCN NO./ PRELIM. CCN NO. F-565

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Project or DCP/MMP 2 & 3 - 6742.07 SM Calc No. M-1203-478-3A

CCN CONVERSION CCN NO. CCN -

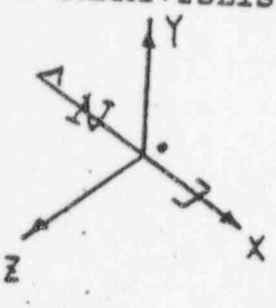
Subject SEE TITLE SHEET

Sheet No. 37

REV	ORIGINATOR	DATE	IRE.	DATE	REV	ORIGINATOR	DATE	IRE	DATE
0	TAO VAN NGUYEN	12-15-92	[signature]	12/22/92					

8.6 EQUIPMENT NOZZLE LOADS EVALUATIONS (Cont'd.)

COPY FOR YOUR INFORMATION

EQUIPMENT I.D./ DATA POINT/ LDCASE	FORCE (LBS) MOMENT (FT-LBS)	ALLOWABLE (LBS & FT-LBS)	REMARK
Tank -T055 Nozzle B / 2A / WT1	FX = - 2 FY = - 15 FZ = + 2 MX = - 2 MY = - 5 MZ = + 2	-	-
THRM1	FX = - 3 FY = - 3 FZ = + 3 MX = + 2 MY = - 5 MZ = - 12	-	
SEIS1	FX = 27 FY = 7 FZ = 24 MX = 2 MY = 59 MZ = 6	-	Seismic loads are +/-
TOTAL LOADS: WT1+THRM1+2SEIS1  	FX = + 59 / - 59 FY = + 32 / = - 32 FZ = + 53 / = - 53 MX = + 6 / = - 6 MY = +128 / = -128 MZ = + 22 / = - 22	-	SAM Loads are negligible See note (1)

SHT. 216

SUPPLEMENT
CALC NO M-DSC-269
REVISION CCN 1
BY ____ DATE ____
CHECKED ____ DATE ____

Notes : (1) Tank nozzle loads are evaluated in calculation M-DSC-269 Rev.0

NES&L DEPARTMENT
CALCULATION SHEET

SHT. D-14

ICCN NO./ PRELIM. CCN NO. F-565	PAGE 217 OF 279
CCN CONVERSION: CCN NO. CCN -	

Project or DCP/MMP 2 & 3 - 6742.07 SM Calc No. M-1203-482-AA

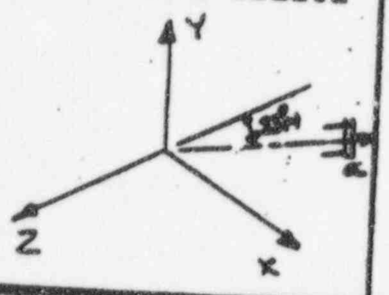
Subject SEE TITLE SHEET Sheet No. 32

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
0	S. BISWAS	12-18-92	[signature]	12/22/92					

NOTE : THIS NOZZLE IS NO LONGER USED AND IS CAPPED. LOADS INCLUDED HERE ARE FOR INFORMATION ONLY.

8.6 EQUIPMENT NOZZLE LOADS EVALUATIONS (CONT'D)

p. 217

EQUIPMENT I.D./ DATA POINT	FORCE (LBS) MOMENT (FT-LBS)	ALLOWABLE (*) (LBS & FT-LBS)	REMARK
Tank - T055 Nozzle C /455/ WT01	Fa = - 2 Fb = + 64 Fc = - 7 Ma = - 2 Mb = - 22 Mc = - 76	-	
THRM01	Fa = + 17 Fb = + 5 Fc = - 2 Ma = + 2 Mb = - 13 Mc = - 63	-	
SEIS01	Fa = 71 Fb = 211 Fc = 108 Ma = 19 Mb = 233 Mc = 410	-	Seismic loads are +/-
TOTAL LOADS: WT01+THRM01+2SEI01 	Fa = +157 -157 Fb = +491 -491 Fc = +225 -225 Ma = + 40 - 40 Mb = +501 -501 Mc = +959 -959	-	See note (1)

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Kcopy F-565 SHT. 217

SUPPLEMENT
CALC NO M-DSC-269
REVISION CCN 1
BY — DATE —
CHECKED — DATE —

Notes : (1) Tank nozzle loads are evaluated in calculation M-DSC-269 Rev. 0

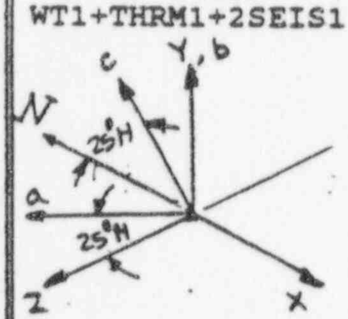
Project or DCP/MMP 2 & 3 - 6742.07 SM Calc No. S-1415-04

CCN CONVERSION
CCN NO. CCN -

Subject SEE TITLE SHEET Sheet No. A - 27

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
0	S.BISWAS	12-29-92	TVN	1-4-93					

8.6 EQUIPMENT NOZZLE LOADS EVALUATIONS

EQUIPMENT I.D./ DATA POINT/ LDCASE	FORCE (LBS) MOMENT (FT-LBS)	ALLOWABLE (LBS & FT-LBS)	REMARK
Tank -T05Ø5 Nozzle ØF / 5 / WT1	FA = - 1 FB = + 44 FC = + 2 MA = + 1 MB = - 5 MC = + 40	-	
THRM1	FA = - 60 FB = - 29 FC = + 1 MA = + 1 MB = + 1 MC = + 42	-	
SEIS1	FA = 85 FB = 255 FC = 73 MA = 23 MB = 132 MC = 557	-	Seismic loads are +/-
TOTAL LOADS: WT1+THRM1+2SEIS1 	FA = + 231 / - 231 FB = + 554 / = - 554 FC = + 149 / = - 149 MA = + 48 / = - 48 MB = + 269 / = - 269 MC = +1196 / = -1196	-	See note (1)

p. 218

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T05 F.565

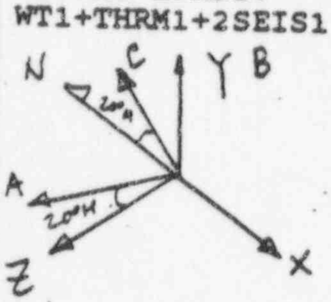
SHT. 218 of 279

SUPPLEMENT
CALC NO. M-DSC-269
REVISION CCN 1
BY DATE
CHECKED DATE

Notes : (1) Tank nozzle loads are evaluated in calculation M-DSC-269 Rev.0

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
0	TAO VAN NGUYEN	12-28-92	[signature]	12-28-92					

8.6 EQUIPMENT NOZZLE LOADS EVALUATIONS

EQUIPMENT I.D./ DATA POINT/ LDCASE	FORCE (LBS) MOMENT (FT-LBS)	ALLOWABLE (LBS & FT-LBS)	REMARK
Tank -T055 Nozzle ~~F~~ G TVN 12/28/92 / 3C1 / WT1	FA = 0 FB = + 24 FC = + 1 MA = + 1 MB = - 2 MC = + 9	-	
THRM1	FA = - 19 FB = - 40 FC = + 4 MA = + 4 MB = - 13 MC = - 56	-	
SEIS1 (OBE)	FA = 43 FB = 91 FC = 81 MA = 9 MB = 192 MC = 205	-	Seismic loads are +/-
TOTAL LOADS: WT1+THRM1+2SEIS1 	FA = + 86 / - 105 FB = + 206 / = - 198 FC = + 167 / = - 161 MA = + 23 / = - 17 MB = + 382 / = - 399 MC = + 419 = - 457	-	See note (1)

Notes : (1) Tank nozzle loads are evaluated in calculation M-DSC-269 Rev.0

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SHT. 219

SUPPLEMENT ___
CALC NO. M-DSC-269
REVISION CCN 1
BY — DATE —
CHECKED — DATE —

CALCULATION SHEET

SUPPLEMENT "A"

ICCN NO./ C-1 F-565 PRELIM. CCN NO.	PAGE 27 OF 61

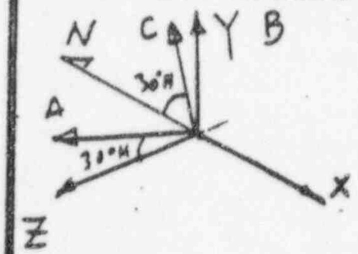
CCN CONVERSION CCN NO. CCN -

Project or DCP/MMP 2 & 3 - 6742.07 SM Calc No. S-1415-07

Subject SEE TITLE SHEET Sheet No. A - 26

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
0	TAO VAN NGUYEN	12-19-92	[signature]	12-22-92					

8.6 EQUIPMENT NOZZLE LOADS EVALUATIONS

EQUIPMENT I.D./ DATA POINT/ LDCASE	FORCE (LBS) MOMENT (FT-LBS)	ALLOWABLE (LBS & FT-LBS)	REMARK
Tank -T055 Nozzle H / 3C1 / WT1	FA = + 19 FB = + 181 FC = - 13 MA = - 14 MB = + 50 MC = + 362	-	
THRM1	FA = - 35 FB = - 24 FC = - 3 MA = - 6 MB = - 3 MC = 71	-	
SEIS1 (OBE)	FA = 136 FB = 542 FC = 230 MA = 47 MB = 638 MC = 1606	-	Seismic loads are +/-
TOTAL LOADS: WT1+THRM1+2SEIS1 	FA = + 291 / - 288 FB = +1265 / = - 927 FC = + 447 / = - 476 MA = + 80 / = - 114 MB = +1326 / = -1229 MC = +3645 / = -2850	-	See note (1)

Notes : (1) Tank nozzle loads are evaluated in calculation M-DSC-269 Rev.0

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p. 224 F-565 +ccn1 SHT. 220 of 279

SUPPLEMENT
CALC NO M-DSC-269
REVISION CCN 1
BY — DATE —
CHECKED — DATE —

NES&L DEPARTMENT

CALCULATION SHEET

SUPPLEMENT B

CCN NO./ C-2 F-565

PRELIM. CCN NO.

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CCN CONVERSION:

CCN NO. CCN--

Project or DCP/MMP 2&3-6742.07 SM Calc No. P-450-1.22

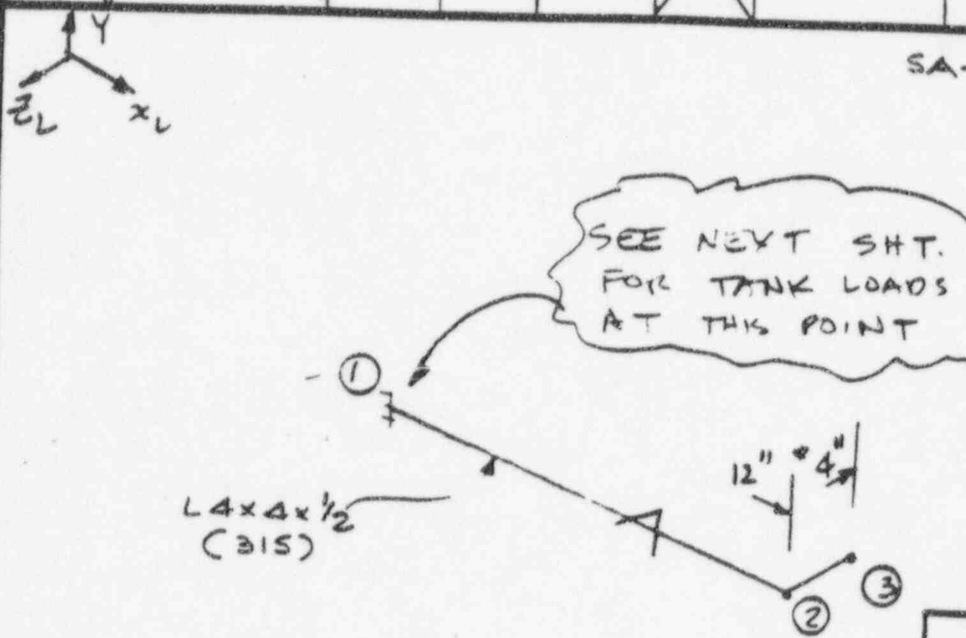
SUB CALC NO: 110

Subject SEE TITLE SHEET

Sheet No. B

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
0	[signature]	2/17/93	[signature]	2-17-93					

REV. INDICATOR



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* CONSERVATIVE

CCN F-565

SHT. 221

SUPPLEMENT

CALC NO M-DSC-269

REVISION CCN 1

BY ——— DATE ———

CHECKED ——— DATE ———

LOAD AT JOINT-3

$F_{X_L} = F_{Z_L} = 300^{\#}$

LOAD AT JOINT-2

$F_Y = 1300^{\#}$

BASED ON FAPPS (ME150) COMPUTER OUTPUT ALL MEMBERS ARE ACCEPTABLE FOR STRESS AND DISPLACEMENT. WELD IS ALSO ACCEPTABLE PER ME150 FAPPS ANALYSIS.

CHECK STRAP CL144N (GRINNELL) - 4" PIPE

ALLOWABLE PER LCD. (FOR 3/8" WELD STRAP) SIDE LOAD = 380# FOR LEVEL-A·B
TENSION LOAD: 2539# FOR LEVEL-A·B

INTERACTION = $\frac{300}{380} + \frac{300}{2539} = 0.91 < 1.0$ O.K.

LEVEL-D LOAD USED WITH LEVEL A·B ALLOWABLES.

SCE 26-426 NEW 4/90

NES&L DEPARTMENT
CALCULATION SHEET

SUPPLEMENT: B

ICCN NO./ C-2 F-565
PRELIM. CCN NO.

CCN CONVERSION
CCN NO. CCN -

Project or DCP/MMP 2&3 - 6742.07 SM   Calc No. P-450-1.22
Sub Calc No. - 110
Subject SEE TITLE SHEET   Sheet No. B

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
0	M. PATEL	2-17-93	MPatel	2-17-93					

SA-NW-228-H-002

STRESS RESULTS IN ABSOLUTE TERMS(+/-)

MEM	JOI	LOAD NAME	TYPE	AXIAL	BENDING Y	BENDING Z	WARPING NORMAL	SHEAR Y	SHEAR Z	SHEAR TORSIONAL	ALLOW. FACTOR	MAXIMUM NORMAL	MAXIMUM SHEAR	STRESS MARGIN FACTOR
1														
	1	FAULTED	ACTUAL	.080	10.537	4.640								
	2		ACTUAL	.080	.617	.272	.000	.456	.456	2.495	1.000	.797	.231	1.254
		FAULTED	ALLOW	17.594	19.140	19.140	.000	.453	.453	2.476	1.000	.051	.229	4.358
							19.140	12.760	12.760	12.760				

OVERALL MINIMUM STRESS MARGIN FACTOR= 1.25397

SHT. 222 P.222

SUPPLEMENT ____
CALC NO M-DSC-269
REVISION CCN 1
BY ____ DATE ____
CHECKED ____ DATE ____

ICCN F-565

UNITS: KIPS, INCH, DEGREES

DISPLACEMENT CHECK RESULTS(GLOBAL)

JOINT	DIRECTION	ALLOW.	ACTUAL
3	X	.06250	.00159
3	Y	.06250	.01023
3	Z	.06250	.00345

COPY FOR YOUR INFORMATION

UNITS: KIPS, INCH, DEGREES

JOINT DISPLACEMENTS(GLOBAL)

JOINT	LOAD NAME		X DISP		Y DISP		Z DISP		X ROT		Y ROT		Z ROT
2	FAULTED	+/-	.00186	+/-	.01276	+/-	.00345	+/-	.32427	+/-	.04919	+/-	.06291
3	FAULTED	+/-	.00159	+/-	.01023	+/-	.00345	+/-	.32427	+/-	.04924	+/-	.06291

UNITS: KIPS, INCH, DEGREES

MEMBER END-ACTIONS IN LOCAL COORDINATE SYSTEM

MEMBER	JOINT	LOAD NAME		AXIAL		SHEAR Y		SHEAR Z		TORSIONAL		BENDING Y		BENDING Z
1	1	FAULTED	+/-	.300	+/-	1.140	+/-	1.140	+/-	.000	+/-	14.480	+/-	14.479
	2	FAULTED	+/-	.300	+/-	1.131	+/-	1.131	+/-	.000	+/-	.849	+/-	.849
2	2	FAULTED	+/-	.300	+/-	.000	+/-	.300	+/-	.000	+/-	1.200	+/-	.000
	3	FAULTED	+/-	.300	+/-	.000	+/-	.300	+/-	.000	+/-	.000	+/-	.000

UNITS: KIPS, INCH, DEGREES

MAXIMUM TANK LOADS AT SUPPORT ... NTS.

SUPPORT REACTIONS(GLOBAL)

JOINT	LOAD NAME		FX		FY		FZ		MX		MY		MZ
1	FAULTED	+/-	.300	+/-	1.313	+/-	.300	+/-	.000	+/-	4.800	+/-	15.677

ICCN NO./ PRELIM. CCN NO. F-365	PAGE 223 OF 279
CCN CONVERSION: CCN NO. CCN- CCN 1	
CALC NO. M-DXC-269	REV.
SUPPLEMENT –	SHT –
ORIGINATOR –	DATE –
IRE –	DATE –

SHT 223

Southern California Edison Company
San Onofre Nuclear Generating Station
P.O. Box 128
San Clemente, California 92672

NUCLEAR ENGINEERING, SAFETY, AND LICENSING
NUCLEAR CONSTRUCTION

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ICCN NO./ PRELIM. CCN NO. F-565	PAGE 224 OF 279
CCN CONVERSION: CCN NO. CCN-	GCN
CALC NO. M-03C-269	REV.
SUPPLEMENT —	SHT —
ORIGINATOR —	DATE —
IRE —	SHEET NO. — DATE

SHT 224 of 279

BECHTEL

CALCULATION SHEET

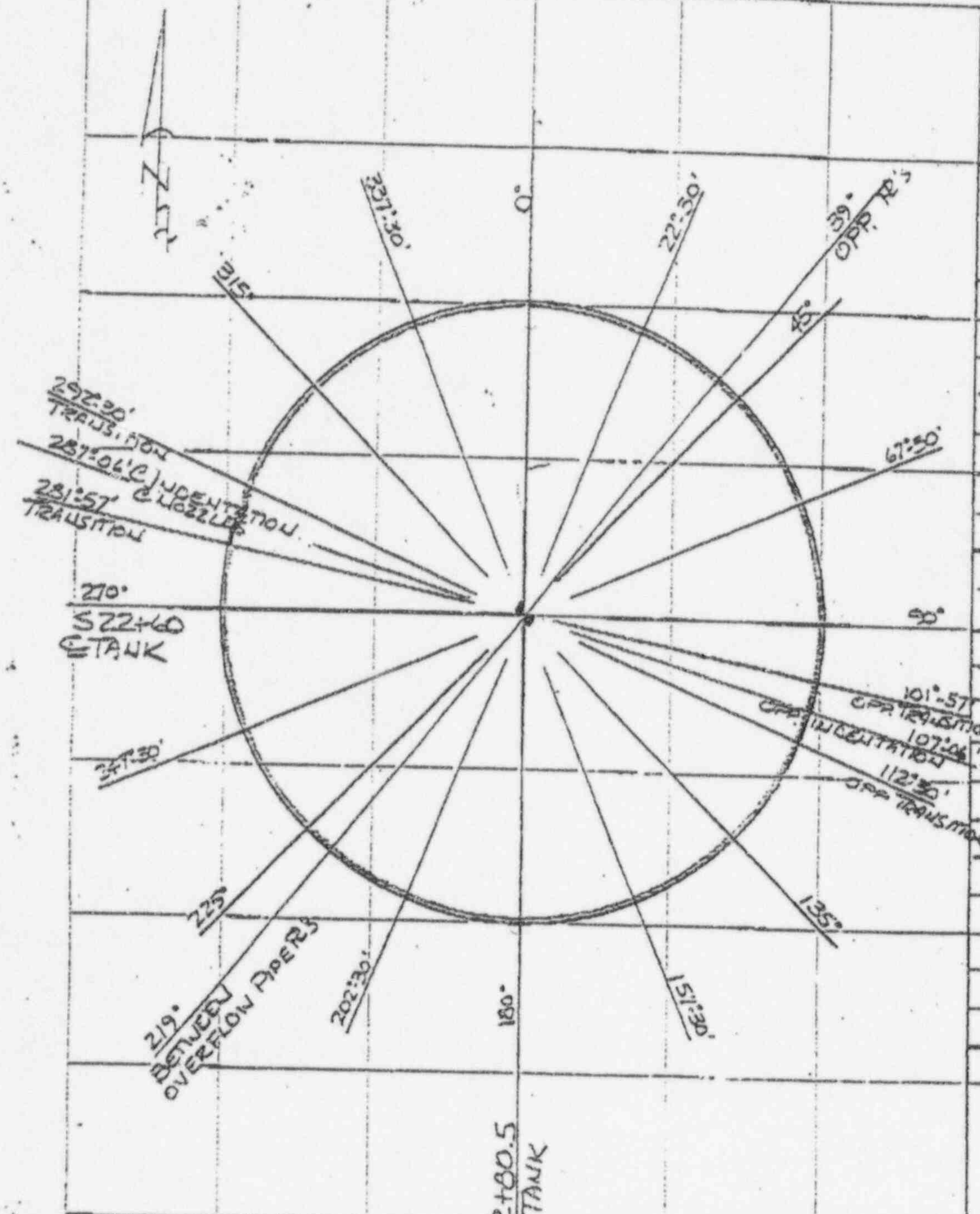
DESIGN BY Darrell Rogers DATE 10-15-93 CHECKED BY

PROJECT Radwaste Bldg #3 @ Elev. 9'-0"

SUBJECT As Built Inside Tank Radius 7055

JOB NO.

FILE NO.



DEG	INSIDE TK RAD. @ BOTT
0°	19.97
22°30'	20.00
39°	20.00
45°	20.02
67°30'	20.01
90°	20.02
101°57'	20.00
107°06'	20.02
112°30'	20.01
135°	20.00
157°30'	19.97
180°	1995
202°30'	1994
219°	1994
225°	1991
247°30'	1993
270°	1995
281°57'	1995
287°06'	1993
292°30'	1996
315°	993
337°30'	1994

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ICCN NO./ F-565 PRELIM. CCN NO.	PAGE 225 OF 279
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CALC NO. M-DSC-269 REV.	
SUPPLEMENT — SHT —	
ORIGINATOR — DATE —	
IRE — DATE —	

SHT 225 oF 279

	INSIDE TK RAD 1' ABOVE BOTT		INSIDE TK RAD 11.2 BELOW TOP		INSIDE TK RAD 6' BELOW TOP	REMARKS
	20.05		20.11		20.13	
	20.03		20.06		20.04	
	20.05		20.03		20.06	OFF #5
	20.06		20.06		20.07	
	20.05		20.05		20.02	
	20.07		20.02		20.03	
	20.04		20.06			OFF TRANSITION PT
	20.03		20.05			OFF INDENTATION PT
	20.00		20.03		2003	OFF TRANSITION PT
	20.02		20.05		20.01	
	20.05		1998		1997	
	1994	(13.4 BELOW TOP	19.94		1997	
	19.91	1969)	19.78		1987	
	1996		1992		1984	BETWEEN OVERFLOW PIPE R's
	19.95		19.92		19.87	
	19.94		20.01		20.01	
	20.00		19.97		19.97	
	20.02		1998			TRANSITION PT
	20.00		19.88			INDENTATION @ NOZZLES
	19.98		19.91		19.99	TRANSITION PT
	19.97		2007		20.06	
	20.00		2003		20.05	

17-84 20-86

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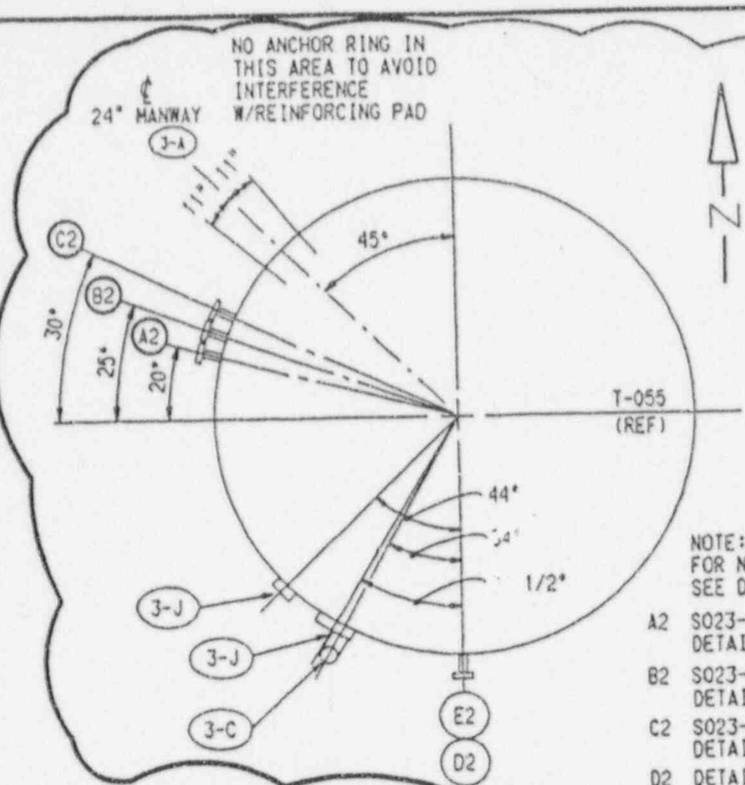
CCN CONVERSION: CCN NO. CCN-
CALC NO. M-DSC-269 REV. 1
SUPPLEMENT — SHT —
ORIGINATOR — DATE —
IRE — DATE —

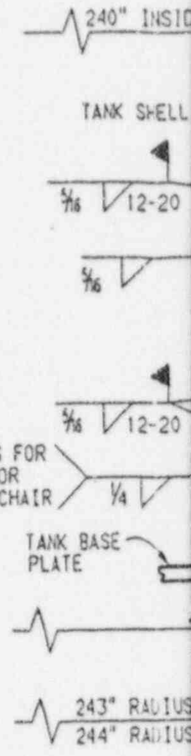
SHT 226



ORIENTATION

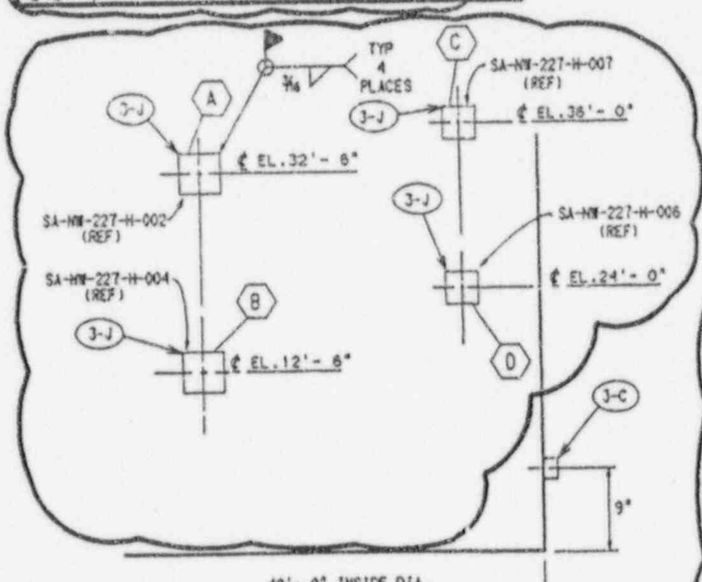
NOTE:
FOR NOZZLE DETAILS SEE DRAWINGS:

A2	S023-407-3-63 DETAIL 3L
B2	S023-407-3-63 DETAIL 3J
C2	S023-407-3-63 DETAIL 3K
D2	DETAIL 6 S3-1203-ML-476 SHT.1
E2	DETAIL 7 S3-1203-ML-480 SHT.1
3C	S023-407-3-63 4" OVERFLOW
3A	S023-407-3-63 24" SHELL MANWAY



NOZZLE SCHEDULE

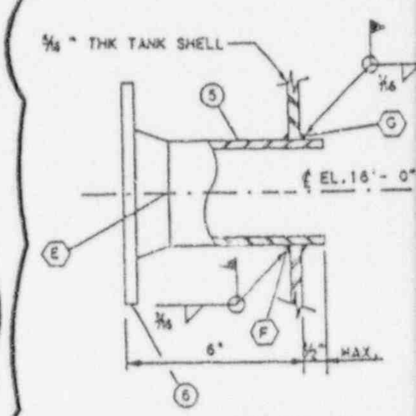
MARK	CUST MARK	DESCRIPTION
4-G	1	REMOVED
4-C	2	REMOVED
4-F	3	REMOVED
A-2		2" INLET-RECIRC.
B-2		2½" INLET
C-2		4" PUMP SUCTION
D-2		3" CCW PUMP SUCT.
E-2		1" CCW PUMP SUCT.



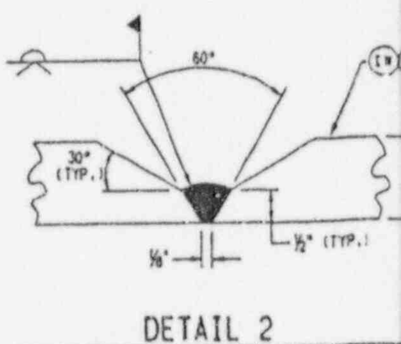
ELEVATION

FIELD NOTE:

1. FIELD MAY RELOCATE GROUNDING PAD AS REQUIRED.
2. PROPER PRECAUTION SHOULD BE TAKEN TO PROTECT CONCRETE.



DETAIL 7
SCALE: NONE



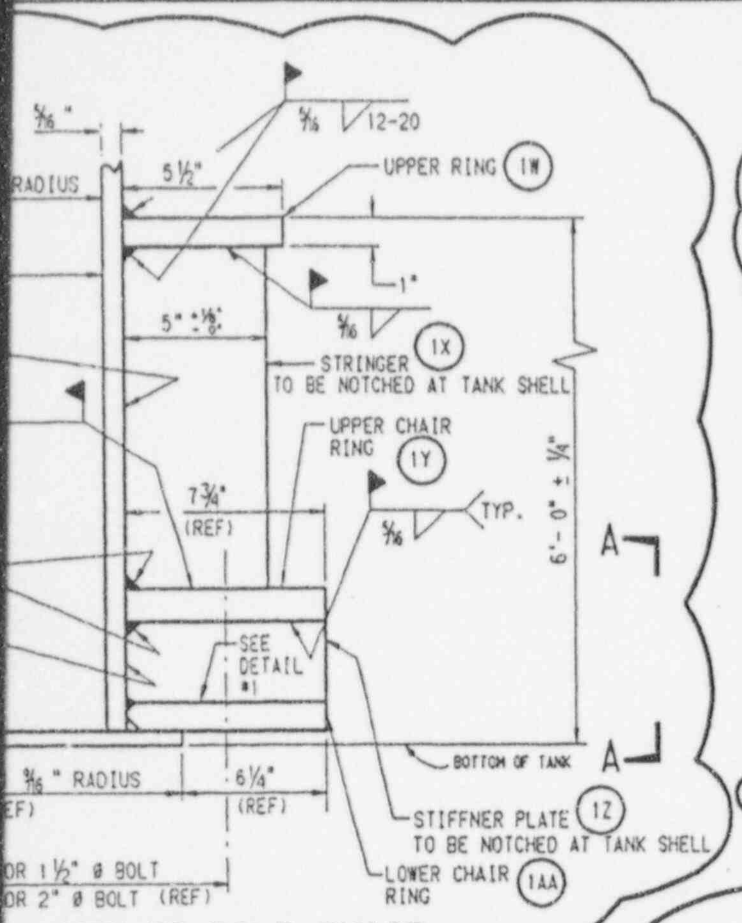
DETAIL 2

LOCATE RING SPLICE AS REQUIRED AT MID POINT ± BETWEEN ADJACENT ANCHOR BOLTS
(SEE NOTE 9)

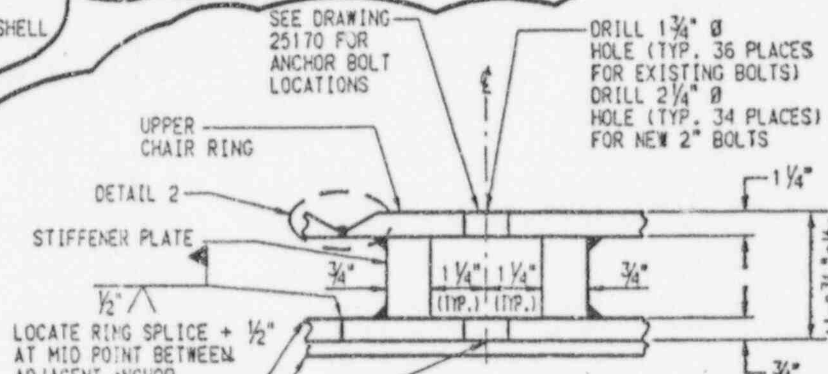
MARK			QTY	DESCRIPTION	SPEC	WT	P.O. NO.
				T4-0103306-1 B/M FOR 2 TANKS			
1-T			14	4 2 1/2"X 2 1/2"X 3/16 "X 20'-0" LG. (TRIM 8" BOTH ENDS) ROLL LEG OUT TO 20'-0" ISE	SA-479-304	(1400)	
1-U			64	1/2" FLE X CELL X SK	FLEXCELL	(298)	60
		1W	1*	UPPER RING 1"X 5 1/2"X 20'-0 3/8 " INSIDE RADIUS FIELD CUT LENGTH AS REQUIRED	SA-36	-	-
		1X	36*	STRINGERS 1 3/8" X 5" X 4'-10" EQUALLY SPACED	SA-36	-	-
		1Y	1*	UPPER CHAIR RING 1 1/4"X 7 3/4"X 20'-0 3/8 " INSIDE RADIUS FIELD CUT LENGTH AS REQUIRED	SA-36	-	-
		1Z	140*	STIFFNER PLATE 3/4"X 7 3/4"X 0'-10 3/4"	SA-36	-	-
		1AA	1*	LOWER CHAIR RING PLATE 3/4"X 7 3/4"X 20'-0 3/8 " I.D. RADIUS FIELD CUT LENGTH AS REQUIRED	SA-36	-	-
		3J	4*	PLATE 1/2" X 8" X 0'- 8" INTEGRAL ATTACHMENT, USE ASME SECTION III, SUBSECTION "ND" MATERIAL.	SA-36		
		1	3L/F*	3"Ø PIPE SCH.40 S.S.	SA-312 TP304		
		2	1*	3"Ø 90° PIPE ELBOW SCH.40	SA-403 WP304		
		3	3L/F*	3"Ø PIPE SCH.40 S.S.	SA-312 TP304		
		4	1*	3" 150# R.F.W.N. FLANGE SCH.40	SA-182 F316		
		5	3L/F*	1" PIPE SCH.80	SA-312 TP304		
		6	1*	1" 150# R.F.W.N FLANGE SCH. 80	SA-182 F316		

* QUANTITIES ARE FOR TANK T-055 ONLY

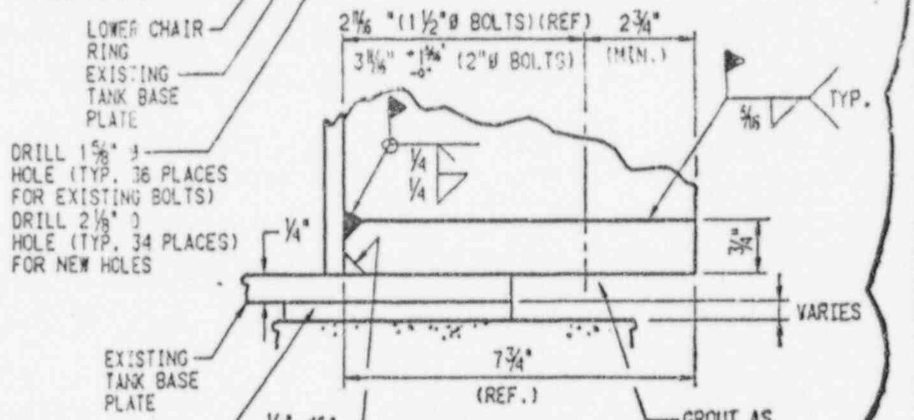
STRESS CALC. M-DSC-269



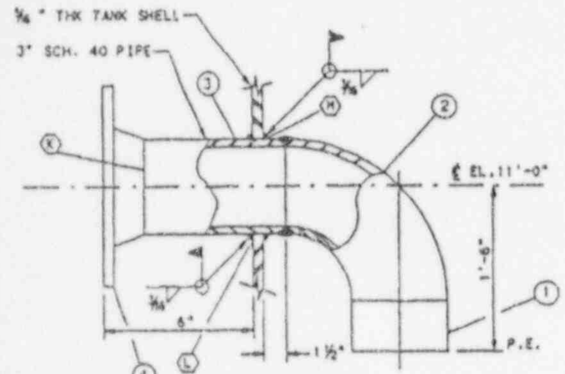
ANCHOR BOLT CHAIR



SECTION A-A



DETAIL 1



DETAIL 6
SCALE: NONE

ANCHOR BOLT CHAIR

NOTES:

1. DRILL BOLT HOLES IN RINGS @ COMPLETION OF ANCHOR BOLT INSTALLATION.
2. SEE BOLT PATTERN ON DWG 25170 FOR NEW & EXISTING LOCATIONS
3. TRIM TO MAINTAIN A CLEARANCE OF 1/2" 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 ± 2" IN EITHER DIRECTION TO AVOID INTERFERENCE.
6. FOR CLASS "Z", PIPE MATERIAL TO BE PER ASME SECTION III, CODE CLASS 3, 1989 EDITION, NO ADDENDA WELDS TO BE PER SECTION IX, 1989 EDITION, NO ADDENDA.
7. DIMENSIONAL TOLERANCE ± 1/8" UNLESS OTHERWISE NOTED
8. ⬡ = WELD JOINT SYMBOL FOR ASME SECTION III CODE WELD.
9. IF UPPER OR LOWER CHAIR RING SPLICES CANNOT BE INSTALLED WITHIN MID POINT TOLERANCES, THEN SPLICE SHOULD BE INSTALLED USING A FULL PENETRATION WELD SHOWN BELOW.

QUALITY CLASS II

PAGE 3 OF 3

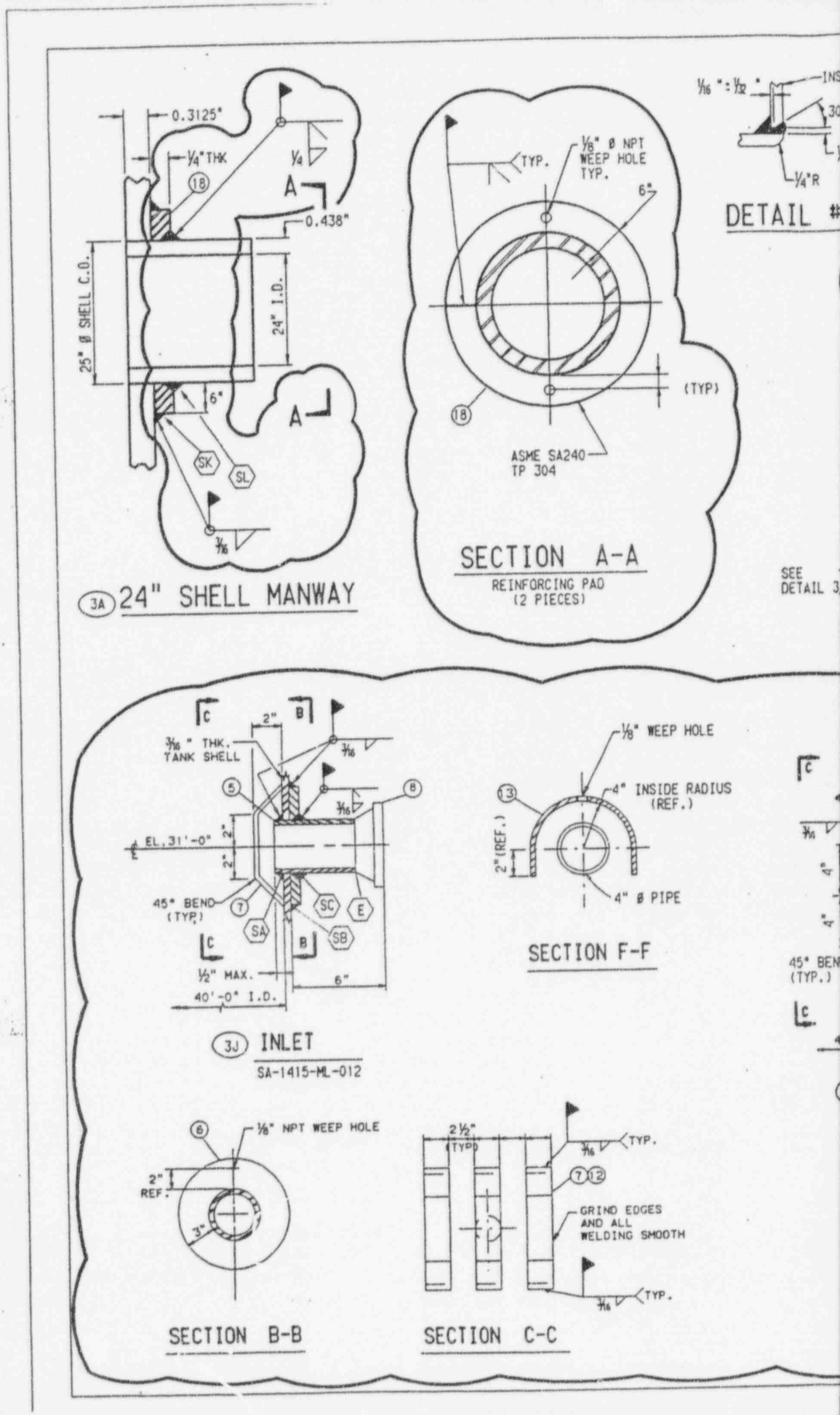
For DCNs Only
DCP/MMP NO. 2&3-6742.07SM REV. 0 PAGE

Southern California Edison Company INTERIM DESIGN CHANGE NOTICE (IDCN)/ ~~DESIGN CHANGE NOTICE (DCN)~~ SUPPLEMENTAL PAGE	DCN NO. S- 2	DCN NO. AB/ABC-	DCN NO.	DOCUMENT REV.
	DOCUMENT NO. S023-407-3-61		SHEET NO. -	REV. 2
	Q-CLASS DOCUMENT II	Q-CLASS EQUIPMENT II	ORIGINATOR F. GOPAR	
DESCRIPTION OF CHANGE	☐ BEFORE ☒ AFTER ☐ AS-FOUND ☐ ADD ☐ INTERIM ☐ INFORMATION ONLY			

9603120063-01

CCN NO./F-565 PAGE 227 of 279
PRELIM. CCN NO.
CCN CONVERSION: CCN NO. CCN- 1
CALC NO. M-DSC-269 REV. —
SUPPLEMENT — SHT —
ORIGINATOR — DATE —
IRE — DATE —

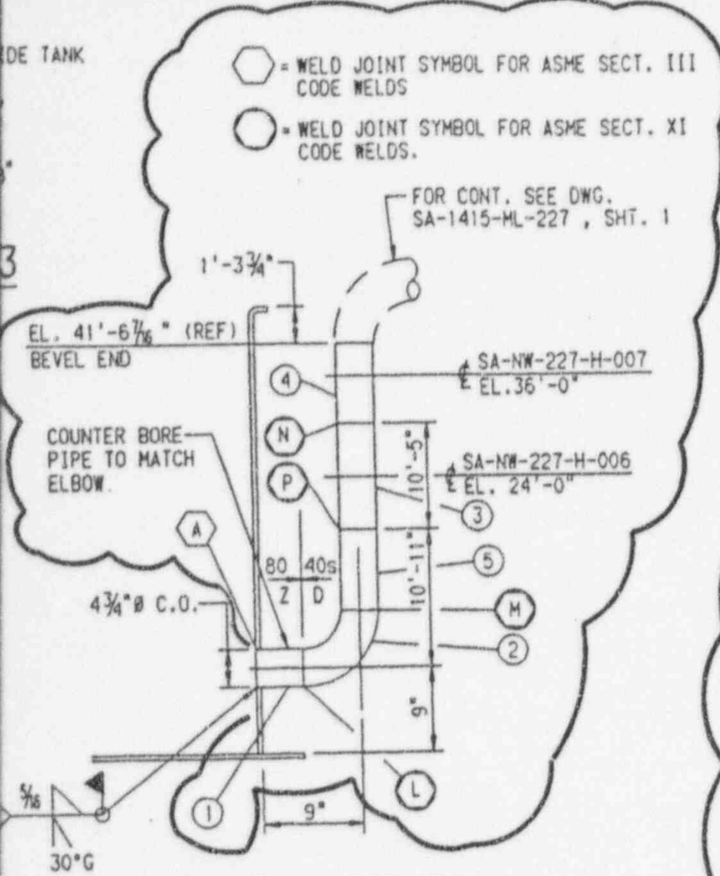
SHT 227



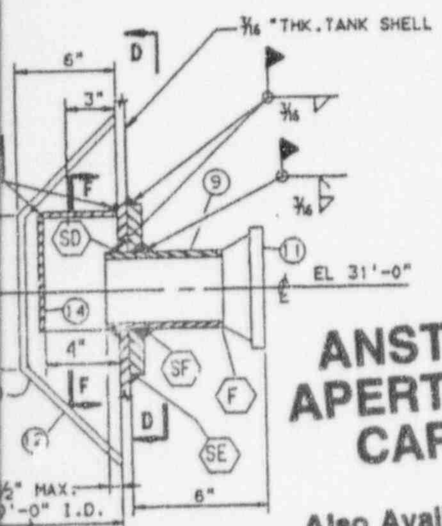
COPY FOR YOUR INFORMATION

MARK (DWG)	MARK (SUB ASM)	MARK (PIECE)	QTY	74-103306-3 DESCRIPTION B/M FOR 2 TANKS	SPEC	WT	P.O. NO.
3-A			2	24" SHELL MANWAY		(503)	
		3-1	2	P 9/16" X 7 1/2" X 6'-4 3/8" LG	SA-240-304	145	11
		3-2	2	P 3/4"X 24 7/8" I.D. X 32 3/4" O.D.	SA-240-304	77	12
		3-3	2	P 3/4"X 32 3/4" O.D.	SA-240-304	242	13
		3-4	4	BAR 3/8" O X 12 3/8" LG X SK	SA-479-304	6	16
		3-5	2	GASKET 1/8" THK. X 24" I.D. X 29 3/4" O.D.	RUBBER	2	15
		3-6	56	BOLT 3/4" O X 2 1/4" LG HEX HD W/HY HEX NUT	SA-193-B7 SA-194-2H	31	14
		18	*2	SPLIT RING REINFORCING PAD 25" ID X 37" O.D. 1/4" THK W/ 1/8" Ø WEEP HOLE 20'-0" RADIUS TANK	SA-240-304		
3-C			2	4" OVERFLOW			
		1	*1	PIPE 4" SCH 80 X 3 5/16" L.G. (COUNTER BORE ONE END TO SCH 40s)	SA-312-TP304		
		2	*1	90° ELBOW 4" LR 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-J		5	*1L/F	2 1/2" PIPE SCH.40S (CUT TO SUIT)	SA-376-TP304		
		6	* 1	RING REINF.PAD 1/2"X 5 7/8" O.D.	SA-240-304		
		7	* 3	PLATE 1/4"X 2 1/2"X 1'-0" (CUT TO SUIT)	SA-240-304		
		8	* 1	2 1/2" FLANGE SCH.40S 150# R.F.W.N.	SA-182-F316		
3-K		9	*1L/F	4" PIPE SCH. 40S	SA-376-TP304		
		10	* 1	RING REINF.PAD 1/2"X 12" O.D.	SA-240-304		
		11	* 1	4" FLANGE SCH. 40S 150# W.N.R.F.	SA-182-F316		
		12	* 3	PLATE 1/4"x 2 1/2"x 2'-0" (CUT TO SUIT)	SA-240-304		
		13	* 1	PLATE 1/4" X 4" X 16 5/8" LONG	SA-240-304		
		14	* 1	PLATE 1/4" X 8 1/4" X 0'-4 1/8" (CUT TO SUIT)	SA-240-304		
3-L		15	* 1	2" FLANGE 150# W.N.R.F. SCH. 80 BW	SA-182-F316		
		16	*1L/F	PIPE SCH. 80S (CUT TO SUIT) SIZE 2"	SA-376-TP304		
		17	* 1	RING REINF. PAD 1/2" X 9 3/8" O.D.	SA-240-304		

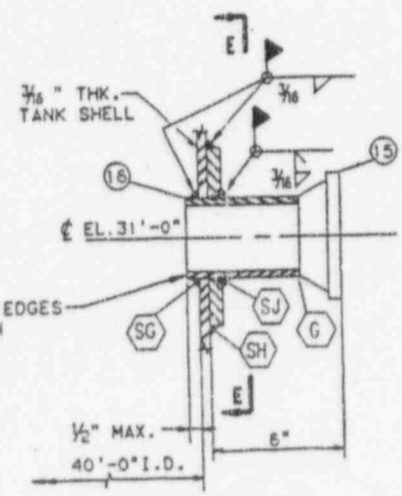
* = QUANTITIES ARE FOR ONE TANK ONLY, T-055
STRESS CALC. M-DSC-269



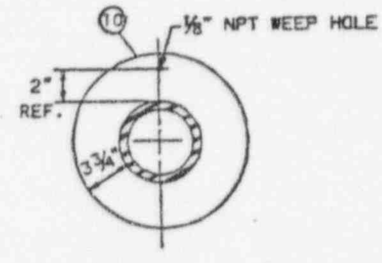
3-C 4" OVERFLOW



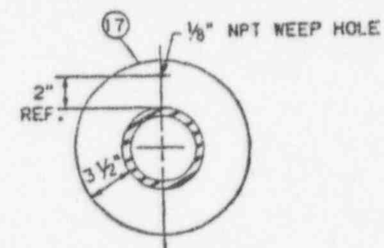
3K PUMP SUCTION
SA-1415-ML-024



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



SECTION D-D



SECTION E-E

9603120063-02

NOTES:

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

Q.C. II

PAGE 3 OF 3

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Southern California Edison Company INTERIM DESIGN CHANGE NOTICE (IDCN)/ ~~DESIGN CHANGE NOTICE (DCN)~~ SUPPLEMENTAL PAGE	DCN NO. S- 2	DCN NO. AB/ABO-	DCN NO.	DOCUMENT REV.
	DOCUMENT NO. S023-407-3-63		SHEET NO. -	REV. 3
	Q-CLASS DOCUMENT II	Q-CLASS EQUIPMENT II	ORIGINATOR F. GOPAR	

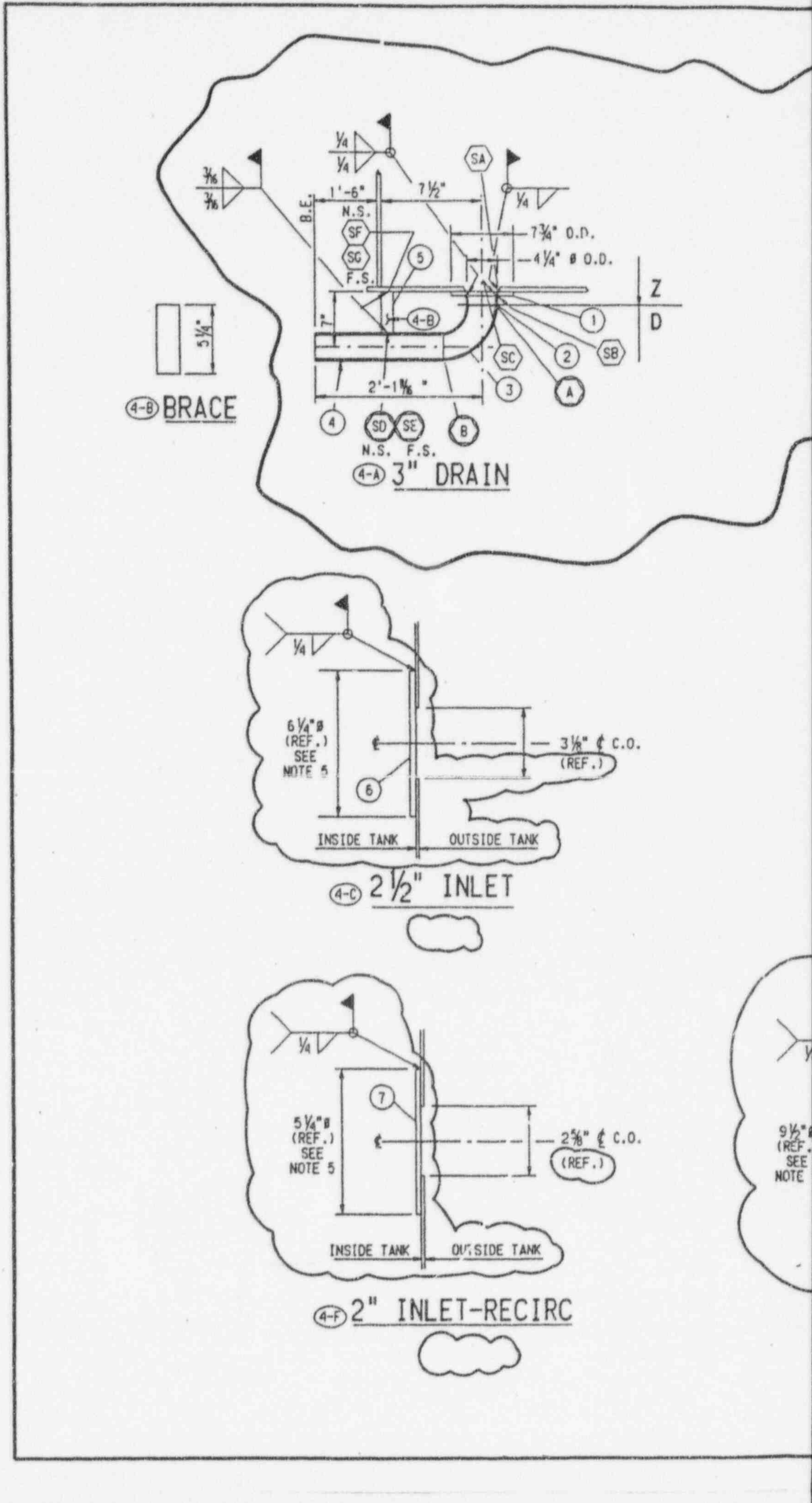
DESCRIPTION OF CHANGE: ☐ BEFORE ☒ AFTER ☐ AS-FOUND ☐ ADD ☐ INTERIM ☐ INFORMATION ONLY

REVISED NOZZLES

SHT 228

ICCN NO/PRELIM. CCN NO. 7F-565	PAGE 228 OF 279
CCN CONVERSION: CCN NO. CCN-	
CALC NO. M-DSC-269	REV.
SUPPLEMENT —	SHT —
ORIGINATOR —	DATE —
IRE —	DATE —

COPY FOR YOUR INFORMATION



MARK			QTY	74-0103308-4 DESCRIPTION B/M FOR 2 TANKS	SPEC	WT	P.O. NO.
4-A				3" DRAIN			
		1	+1	PLATE 3/8" X 3½" I.D. X 7¾" O.D.	* SA-240-304		
		2	+1	PIPE 3" SCH. 80 X 2⅛" LG.	SA-312 TP304		
		3	+1	90° ELBOW SCH. 80	SA-403 WP304		
		4	+1	PIPE 3" SCH. 80 X 1'-9⅝" LG.	SA-312 TP304		
4-B		5	+1	F.B. ¼" X 4" X 5¼" LG. (BRACE)	* SA-240-304		
4-C			2	PIPE 2½" SCH. 80 X 7⅛" LG. (INLET)	SA-312-304	(18)	39
		6	+1	PLATE 3/8" X 8¼" DIA. (REF.)	* SA-240-304		
4-F		7	+1	PLATE 3/8" X 5¼" DIA. (REF.)	* SA-240-304		
4-G		8	+1	PLATE 3/8" X 9½" DIA. (REF.)	* SA-240-304		

* INTEGRAL ATTACHMENT, USE ASME SECTION III, SUBSECTION "ND" MATERIAL.

\+ QUANTITIES FOR ONE TANK ONLY T055

NOTES:

1.) FOR CLASS "Z", PIPE & TANK MATERIAL TO BE PER ASME SECTION III, CODE CLASS 3, 1989 EDITION, NO ADDENDA WELDS TO BE PER SECTION IX, 1989 EDITION, NO ADDENDA.

2.) DIMENSIONAL TOLERANCE ± ⅛".

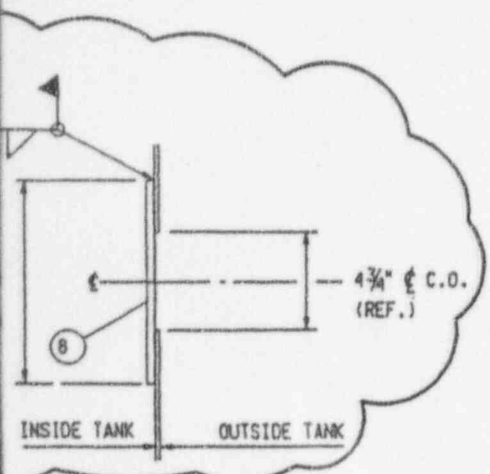
3.) ⟨A⟩ = WELD JOINT SYMBOL FOR ASME SECTION III CODE WELD

⟨SA⟩ = WELD JOINT SYMBOL FOR ASME CODE WELDS; EG. SOCKETWELD, SEAL WELD, AND FILLET OR ATTACHED WELD.

◯ = WELD JOINT SYMBOL FOR ASME SECTION XI CODE WELD.

4.) FOR NOZZLE LOCATION SEE DWG. S023-407-3-61

5.) DIAMETER OF PLATE TO BE TWICE THE DIAMETER OF THE HOLE CREATED BY REMOVING THE NOZZLE. PLATE TO BE CENTERED ON HOLE CENTER.



(4-G) 4" PUMP SUCTION

9603120063-03

QUALITY CLASS II

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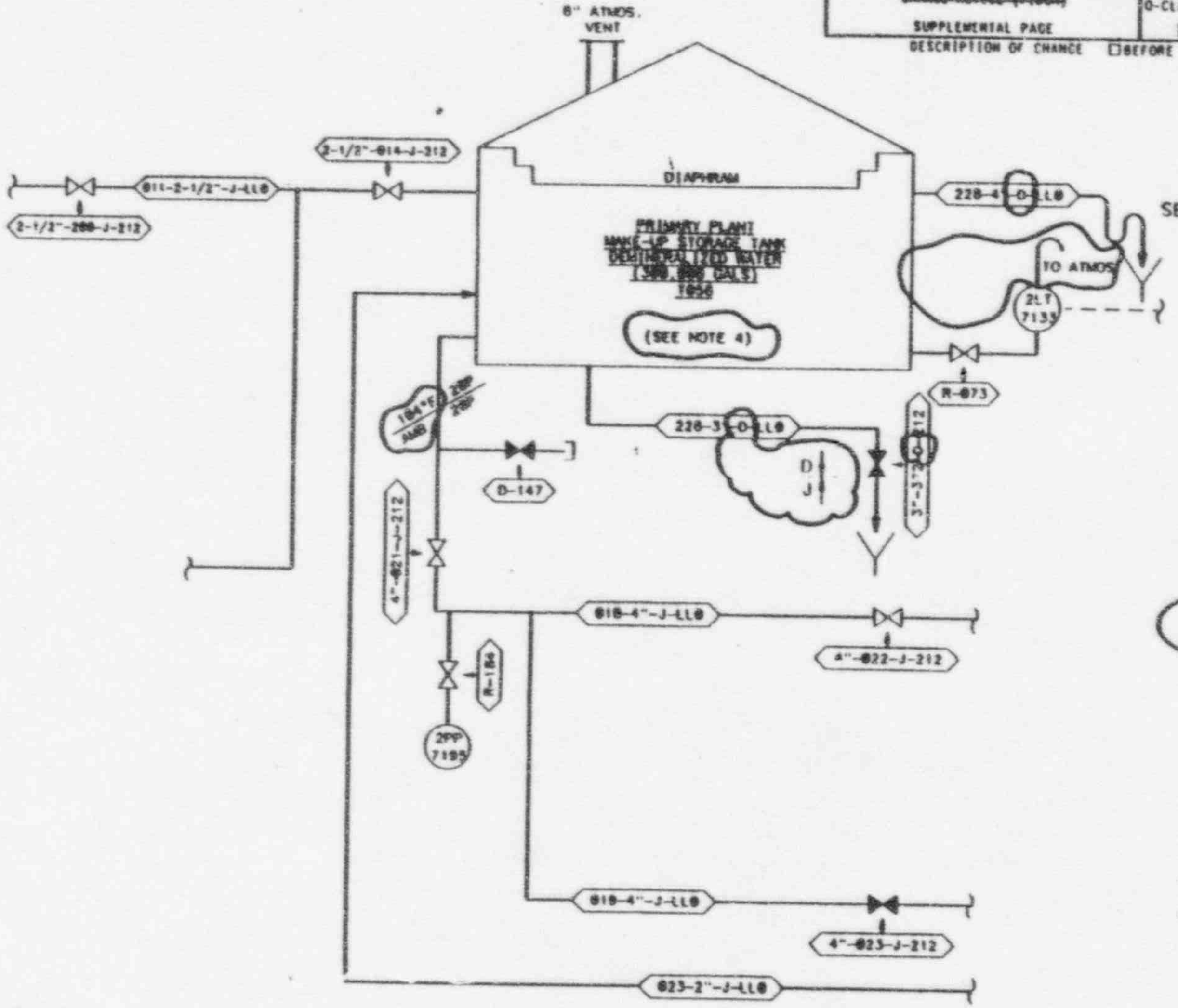
	(For IDCNs Only) DCP/MMP NO. 2&3-6742.07SM REV. 0 PAGE			
Southern California Edison Company INTERIM DESIGN CHANGE NOTICE (IDCN)/ ~~DESIGN CHANGE NOTICE (DCN)~~ SUPPLEMENTAL PAGE	DCP NO. S- 1	DCN NO. AB/ABC-	DCN NO.	DOCUMENT REV.
	DOCUMENT NO. S023-407-3-64		SHEET NO. –	REV. 1
	Q-CLASS DOCUMENT II	Q-CLASS EQUIPMENT III	ORIGINATOR F.GOPAR	

DESCRIPTION OF CHANGE ☐ BEFORE ☒ AFTER ☐ AS-FOUND ☐ ADD ☐ INTERIM ☐ INFORMATION ONLY

g:/mech/36742p07/TANK064

SOUTHERN CALIFORNIA EDISON COMPANY FIELD CHANGE NOTICE(FCN)/ ~~FIELD INTERIM DESIGN CHANGE NOTICE (FIDCN)~~ SUPPLEMENTAL PAGE	DCP/ NO. (For FIDCNs Only) —		REV.	
	FCN NO. F-7519M	FIDCN NO. —	DCN NO.	DOC. REV.
	DOCUMENT NO. 40133E		SHEET NO. —	REV. 10
	Q-CLASS: DOCUMENT II	Q-CLASS: EQUIP. II	ORIGINATOR A. ZUNIGA	

DESCRIPTION OF CHANGE ☐BEFORE ☒AFTER ☐AS-FOUND ☐ADD ☐INTERIM ☐INFO. ONLY



SHT 229

SUPPLEMENT	—
CALC NO	M-DSC-269
REVISION	CCN 1
BY —	DATE —
CHECKED —	DATE —

COPY FOR YOUR INFORMATION

NOTE:

4. TANK T-056 IS PROJECT CLASS Z.

ICCN F-565
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NES&L DEPARTMENT

CALCULATION SHEET

ICCN NO./ PRELIM. CCN NO. F-565	PAGE 230 OF 279
CCN CONVERSION CCN NO. CCN - 1	

Project or DCP/MMP SONGS 2/3 Calc No. M-DSC-269

Subject see title sheet Sheet No. 230

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	WUSHONG YOW WY	9/30/93	J. GAOR JG.	10/7/93					

APPENDIX E

ESTIMATION OF 95TH PERCENTILE FLAW LENGTH BY STATISTICAL ANALYSIS

1. PURPOSE

Appendix E performs a statistical analysis on the sample welding flaws taken by radiographic films from the Unit 3 Primary Plant Makeup Storage Tank weld seams in August 1993 prior to the Cycle 7 refueling outage. The statistical analysis is the first phase of the two phase analyses to determine the acceptability of the welding defects for the structural integrity of the tank. The statistical analysis determines the 95th percentile defect length which bounds a 95% probability of the total flaw population on the tank at a 95% confidence level. The calculated 95th percentile defect length will be the basis for the phase two fracture analysis to demonstrate acceptability of the weld defect with a high degree of reliability. Phase two analysis is contained in Appendix F.

2. RESULTS/ CONCLUSIONS

From a total of 126 sample welding flaws ranging from 0.0625 inches to 4.5 inches, it was determined that the 95th percentile defect length is 3.5 inches. That is, there is a 95% chance that the flaw length in the total flaw population on the tank will be less than 3.5 inches at a 95% confidence level.

NES&L DEPARTMENT

CALCULATION SHEET

ICCN NO./ PRELIM. CCN NO. F-565	PAGE 232 OF 279
	CCN CONVERSION CCN NO. CCN - 1

Project or DCP/MMP SONGS 2/3 Calc No. M-DSC-269

Subject see title sheet Sheet No. 232

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	WUSHONG YOW WY	9/30/93	J. GAOR J.G.	10/7/93					

3. ANALYSIS

(1) Sample Data

In August 1993, radiographic films were taken (Figure E.1) showing the welding flaws on the Primary Plant Makeup Storage Tank (SA1415-MT055). These flaws were apparently the results of poor workmanship in the original construction welding of the tank. Attachment E.1 shows the film locations, flaw characteristics, and the sizes of flaws as obtained from QC (Reference 3). Based on the examination of 61 films, produced by spot radiography, 126 flaws were identified. Table E.1 lists all these 126 sample flaws in an ascending order of flaw length.

(2) Characteristics of Sample Data

Among the 126 sample data, the range of the flaw length is from a minimum of 0.0625 inches to a maximum of 4.5 inches. The sample mean and standard deviation are calculated as

$$\bar{x} = \sum_{i=1}^{n} x_i / n = 59.56/126 = 0.472$$

$$s = [\sum_{i=1}^{n} (x_i - \bar{x})^2 / (n-1)]^{1/2} = 0.714$$

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	WUSHONG YOW WY	9/30/93	J. GAOR J.G.	10/7/93					

Figure E.2 shows the probability distribution curve of the sample data. It can be seen that the probability distribution function does not have a normal or near-normal distribution. In fact, the probability distribution of the sample data fails to pass the goodness-of-fit tests for normal distribution, log-normal distribution, and the second-order Erlang distribution functions. Therefore, instead of pursuing an extensive mathematical derivation to establish theoretical confidence intervals, it is necessary to pursue an alternative procedure using the theory of order statistics for a non-parametric testing as discussed in next section.

(3) Non-Parametric Confidence Intervals

A. Minimum Sample Size

The minimum sample size required to perform a non-parametric test is dependent on the required probability of the population and the level of confidence. According to Reference (1), the minimum sample size to ensure with 95% confidence that 95% of the population will be less than a certain sample flaw length is 93. The sample size of 126 used in this study is more than the smallest sample size required to produce the specified probability at the level of confidence desired.

B. Estimation of Flaw Length for 95/95 Probability and Confidence Level

The theory of order statistics with binominal test is used to determine the upper bound of the flaw length which will envelop 95% of the flaw population on the tank

with 95% confidence level. Table E.1 shows the 126 sample observations in the ascending order.

Let

$$X_1 \leq X_2 \ldots\ldots\ldots\ldots \leq X_s \leq \ldots \leq X_n$$

represent the ordered sample, where X's are the observed flaw lengths and n = 126. According to Reference (2), the upper bound flaw length X_s which has a 95% confidence level for the 95% probability of the total flaw population being less than X_s is determined as

$$\begin{aligned} s &= np + w_\alpha \, \mathrm{sqrt}[np(1-p)] \\ &= 126 * 0.95 + 1.645 * \mathrm{sqrt}(126*0.95*0.05) \\ &= 123.7 \end{aligned}$$

where p is the specified probability, and α is the desired confidence level. w_α is the one-tailed 95th percentile of a standardized normal random variable. The value for w_α is available from the standard normal distribution table in any statistical handbook. By rounding s upward to the next higher integer, we obtain s = 124. From Table E.1,

$$X_{124} = 3.5 \text{ inches.}$$

Therefore, from the 126 sample observations, we determine with 95% confidence that 95% of the total flaw population will have flaw lengths less than 3.5 inches.

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	WUSHONG YOW WY	9/30/93	J. GAOR JG.	10/7/93					

4. REFERENCES

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

(2) W.J., Conover, Practical Nonparametric Statistics, John Wiley & Sons, Inc.

(3) SCE NDE Data Report, Radiographic Examination Technique Sheet Report Nos. 3RT-035-93, 3RT-049-93, 3RT-055-93, 3RT-064-93 3RT-065-93

NES&L DEPARTMENT
CALCULATION SHEET

ICCN NO./ PRELIM. CCN NO. F-565	PAGE 236 OF 279
	CCN CONVERSION CCN NO. CCN - 1

Project or DCP/MMP SONGS 2/3 Calc No. M-DSC-269

Subject see title sheet Sheet No. 235

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	WUSHONG YOW WM	9/30/93	J. GAOR J.G.	10/7/93					

TABLE E.1 RADIOGRAPHIC FILM FLAWS FOR MT-055

Sample No	x	x^2
1	0.06250	0.00391
2	0.06250	0.00391
3	0.06250	0.00391
4	0.06250	0.00391
5	0.06250	0.00391
6	0.06250	0.00391
7	0.06250	0.00391
8	0.06250	0.00391
9	0.06250	0.00391
10	0.06250	0.00391
11	0.06250	0.00391
12	0.06250	0.00391
13	0.09375	0.00879
14	0.09375	0.00879
15	0.09375	0.00879
16	0.09375	0.00879
17	0.09375	0.00879
18	0.09375	0.00879
19	0.09375	0.00879
20	0.09375	0.00879
21	0.12500	0.01563
22	0.12500	0.01563
23	0.12500	0.01563
24	0.12500	0.01563
25	0.12500	0.01563
26	0.12500	0.01563
27	0.12500	0.01563
28	0.12500	0.01563
29	0.12500	0.01563
30	0.12500	0.01563
31	0.12500	0.01563
32	0.12500	0.01563
33	0.12500	0.01563

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	WUSHONG YOW	9/30/93	J. GAOR	10/7/93					

TABLE E.1 RADIOGRAPHIC FILM FLAWS FOR MT-055 (continued)

Sample No	x	x^2
34	0.12500	0.01563
35	0.12500	0.01563
36	0.12500	0.01563
37	0.15625	0.02441
38	0.15625	0.02441
39	0.15625	0.02441
40	0.15625	0.02441
41	0.15625	0.02441
42	0.15625	0.02441
43	0.15625	0.02441
44	0.15625	0.02441
45	0.15625	0.02441
46	0.18750	0.03516
47	0.18750	0.03516
48	0.18750	0.03516
49	0.18750	0.03516
50	0.18750	0.03516
51	0.18750	0.03516
52	0.18750	0.03516
53	0.21875	0.04785
54	0.21875	0.04785
55	0.21875	0.04785
56	0.21875	0.04785
57	0.21875	0.04785
58	0.25000	0.06250
59	0.25000	0.06250
60	0.25000	0.06250
61	0.25000	0.06250
62	0.25000	0.06250
63	0.25000	0.06250
64	0.25000	0.06250
65	0.25000	0.06250
66	0.25000	0.06250

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	WUSHONG YOW	9/30/93	J. GAOR	10/7/93					

TABLE E.1 RADIOGRAPHIC FILM FLAWS FOR MT-055 (continued)

Sample No	x	x^2
67	0.25000	0.06250
68	0.25000	0.06250
69	0.25000	0.06250
70	0.25000	0.06250
71	0.25000	0.06250
72	0.25000	0.06250
73	0.25000	0.06250
74	0.28125	0.07910
75	0.28125	0.07910
76	0.31250	0.09766
77	0.31250	0.09766
78	0.31250	0.09766
79	0.31250	0.09766
80	0.37500	0.14063
81	0.37500	0.14063
82	0.37500	0.14063
83	0.37500	0.14063
84	0.37500	0.14063
85	0.37500	0.14063
86	0.37500	0.14063
87	0.37500	0.14063
88	0.37500	0.14063
89	0.37500	0.14063
90	0.37500	0.14063
91	0.37500	0.14063
92	0.43750	0.19141
93	0.43750	0.19141
94	0.43750	0.19141
95	0.43750	0.19141
96	0.43750	0.19141
97	0.43750	0.19141
98	0.50000	0.25000
99	0.50000	0.25000

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	WUSHONG YOW WY	9/30/93	J. GAOR J.G.	10/7/93					

TABLE E.1 RADIOGRAPHIC FILM FLAWS FOR MT-055 (continued)

Sample No	x	x^2
100	0.50000	0.25000
101	0.50000	0.25000
102	0.50000	0.25000
103	0.50000	0.25000
104	0.62500	0.39063
105	0.62500	0.39063
106	0.75000	0.56250
107	0.75000	0.56250
108	0.75000	0.56250
109	0.75000	0.56250
110	0.75000	0.56250
111	0.75000	0.56250
112	1.00000	1.00000
113	1.00000	1.00000
114	1.00000	1.00000
115	1.00000	1.00000
116	1.00000	1.00000
117	1.25000	1.56250
118	1.50000	2.25000
119	1.50000	2.25000
120	2.00000	4.00000
121	2.00000	4.00000
122	2.50000	6.25000
123	3.25000	10.56250
124	3.50000	12.25000
125	3.50000	12.25000
126	4.50000	20.25000
SUM=	59.50000	91.73828

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SUPPLEMENT ______ SHT. ______

ORIGINATOR Wy DATE 9/30/93

IRE T-G. DATE 11/13/93

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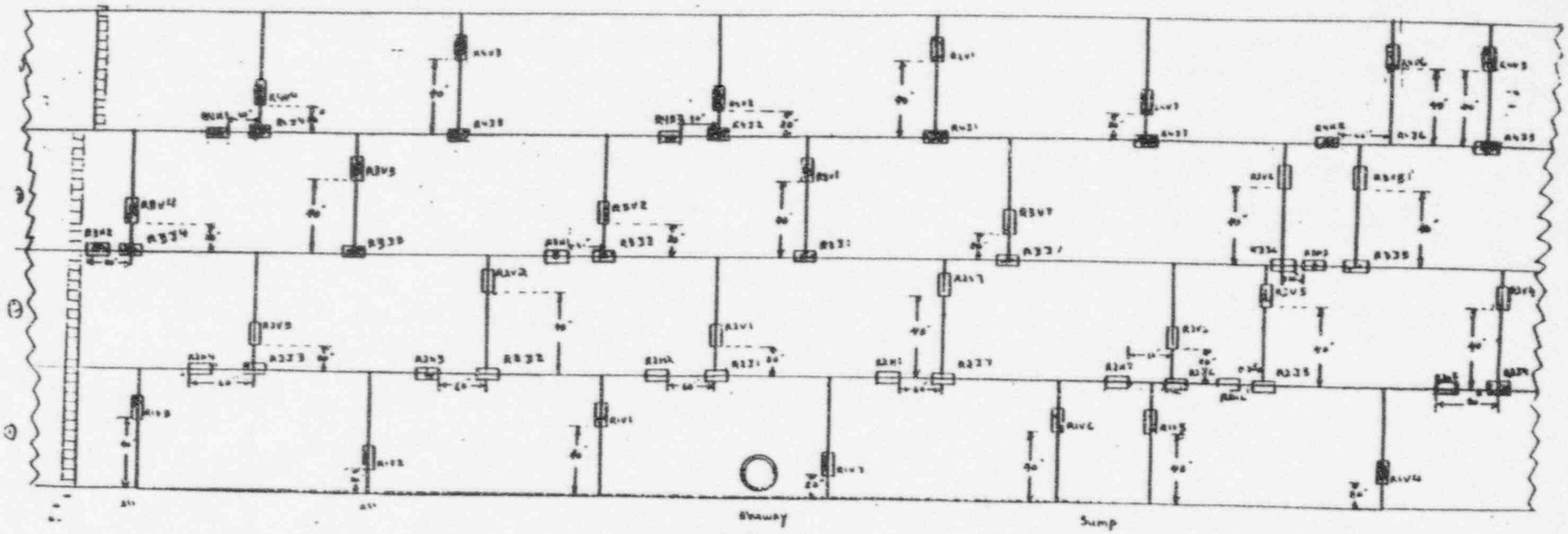

FIGURE E.1 RADIOGRAPHY MAP FOR TANK SA-1415-MT055

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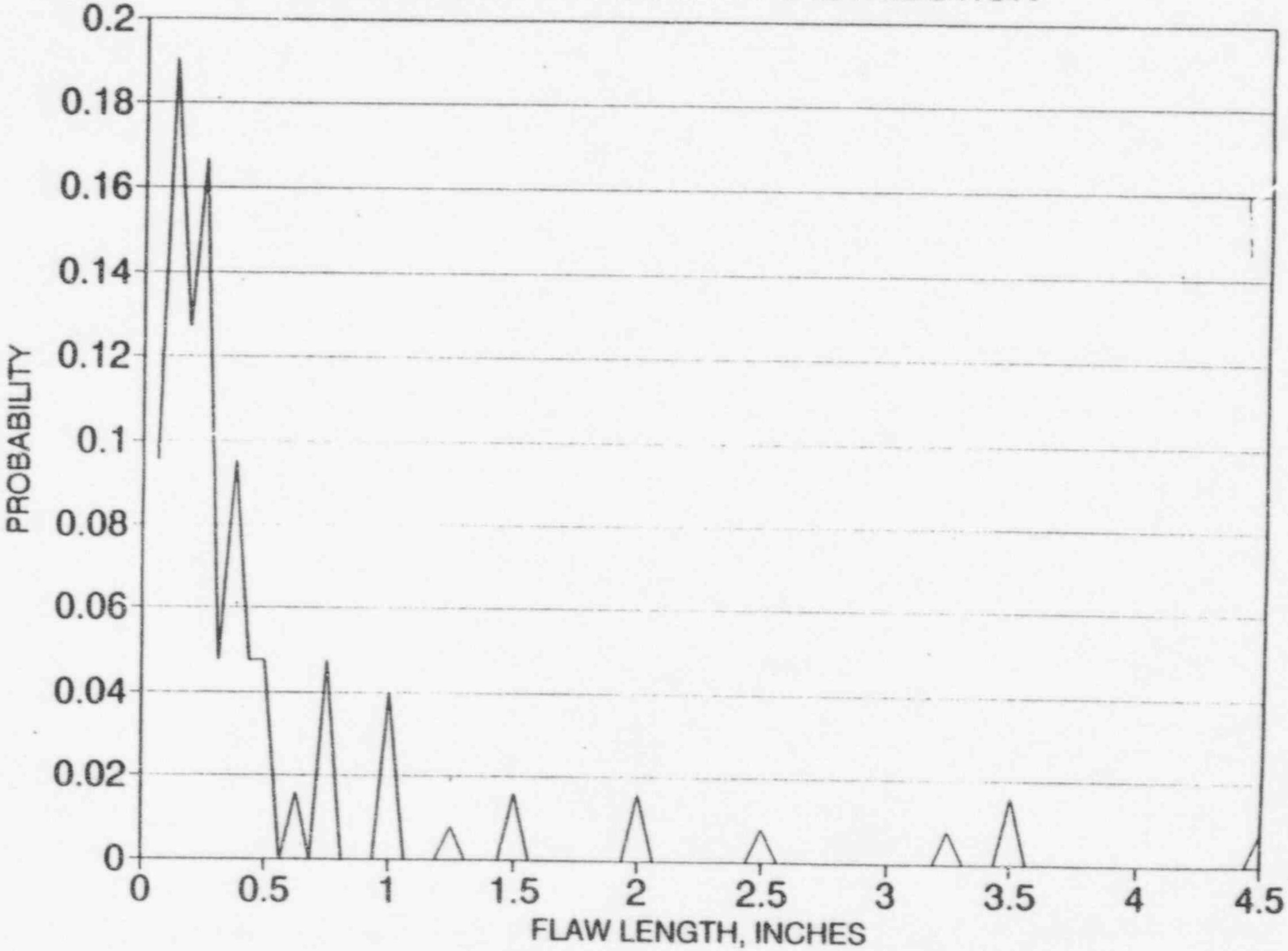
	MUSHONG YOU	9/30/93	J. GAOR	10/7/93					

FIGURE E.2 PROBABILITY DISTRIBUTION



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	WUSHONG YOW WY	9/30/93	J. GAOR J.G.	10/7/93					

ATTACHMENT E.1

RADIOGRAPHIC FILM RESULTS FOR MT-055

(Source: Reference 3)

SCE 26-426 NEW 4/90

Film Location	Accept (A) Reject (R)	Flaw Charac.	Size of Flaw
R1V1	R(1)	UC(2)	5/32 X 1/32
			1/2 X 1/16
			1/4 X 1/16
			3/4 X 1/32
			1 X 1/16
R1V2	R	UC	1/8 X 1/16
			1/4 X 3/32
			1 1/2 X 1/16
R1V4	R	UC	1/4 X 1/32
			1 1/2 X 1/16
			7/16 X 1/32
R1V5	R	SI	1/16 X 1/16
			1/8 X 1/16
			5/16 X 1/16
			1/8 X 1/16
			1/8 X 1/16
			3/8 X 3/32
		UC	3/8 X 1/16
			5/32 X 1/16
			1 X 1/16
			3 1/4 X 5/32
R1V6	R	UC	1 X 1/16
		IF	1/2 X 1/32
R1V7	R	UC	3/4 X 1/32
			1 X 1/32
			5/32 X 1/32
			1 X 1/32

Film Location	Accept (A) Reject (R)	Flaw Charac.	Size of Flaw
R2V1	R	SI	3/8 X 1/16
			1/8 X 1/32
			1/8 X 1/32
R2V3	R	UC	3/8 X 1/16
R2V6	R	IF	3/16 X 1/64
R2J1	R	UC	1/16 X 1/32
			1/16 X 1/32
			3/32 X 1/16
			3/8 X 3/32
		IF	9/32 X 1/32
			5/16 X 1/32
			7/16 X 1/64
			3/16 X 1/32
R2J2	R	UC	1/4 X 1/64
			1/8 X 3/32
			3/32 X 3/32
		IF	7/16 X 1/64
			1/16 X 1/64
			3/16 X 1/64
R2J4	R	UC	1/2 X 1/32
			5/32 X 3/32
			1/8 X 1/16
		IF	3/4 X 1/32
R2J5	R	IP	1 1/4 X 1/64
		IF	1/8 X 1/64
R2J6	R	IF	1/2 X 1/32
		UC	3/8 X 1/32

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	WUSHONG YOW WY	9/30/93	J. GAOR J.G.	10/7/93					

Film Location	Accept (A) Reject (R)	Flaw Charac.	Size of Flaw
R2J7	R	IF	7/32 X 1/32
R2H1	R	UC	2 X 1/16
			2 X 1/16
R2H4	R	UC	1/4 X 1/16
			3/16 X 1/16
R2H7	R	UC	3 1/2 X 1/16
R2H2	R	UC	3/4 X 1/32
			9/32 X 1/32
			1/8 X 1/32
			3/32 X 1/16
			5/32 X 1/16
			3/32 X 1/32
R3V1	R	IF	3/8 X 1/32
			5/8 X 1/32
R3V5	R	SI	7/16 X 1/16
			5/16 X 1/16
		IF	1/8 X 1/64
			7/16 X 1/32
		UC	1/4 X 1/16
			3/8 X 1/16
R3V6	R	IF	1/4 X 1/64
R3V7	R	SI	7/32 X 1/16
			1/16 X 1/16
		UC	3/4 X 1/8

Film Location	Accept (A) Reject (R)	Flaw Charac.	Size of Flaw
R3J2	R	IF	5/32 X 1/32
R3J3	R	SI	1/4 X 1/32
			3/16 X 1/32
			3/32 X 1/32
R3J4	R	IF	1/4 X 1/64
			1/8 X 1/64
			3/32 X 1/64
R3J5	R	IF	1/2 X 1/32
R3J6	R	UC	3/8 X 1/16
R3J7	R	SI	5/32 X 1/16
			1/4 X 1/16
R4H1	R	IF	3/8 X 1/32
		M	2 1/2 X 1/32
		UC	1/2 X 1/16
R4H2	R	UC	3 1/2 X 1/32
R4H3	R	UC	4 1/2 X 1/32
R4V1	R	IF	1/4 X 1/32
R4V4	R	IF	1/4 X 1/32
R4V5	R	SI	1/4 X 1/32
			1/8 X 1/32
R4V7	R	IF	7/16 X 1/64

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	WUSHONG YOW	9/30/93	J. GAOR J.G.	10/7/93					

Film Location	Accept (A) Reject (R)	Flaw Charac.	Size of Flaw
R4J1	R	IF	1/16 X 1/64
			1/8 X 1/64
			3/16 X 1/32
R4J2	R	UC	5/8 X 3/16
			1/4 X 3/32
			1/16 X 1/32
			1/4 X 1/16
			3/32 X 1/16
		IF	1/8 X 1/64
			1/16 X 1/32
R4J3	R	IF	3/16 X 1/64
			5/32 X 1/64
R4J4	R	UC	3/8 X 1/16
			1/16 X 1/32
			1/8 X 1/32
			5/32 X 1/16
			7/32 X 1/16
			1/16 X 1/16
		IF	1/16 X 1/32
R4J5	R	UC	3/4 X 1/16
			1/4 X 1/32
		IF	5/16 X 1/64
R4J7	R	UC	1/16 X 1/32
			7/32 X 1/32
			3/8 X 1/32
			3/32 X 1/32
		IF	7/32 X 1/64

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	WUSHONG YOW	9/30/93	J. GAOR	10/7/93					

Notes:

(1) A designates "Accept"; R designates "Reject"

(2) The defect Codes for the flaw characteristics are

IF - Incomplete fusion
IP - Inadequate penetration
SI - Slag inclusion
TI - Tungsten inclusion
BT - burn through
M - Mismatch
DT - Drop through
UC - Undercut
OX - Oxidized root
CV - Root concavity
CX - Root convexity
P - Porosity
FA - Film artifact

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	NABIL M. EL-AKILY	10/12/93	JUN GAOR J.G.	10/12/93					

APPENDIX - F

FRACTURE MECHANICS EVALUATION

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	R. QASHU	11/10/93	JUN GAOR J.G.	11/10/93					

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	R. QASHU	11/10/93	JUN GAOR J.G.	11/10/93					

1.0 PURPOSE/BACKGROUND:

During a QA surveillance activities of the primary make up storage tank T-056 (Unit-2) modifications, QA identified evidence of poor workmanship in the original construction welding of the tank. The poor workmanship was identified for example; as excessive weld reinforcement (greater than 3/32"), and undercut (greater than 1/32"). QA also reviewed the original 10 radiographs and found two unacceptable. The QA assessment was later confirmed by QC. Additional five radiographs were taken and found unacceptable by QC. It was evident at this point that continuing the radiography will continue to show same type of weld defects, and an evaluation must be developed to address the structural integrity of the tank with the weld defects. It was also concluded that similar defects are to expected in T-055 (Unit-3).

In order to address the weld defects, a plan was put to try to characterize statistically a bounding defect with high confidence. The number of radiographs was increased to a total of 60, covering basically all of the tank shell weld seams. The results of the radiographs is used to perform a bounding fracture mechanics analysis to demonstrate acceptability of the welds with high reliability.

The analysis is comprised of two phases. Phase one a statistical analysis to try to calculate a reliability of at least 95% of a defect length not to exceed a given length, with 95% confidence level. The bounding defect will be used in phase 2 conservative fracture analysis to show that the defect, simulated as a crack will be acceptable for the life of the tank.

Phase 1 is addressed in appendix E, and phase 2 is addressed in this appendix.

The following calculation was originally performed to address the welding defects of Unit-2 PPMS tank (T-056), and the results are documented in calculation number M-DSC-280. However, the maximum defect size found in T055 of Unit-3 is enveloped by T-056 maximum defect size. Therefore, Unit-2 calculation is bounding, and applying the results to Unit-3 PPMS tank is conservative.

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	R. QASHU	11/10/93	JUN GAOR J-G.	11/10/93					

2.0 RESULTS/CONCLUSIONS:

The worst defect reported in appendix E was assumed to exist in the highest stress region of the tank shell, and oriented axially to maximize the stress and the stress intensity. The defect was analyzed by two methods:

In the first method the defect was assumed infinitely long and depth equals to half the shell thickness. The analysis showed that the flaw will be stable with a safety factor of 4.4, and the amount of radial crack growth over the life of the tank is within the remaining tank shell thickness.

In the second methodology the crack was assumed through wall and 5" long. The results showed that the crack will be stable with a safety factor of 3.13.

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3.0 ASSUMPTIONS:

1. The material is isotropic and elastic (the nominal stress is within the yield strength).
2. None of the specifications of the used filler metal in the tank shell welding (E308, E308L, E309), requires material toughness value. But the data published by EPRI and others (Reference 4) provide toughness values in the form of J_{IC} which was used to calculate K_{IC} of the filler metal.
3. The tank was assumed to undergo 400 cycles of fill and refill corresponding to the number of plant shut downs over 40 years.

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4.0 DESIGN INPUT:

Tank material SA-240-304	Reference 8
Tank Radius, 240 inch	Reference 8
Filler metal E308,308L,309	Reference 6
J_{IC}, 990 in-lb/in^2	Reference 4
E, 25 E3 Ksi	Reference 4
Material Yield Strength 29.8 Ksi @104 F	Reference 7
Tank shell thicknesses 5/16", 1/4" and 3/16"	Reference 8
Maximum defect 4.875	Appendix E

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5.0 **METHODOLOGY:**

From appendix E the worst (largest) defect is identified as 4.875 inch long lack of fusion (radiograph G2-3, in the second horizontal seam 14 feet from the tank bottom).

For the purpose of the analysis the defect will be assumed as a five inch long vertical flaw (the ratio of hoop stress to meridional stress is about 3), extending halfway through the plate thickness as shown in figure 1. Also in figure 1, in dotted lines the credible paths of flaw propagation are shown.

The stress intensity factor at c_1 the crack tip can be conservatively calculated as if the crack front is in the radial direction as in profile c_2 Figure 1.

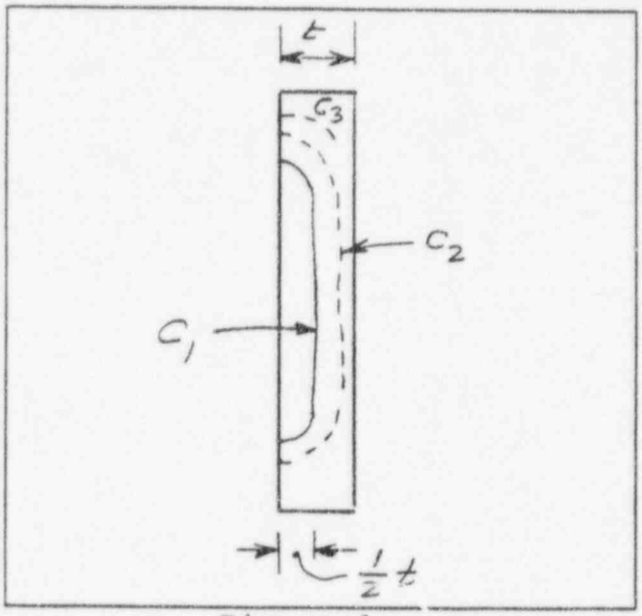

Figure 1

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For such a case the crack tip stress intensity is defined by the expression from Reference 1.

$$k = G_0 \sigma \sqrt{(\pi a/Q)} \qquad (1)$$

where G_0 = Free surface correction factor for the given stress variation provided in Tables A-3320-1 as function of flaw aspect ratio (a/l = 0), and flaw tip position 1.

σ = Maximum hoop stress Ksi in the tank including effects of water sloshing due to earthquake and local stress due to the ring, calculated using finite element analysis.

a = Crack depth (half plate thickness = 0.125")

Q = Flaw shape parameter as given by equation 2 below:

$$Q = 1 - [G_0 \sigma / \sigma_{ys}]^2 / 6 \qquad (2)$$

Where σ_{ys} is the material yield strength

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Another credible path for the flaw to propagate, is to become through wall and extend longitudinally as in profile c_3 in Figure 1.

Given the crack is through wall, and 5 inches long, the stress intensity factor can be calculated for this case using linear elastic fracture mechanics (LEFM) provided in standard computer program PcCrack. LEFM crack model E, through wall axial crack in a pressurized cylindrical shell was chosen to perform the analysis. Detail discussion of this methodology is provided in Reference 2.

The crack growth will be calculated based on Figure A-4300-1 of reference 5, assuming water environment and R = 0.25. DK is conservatively assumed equal to K_{max}.

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	R. QASHU	11/10/93	JUN GAOR J.G.	11/10/93					

6.0 REFERENCES:

1. ASME Section XI working group on flaw evaluation, replacement of stress intensity factor calculation of Article A-3000 of Appendix A of Section XI, based on Stress Analysis of Cracks Handbook by Tada and Paris, Second Edition (Section 2).
2. PcCrack Fracture Mechanics Software, Version 2.1, Structural Integrity Associates, Inc.
3. ANSYS User's Manual, Revision 4.4A, Swanson Analysis System.
4. Journal of Pressure Vessel Technology, Vol 108, August 1986.
5. ASME Code Section XI, 1989 Edition.
6. Data report SA-1415-1.
7. ASME Code Section III, Appendices, 1989 Edition.
8. Drawing S023-407-3-61-2, Primary Make-up Storage Tank shell plate layout.

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7.0 NOMENCLATURE:

a	Crack depth (in)
F	Factor of safety (K_{IC}/K_I)
G_0	Correction factor (2.8254)
I	Tank cross section moment of inertia (in^4)
r	Tank radius (in)
t	Tank shell plate thickness (in)
K	Stress intensity factor (Ksi$\sqrt{in}$)
K_{Ic}	Critical stress intensity (Ksi$\sqrt{in}$
DK	Stress intensity range (Ksi$\sqrt{in}$)
M	Bending Moment (in-lb)
N	Number of stress cycles
Q	Flaw shape parameter
σ	Stress (Ksi)
σ_{ys}	Material yield strength
E	Modulus of elasticity (Ksi)

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	R. QASHU	11/10/93	JUN GAOR J.G.	11/10/93					

8.0 CALCULATIONS:

8.1 STRESS CALCULATIONS:

8.1(a) Meridional Stress, the meridional stress is calculated from the over turning moment as follows:

From page A34 the overturning moment is given at the ring elevation (M = 237,927,613 in lb).

The meridional stress σ at the ring location can be calculated as:

$$\sigma = M\, r / I$$

where r = 240 inch, tank radius

$I = \pi\, t\, r3$

t = 1/4 inch, tank thickness at location of maximum stress

$$\sigma = 237927613*240/\pi*0.25*240^3$$

$$= 5.3 \text{ Ksi}$$

8.1(b) Hoop Stress, To account for the discontinuity of the tank shell at the ring location, a three dimensional finite element analysis was performed using standard computer program ANSYS (Reference 3). The tank finite element model is depicted in

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Figure 2. The stress analysis results are provided in Figure 3. The computer input image listing is provided in the attachment section. The water sloshing effect due to earthquake (SSE) was converted to hydrostatic pressure and added to the tank hydrostatic pressure. The maximum hoop stress calculated by ANSYS is 15.9 Ksi.

8.2 FRACTURE MECHANICS CALCULATIONS:

The stress intensity factor can be calculated using Equations 1, and 2.

G_0 = 2.8254 from table A-3320-1 @ a/t=0.5 and a/l=0.

$$Q = 1-(15.9*2.8254/29.8)^2/6$$
$$= 0.6213$$

$$K = 2.8254*15.9(\pi*0.125/0.6213)^{1/2}$$
$$= 35.72 \text{ Ksi } \sqrt{in}$$

A factor of safety is calculated by ratio of K_{IC}/K,

$$K_{IC} = \sqrt{(J_{IC}*E)}$$
$$= \sqrt{(990*25E6)}$$
$$= 157.32 \text{ Ksi}\sqrt{in}$$
$$F = 157.32/35.72$$
$$= 4.4$$

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The analysis was repeated using PcCrack Reference 2, assuming a through wall crack of 5 inch. The results of PcCrack are graphed in Figure 4. The calculated stress intensity is 50.802 Ksi $\sqrt{in}$. Based on the PcCrack results a factor of safety equals to 3.13 is calculated.

8.3 da/dN CALCULATION

The crack growth is calculated using figure A-4300-1 (Reference 5) for water environment, and R = 0.25. DK = 50 Ksi$\sqrt{in}$, which is the maximum stress intensity based on 5 inch axial crack.

From figure A-4300-1 @ DK = 50 Ksi$\sqrt{in}$, find da/dN = 200 E-6 inch/cycle.

conservatively assume that the tank will undergo 400 cycles of filling and refilling, corresponding to the number of plant shutdowns over 40 years.

Crack growth = 400 * 200E-6

= 0.08 inch

The remaining tank thickness at defect location =

= 0.125-.08

= 0.045 inch

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Subject see title sheet Sheet No. 264

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	R. QASHU	11/10/93	JUN GAOR J-L	11/10/93					

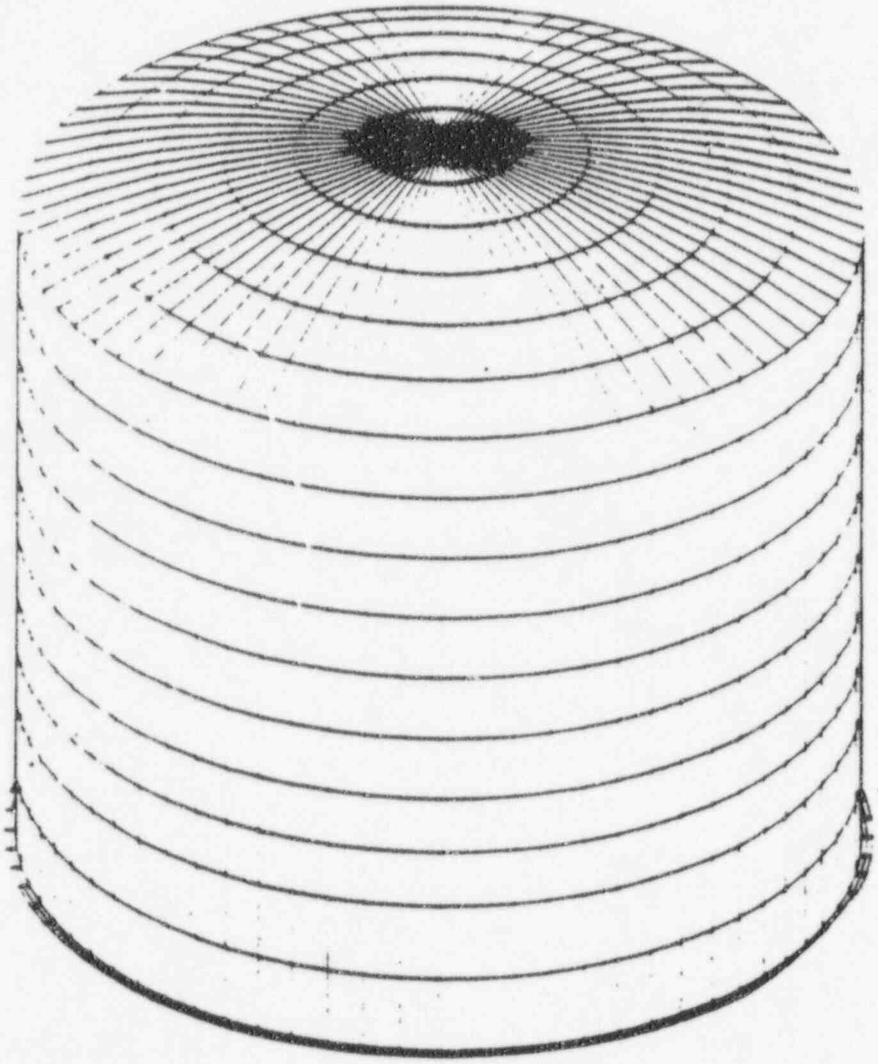

Figure 2, Tank shell finite element model

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CALCULATION SHEET

Project or DCP/MMP SONGS 3 Calc No. M-DSC-269

Subject see title sheet

Sheet No. 265

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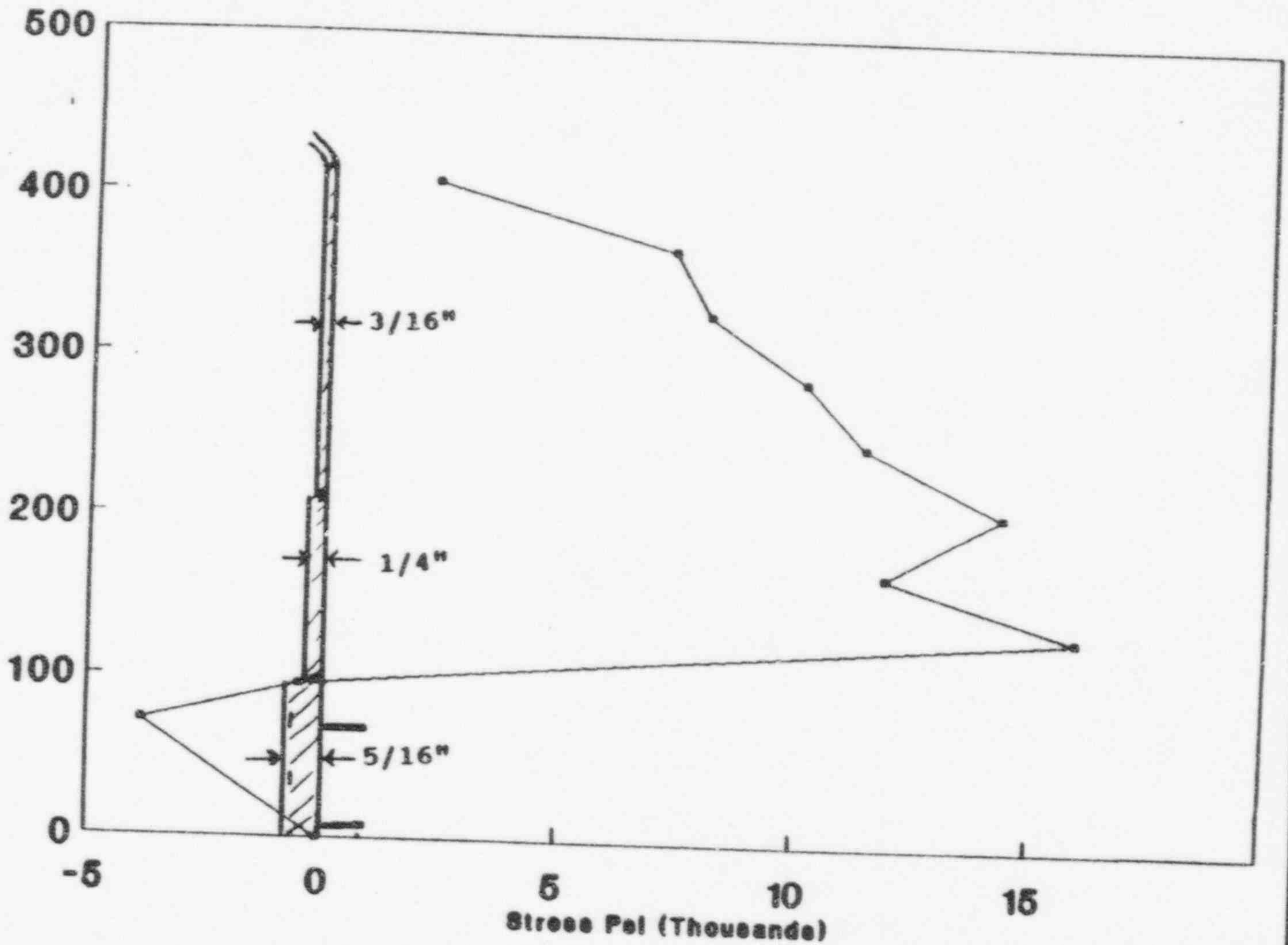
REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	R. GASHU	11/10/93	JUN GAOR J.G.	11/10/93					

Figure 3 Hoop stress distribution



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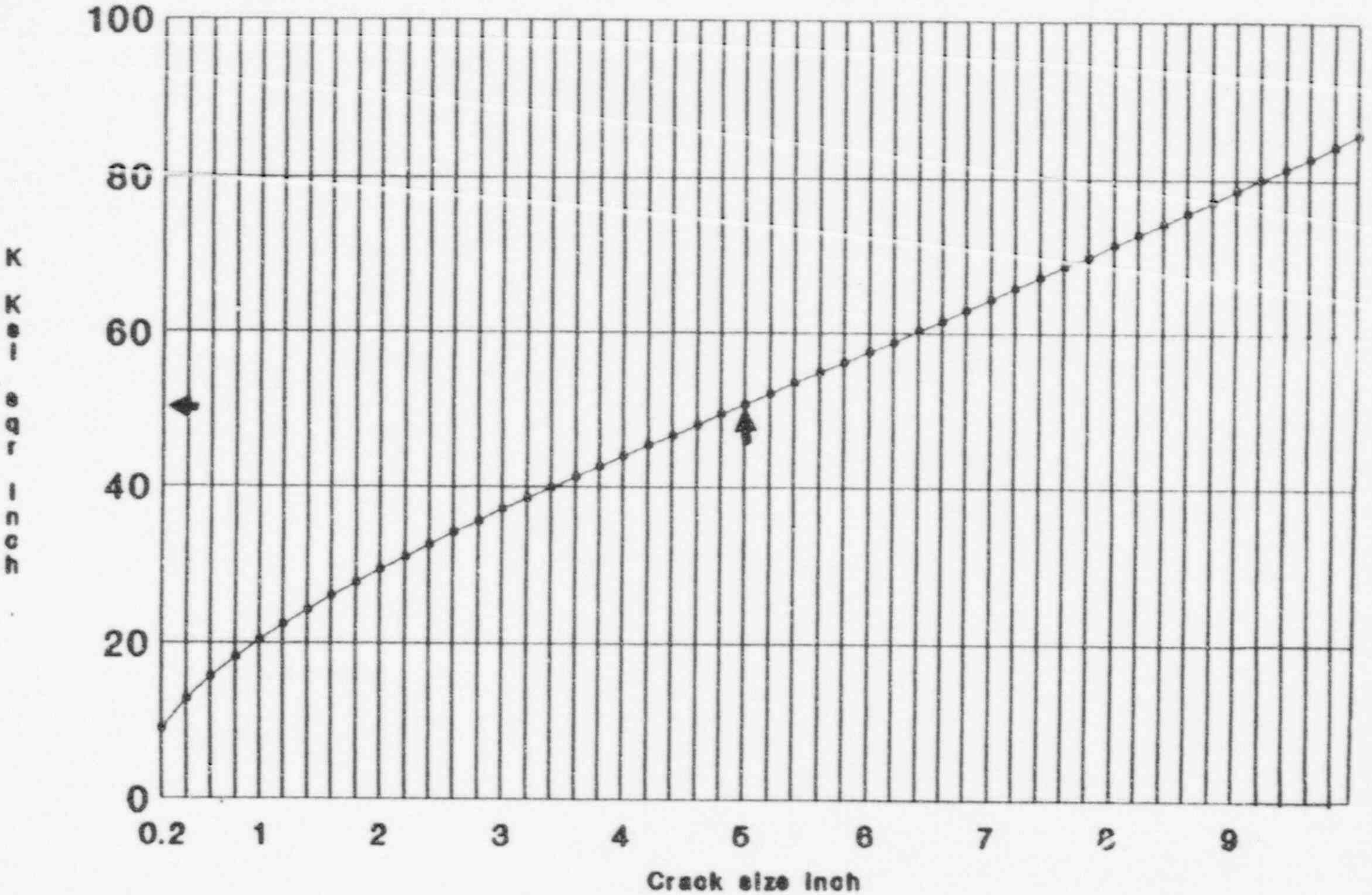
	R. GASHU	11/10/93	JUN GAOR J-G.	11/10/93					

Figure 4, K vs Crack size



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REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	R. QASHU	11/10/93	JUN GAOR JG	11/10/93					

ATTACHMENTS TO APPENDIX F

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REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	R. QASHU	11/10/93	JUN GAOR JG.	11/10/93					

```
/PREP7
/TITLE,PRIMARY PLANT MAKE-UP TANK
C***FILE NAME: PPMS1.
C***
C***    FORCE APPLIED NEAR THE TOP
C***
KAN,0
C***
C***           ELEMENT TYPE: ELASTIC SHELL
ET,1,63
ET,2,8
C***
C***           MATERIAL PROPERTIES
EX,1,28.3E6                   * TANK SHELL (TYPE 304 SS)
NUXY,1,0.3                    *
EX,2,30.0E9
NUXY,2,0.3
C***
C***           REAL CONSTANTS
R,1,0.25                      * BOTTOM
R,2,0.3125                    * FIRST TIER
R,3,0.25                      * SECOND TIER
```

```
R,4,0.1875                   * THIRD TIER
R,5,0.25                     * ROOF
R,6,1.0                      * SPOKES
C***
C***          GEOMETRY
RT=240.0                     * TANK RADIUS
H1=95.625                    * HEIGHT TO TOP OF FIRST TIER
H2=167.25                    * HEIGHT TO TOP OF SECOND TIER
HT=408.0                     * TANK HEIGHT
RBL=243.0                    * BOLT CIRCLE RADIUS
RBT=246.0                    * OUTSIDE RADIUS OF THE BOTTOM
RR=576.0                     * ROOF RADIUS
A1=SQRT(RR*RR-RT*RT)
A2=HT-A1                     * CENTER OF COORDINATE SYSTEM 11
A3=A2+576.0
C***
C***          NODE DEFINTION
N,1,1.0                      * CENTER OF THE TANK
N,7,RT                       * TANK RADIUS
FILL,1,7                     *
N,9,RT,H1
FILL,7,9,,,,,0.328125
```

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	R. QASHU	11/10/93	JUN GAOR JG	11/10/93					

```
N,11,RT,H2
FILL,9,11
N,17,RT,HT
FILL,11,17
C***
N,23,1.0,A3
N,9000,0.,A2
NGEN,2,1,9000,,,1.0
NGEN,2,1,9001,,,,1.0
CS,11,1,9000,9001,9002
CSYS,11
FILL,17,23
C***
CSYS,0
N,24,RBL
N,25,RBT
C***
N,9003,0.,0.,0.
N,9004,1.0,,-1.0
CS,12,1,9003,7,9004
CSYS,12
NGEN,72,25,1,25,,,5.0
```

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	R. QASHU	11/10/93	JUN GAOR JG	11/10/93					

```
NDEL,9000,9004
C***
CSYS,0
N,1801,,367.875
C***
C***          ELEMENT DEFINITION
MAT,1
TYPE,1
REAL,1                            * BOTTOM
E,1,2,27,26
EGEN,6,1,1
E,7,24,49,32
E,24,25,50,49
EGEN,71,25,1,8
E,1776,1777,2,1
EGEN,6,1,569
E,1782,1799,24,7
E,1799,1800,25,24
C***
REAL,2                            * FIRST TIER
E,7,8,33,32
EGEN,71,25,577
```

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	R. QASHU	11/10/93	JUN GAOR J.G.	11/10/93					

```
E,7,1782,1783,8
EGEN,2,1,577,648
C***
REAL,3                          * SECOND TIER
E,9,34,35,10
EGEN,71,25,721
E,1784,9,10,1785
EGEN,2,1,721,792
C***
REAL,4                          * THIRD TIER
E,11,36,37,12
EGEN,71,25,865
E,1786,11,12,1787
EGEN,6,1,865,936
C***
REAL,5                          * ROOF
E,17,42,43,18
EGEN,71,25,1297
E,1792,17,18,1793
EGEN,6,1,1297,1368
C***          LOADING AND BOUNDARY CONDITIONS
WSORT,ALL
```

```
NSEL,,24,1799,25          * FIXED NODES ALONG THE BOLT
CIRCLE
D,ALL,ALL                 *
NSEL,,9,1784,25
D,ALL,ALL
NALL                      *
NSEL,Y,0
D,ALL,UY,0
NALL
C***
ITER,-100,100,1
ESEL,,649,720
EP,ALL,1,14.4
ESEL,,721,792
EP,ALL,1,13.6
ESEL,,793,864
EP,ALL,1,12.4
ESEL,,865,936
EP,ALL,1,11.2
ESEL,,937,1008
EP,ALL,1,9.85
ESEL,,1009,1080
```

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	R. QASHU	11/10/93	JUN GAOR JG.	11/10/93					

```
EP,ALL,1,8.5
ESEL,,1081,1152
EP,ALL,1,7.2
ESEL,,1153,1224
EP,ALL,1,5.8
ESEL,,1225,1296
EP,ALL,1,4.5
EALL
AFWRITE
FINISH
/INPUT,27
FINISH
```

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	R. QASHU	11/10/93	JUN GAOR J.G.	11/10/93					

tm

pc-CRACK

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

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	R. QASHU	11/10/93	JUN GAOR J.G.	11/10/93					

CASE ID	STRESS
1	15.9000

CRACK ---------------STRESS INTENSITY

FACTOR-----------------

SIZE	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

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
	R. QASHU	11/10/93	JUN GAOR JG.	11/10/93					

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
2.6000	52.154
2.7000	53.505
2.8000	54.856
2.9000	56.209
3.0000	57.565
3.1000	58.923
3.2000	60.284
3.3000	61.650
3.4000	63.020
3.5000	64.394

NES&L DEPARTMENT

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	R. QASHU	11/10/93	JUN GAOR J.G.	11/10/93					

3.6000	65.774
3.7000	67.160
3.8000	68.551
3.9000	69.949
4.0000	71.353
4.1000	72.764
4.2000	74.182
4.3000	75.607
4.4000	77.039
4.5000	78.479
4.6000	79.926
4.7000	81.382
4.8000	82.845
4.9000	84.316
5.0000	85.796

TABLE A-3320-1

COEFFICIENTS G0 THROUGH G3 FOR SURFACE CRACK AT POINT 1

	a/t	FLAW ASPECT RATIO a/l 0.0	0.1	0.2	0.3	0.4	0.5
UNIFORM G0	0.00	1.1208	1.0949	1.0856	1.0727	1.0564	1.0366
	0.05	1.1461	1.1000	1.0879	1.0740	1.0575	1.0373
	0.10	1.1945	1.1152	1.0967	1.0779	1.0609	1.0396
	0.15	1.2670	1.1402	1.1058	1.0842	1.0664	1.0632
	0.20	1.3654	1.1764	1.1210	1.0928	1.0739	1.0482
	0.25	1.4929	1.2170	1.1399	1.1035	1.0832	1.0543
	0.30	1.6539	1.2670	1.1621	1.1160	1.0960	1.0614
	0.40	2.1068	1.3840	1.2135	1.1448	1.1190	1.0772
	0.50	2.8254	1.5128	1.2693	1.1757	1.1457	1.0931
	0.60	4.0420	1.6372	1.3216	1.2039	1.1699	1.1058
	0.70	6.3763	1.7373	1.3610	1.2237	1.1868	1.1112
	0.80	11.991	1.7899	1.3761	1.2285	1.1902	1.1045
LINEAR G1	0.00	0.7622	0.6635	0.6826	0.7019	0.7214	0.7611
	0.05	0.7624	0.6651	0.6833	0.7022	0.7216	0.7613
	0.10	0.7732	0.6700	0.6855	0.7031	0.7221	0.7618
	0.15	0.7945	0.6780	0.6890	0.7046	0.7230	0.7626
	0.20	0.8267	0.6891	0.6939	0.7067	0.7243	0.7620
	0.25	0.8706	0.7029	0.7000	0.7094	0.7260	0.7651
	0.30	0.9276	0.7193	0.7073	0.7126	0.7282	0.7668
	0.40	1.0907	0.7584	0.7249	0.7209	0.7338	0.7511
	0.50	1.3501	0.8029	0.7454	0.7316	0.7417	0.7566
	0.60	1.7863	0.8488	0.7671	0.7461	0.7520	0.7631
	0.70	2.6125	0.8908	0.7882	0.7588	0.7653	0.7707
	0.80	4.5727	0.9288	0.8063	0.7753	0.7822	0.7792
QUADRATIC G2	0.00	0.6009	0.5078	0.5310	0.5556	0.5815	0.6084
	0.05	0.5969	0.5086	0.5313	0.5557	0.5815	0.6084
	0.10	0.5996	0.5109	0.5323	0.5560	0.5815	0.6085
	0.15	0.6088	0.5148	0.5340	0.5566	0.5815	0.6087
	0.20	0.6267	0.5202	0.5366	0.5571	0.5815	0.6089
	0.25	0.6473	0.5269	0.5394	0.5580	0.5817	0.6093
	0.30	0.6775	0.5350	0.5430	0.5592	0.5820	0.6099
	0.40	0.7651	0.5545	0.5520	0.5627	0.5835	0.6115
	0.50	0.9048	0.5776	0.5632	0.5680	0.5869	0.6144
	0.60	1.1382	0.6027	0.5762	0.5760	0.5931	0.6188
	0.70	1.5757	0.6281	0.5907	0.5874	0.6037	0.6255
	0.80	2.5997	0.6513	0.6063	0.6031	0.6200	0.6351
CUBIC G3	0.00	0.5060	0.4246	0.4480	0.4735	0.5006	0.5290
	0.05	0.5012	0.4250	0.4482	0.4736	0.5006	0.5290
	0.10	0.5012	0.4264	0.4488	0.4736	0.5004	0.5290
	0.15	0.5059	0.4286	0.4498	0.4737	0.5001	0.5289
	0.20	0.5152	0.4317	0.4511	0.4738	0.4998	0.5289
	0.25	0.5292	0.4357	0.4528	0.4741	0.4996	0.5289
	0.30	0.5683	0.4406	0.4550	0.4766	0.4992	0.5291
	0.40	0.6045	0.4522	0.4605	0.4763	0.4993	0.5298
	0.50	0.6963	0.4665	0.4678	0.4795	0.5010	0.5316
	0.60	0.8435	0.4829	0.4769	0.4853	0.5054	0.5349
	0.70	1.1207	0.5007	0.4880	0.4965	0.5141	0.5407
	0.80	1.7616	0.5190	0.5013	0.3085	0.5286	0.5487

Note: Interpolation in a/t and a/l is permitted

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CALC NO. M-DSC-269 REV. ___

SUPPLEMENT — SHT 279

ORIGINATOR — DATE —

IRE — DATE —

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