

Reliability

Integrity

Quality

Safety



TANK S-1
API-653 In-Service Inspection
September 15, 2020



To: **NAVFAC**
Honolulu, HI 96819

From:



P.O. Box 700217
Kapolei, HI. 96709-0217

**"Providing Excellence in NDE and Quality
Inspection Services to Industries Worldwide"**

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September 15th, 2020

Mr. Darryl Yokoyama, P.E.
PRJ61 Potable Branch
NAVFAC HI Utilities Management
Public Works Department, JBPHH, Bldg. 638

Subject: In-service (External) API 653 inspection including Ultrasonic Thickness (UTT) Survey on Tank #S-1, located in Honolulu, Hawaii.

Tank Data

Tank ID: S-1
Built By: Pittsburgh Des Moines Inc.
Year Built: 1996
Product: Potable Water
Product SPG: 1.00
Capacity: 125,000 Bbls.
Size: 165' Diameter x 40' Height

SYNOPSIS:

On September 15th, 2020 Engineering & Inspections Hawaii performed an API-653; In-Service external inspection of S-1 potable water tank located in Honolulu, HI for NAVFAC in the Aliamanu Military Reservation. A visual inspection was completed on the visible external surfaces of the tank shell, nozzles, stairway, and the tank roof from the ground, roof, and stairway. Several areas of active corrosion were noticed around the tank shell on the first shell course that were identified and measured less than 0.200" deep. Two (2) areas of severe active corrosion on the tank roof were noted and identified for repair. Several of the roof anode bases were identified with missing hardware or corrosion. Inspection of the rim angle of the tank roof revealed moderate active corrosion location in one (1) area on the south side of the tank roof.

The tank shell was double butt-welded with shell plates staggered to the left. Supplemental Ultrasonic Thickness (UTT) Testing was completed on the tank in conjunction with the visual inspection, revealing no significant wall loss from nominal thickness. Tank S-1 was constructed in 1996 by Pittsburgh Des Moines Inc. and was constructed of A36 carbon steel. A new double bottom tank floor was installed in 2013 and several patches were installed on the tank roof due to external corrosion.



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The tank was constructed to AWWA D-100 89a Edition code. The tank has a nominal height of 40' and a diameter of 165'.

Surrounding Area:

Tank S-1 was located inside of a controlled fenced area. The nearest tank (S-2) was approximately 100' to the north. A 3' high brick retaining wall was constructed at the base of the tank on the east side. A large hatch on the south side of the tank was found at the base of the tank near the overflow nozzle piping. Fencing with a lockable gate was constructed around the stairway access to the roof of the tank.

Foundation:

The tank rested on top of an elevated concrete slab. The concrete sat approximately 6" above grade. The existing concrete was found with slight cracking and spalling located randomly around the tank. Vegetation growth was noted around the base of the tank with some of the vegetation in direct contact with the tank floor. No tank grounding was associated with the tank. One leak detection port was associated with the tank; it was found dry with no obvious evidence of leakage from the tank floor.

Cathodic Protection:

An El Segundo style floor acts as cathodic protection for the current tank floor bottom.

Tank Chime:

Tank S-1 was noted with a full projection plate that extended 2" past the toe of the chime weld around the base of the tank shell. Minor topside coating failure with active corrosion was noted. Several areas of the projection plate was also noted with moderate underside corrosion. No knifing, severe corrosion, or other deterioration was found at the projection plate.

Tank Shell:

The tank shell was a five-course double butt-welded designed tank where the shell plates were staggered to the left. Discoloring of the tank coating was noted around the entire shell due to micro bacterial growth on the external surfaces. Seven (7) areas of moderate active corrosion were found on the first course of the tank shell that were evaluated using a hammer, scraper, and pit gauge revealing localized corrosion measuring less than 0.200" deep. The areas of corrosion were measured less than 8" in overall diameter. The nominal thickness of the first shell course was 1.262". Several other areas of external corrosion were noted to have been previously arrested and recoated scattered across all shell courses with the more significant arrested areas found on the first and second shell courses. No other significant external corrosion was found on the shell plates or their associated connection welds. The external surfaces of the shell were fully coated with several areas of light coating failure present. The tank does not have any active rim vents or overflows. No reinforcement plates were installed between the tank shell and external attachment bracket connections for the piping and conduit extending up the tank shell.

Tank Nozzles:

Tank S-1 has two (2) 24" manways found on the Northwest and Southeast sides of the first shell course. The 24" fill/suction line was found on the west side of the first shell course. Light isolated corrosion was observed in several locations of the external portions of the tank nozzle bores. A low-level alarm 1" nozzle on the south side of the shell were not seal welded to their first isolation point. The nozzle to shell and nozzle to repad connection welds were found intact and secure with no preferential corrosion noted. A 24" overflow nozzle was found on the south side of the tank shell near the upper section of the fifth shell course. All associated nozzle reinforcing plates were found tombstoned to the tank bottom. The 1" high level alarm nozzle near the top of the tank shell was found threaded at its shell connection below a stair tread.

Fire Suppression:

The product being stored in S-1 is Potable Water and a fire suppression system is not required.



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Tank Gauging System:

The Varec-gauge was found on the west side of the tank shell. The gauge was showing a product height of 2'-7" with the bump check not being operational at the time of inspection.

Tank Stairway, Roof Platform:

The stairway access to the roof was fully coated with several areas of discoloration found due to active corrosion. The roof access platform was a diamond plate base with light coating failure and active corrosion found around the edge of the plate.

Tank Roof and Appurtenances:

The tank roof had been recently recoated. Several areas of the tank roof were experiencing light to moderate coating failure with active corrosion present underneath. Numerous previous repairs were completed on the tank roof after severe active corrosion was identified on the previous drawing. Two (2) areas of the tank roof were identified with severe isolated corrosion and were identified on the tank roof as well as the attached drawing. The two identified areas were marked up to have lap patches installed over the active corrosion. The identified areas of significant corrosion on the tank roof were identified with X and Y coordinates with the starting location being the south west corner of each individual roof plate, and extend to the center of the corroded area. One (1) area of coating failure and moderate active corrosion was found on the southern side of the tank roof along the peripheral edge of the tank and was identified on the associated drawing. Eight of the anode beds found on the tank roof were found with missing hardware, corroded base covers, or duct tape covering the tops, indicating a need to be repaired or replaced. Several areas of isolated pitting were also noted on the tank roof that had been arrested and recoated with no discoloration or further corrosion noted. The roof has one 24" center vent with the screen intact, clear, and secured. The flange of the vent base was found with active corrosion and slight loss of profile and knifing at the edge of the flange. A single 1" coupling on the southwest side of the tank roof was discovered with severe active corrosion with loss of profile to the coupling and attachment weld to the tank roof. The toe boards of the roof access handrailing system was found in direct contact with the tank roof on the north side. Several of the vertical handrail supports were found with active severe corrosion with thru-wall indications noted.



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Recommendations:

Shell:

1. Mechanically clean and recoat the scattered areas of active localized corrosion found scattered across the tank shell and projection plate on both the top and bottom side, using an approved coating procedure and specification by NAVFAC.
2. Remove the vegetation found around the base of the tank.

Roof:

1. Corrosion Area #1: Install a 12" diameter lap patch over the active corrosion.
2. Corrosion Area #2: Install a 10" diameter lap patch over the active corrosion.
3. Replace the eight (8) anode bases that were identified with mechanical or corrosion deficiencies that were identified on the attached roof drawing.
4. Replace the corroded conduit coupling attached on the southwest side of the tank roof in-kind.
5. Perform weld build-up on the one (1) area of external corrosion on the peripheral edge that was identified on the south side of the tank roof.
6. Mechanically clean and recoat the scattered coating failure with active corrosion present on the tank roof and roof vent nozzle, using an approved coating procedure and specification by NAVFAC.



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Based on the satisfactory completion of the In-Service inspection; NAVFAC Potable Water Tank S-1 located in the Aliamanu Military Reservation of Honolulu, HI is approved for continued service based on the time frames noted below.

Next API-653 In-Service Inspection Due: **September 2025**

Next API-653 Out-of-Service Inspection Due: **TBD by NAVFAC**

If you have any questions regarding this matter or require any additional information, please do not hesitate to contact Daniel Elling at (320) 310-2764.

Respectively submitted,

Daniel Elling

Daniel Elling

Certified API-653 Inspector No. 36003

STI SP-001 No. AC44302

Engineering & Inspections Hawaii, Inc.

Attachments: A. Pictures
B. UT Data
C. Drawings
D. T-Min Calculations

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Appendix A

Photographs



Tank Dataplate



Tank Manway access



Tank ID



Projection Plate (typical)



Leak detection port



Base of tank (typical)



Concrete shrink cracking



Vegetation around tank base (typical)



Varc gauge



Varc gauge and conduit to roof



Corrosion on projection plate underside



Shell corrosion



Shell corrosion



Shell corrosion



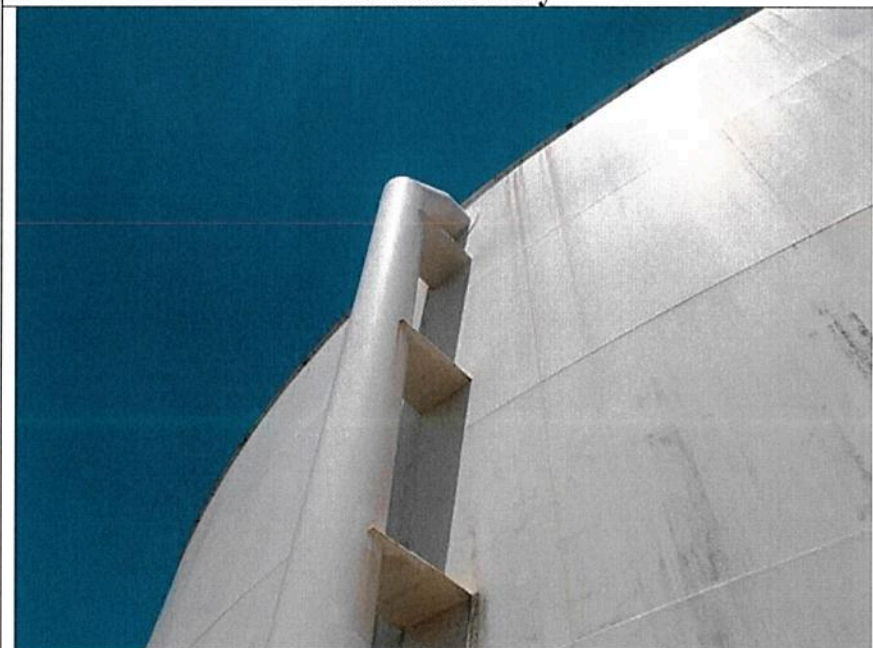
1" nozzle



Fill/Suction nozzle



Tank manway



Overflow



Level alarm meter



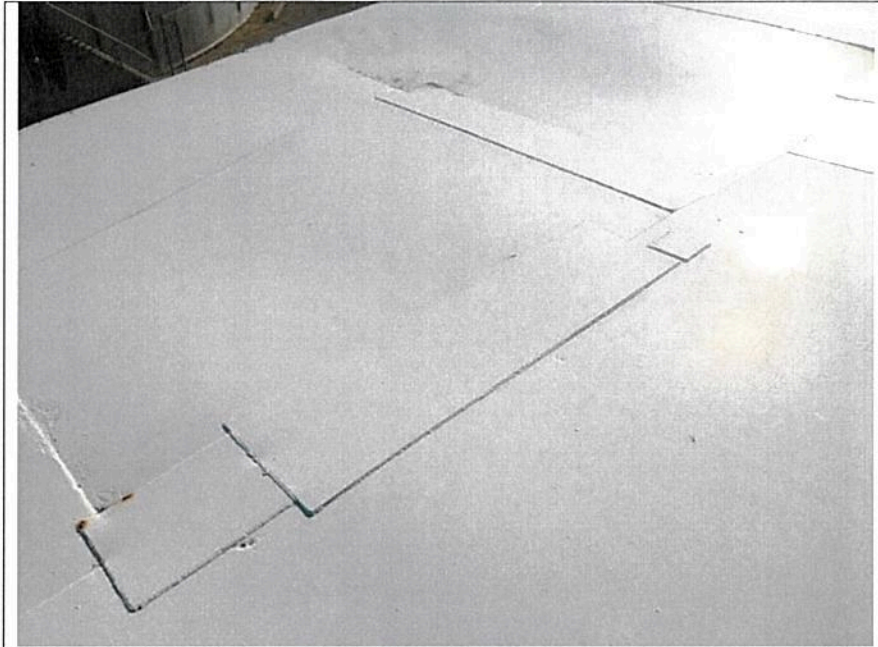
10" nozzle



Outside perimeter of tank



Roof joint connection



Tank roof plates



Tank roof with anode connection



Roof access platform



Corrosion at roof access



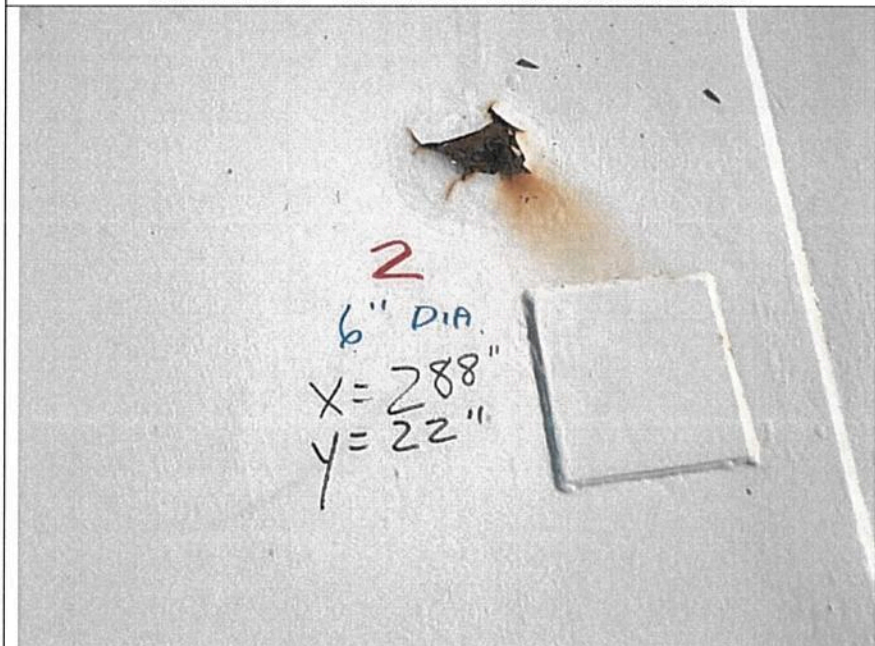
Varc gauge



Anode base



Area #1: 9" diameter area of corrosion



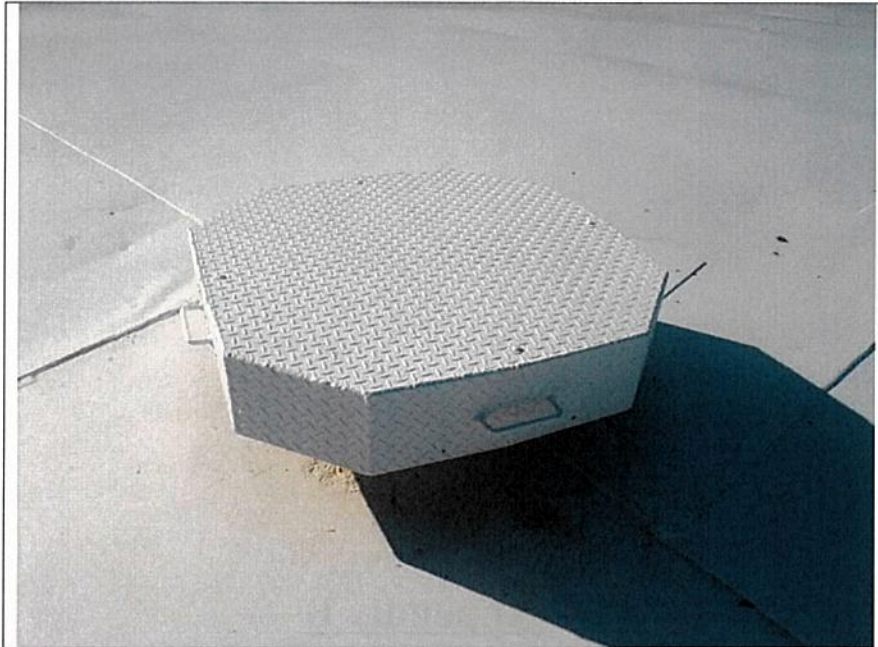
Area #2: 6" diameter area of corrosion



Corrosion at coupling attached to tank roof



Corrosion at anode base



Roof vent



Roof vent



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Appendix B

UT Data

Appendix B

Nozzle Thickness readings

UT Locations: 0 deg = Top
(See shell layout drawing for Nozzle Locations)

Shell Nozzles	Size	Location				Reinforcement Pad
		0 deg	90 deg	180 deg	270 deg	
N1 Manway (Southeast)	24"	1.039	1.069	1.079	1.069	1.486
N2 Nozzle	10"	.470	.487	.480	.465	1.350
N3 Manway (Northwest)	24"	1.100	.989	1.041	1.000	1.350
N4 Fill/Suction	24"	.428	.455	.500	.505	1.423
N5 Nozzle	1"	.141	N/A	N/A	N/A	N/A

Appendix B

UT Measurements Tank Shell 1st Course									
Location	1	2	3	4	5	6	7	8	9
C1 P1	1.350	1.397	1.397	1.360	1.409	1.398	1.390	1.410	1.371
C1 P2	1.410	1.379	1.391	1.369	1.381	1.354	1.407	1.412	1.353
C1 P3	1.403	1.384	1.400	1.401	1.379	1.394	1.399	1.400	1.400
C1 P4	1.361	1.358	1.383	1.381	1.378	1.384	1.364	1.370	1.389
C1 P5	1.395	1.421	1.372	1.430	1.420	1.371	1.417	1.383	1.380
C1 P6	1.368	1.371	1.380	1.364	1.366	1.372	1.362	1.397	1.378
C1 P7	1.348	1.375	1.354	1.401	1.352	1.361	1.350	1.370	1.385
C1 P8	1.399	1.420	1.419	1.401	1.416	1.417	1.392	1.327	1.420
C1 P9	1.420	1.378	1.381	1.373	1.376	1.382	1.415	1.400	1.415
C1 P10	1.378	1.382	1.399	1.380	1.391	1.390	1.400	1.390	1.392
C1 P11	1.390	1.398	1.392	1.399	1.382	1.391	1.390	1.392	1.406
C1 P12	1.343	1.365	1.370	1.375	1.406	1.412	1.402	1.359	1.375
Note: Plate 1 starts at the Southeast 24" Manway and proceeds in a CCW direction around Tank.									

	Left	Middle	Right
Top	1	4	7
Middle	2	5	8
Bottom	3	6	9

UT Measurements Tank Shell 1st Course									
Location	1	2	3	4	5	6	7	8	9
C1 P13	1.395	1.415	1.390	1.389	1.366	1.390	1.389	1.350	1.385
C1 P14	1.429	1.393	1.396	1.396	1.384	1.398	1.388	1.387	1.391
C1 P15	1.326	1.427	1.382	1.367	1.437	1.400	1.326	1.429	1.437
C1 P16	1.326	1.383	1.399	1.410	1.385	1.400	1.400	1.400	1.400
C1 P17	1.370	1.372	1.400	1.390	1.404	1.399	1.370	1.390	1.397
C1 P18	1.400	1.353	1.371	1.400	1.393	1.339	1.401	1.374	1.350

	Left	Middle	Right
Top	1	4	7
Middle	2	5	8
Bottom	3	6	9

Appendix B

Tank S-1; 6 Inch Drop; Shell Readings					
Location	Starting from Tank Roof to Tank Floor				
C5- 1	.296	C4- 1	.644	C3- 1	.804
2	.298	2	.641	2	.807
3	.299	3	.642	3	.808
4	.298	4	.643	4	.809
5	.299	5	.643	5	.810
6	.300	6	.645	6	.805
7	.300	7	.645	7	.824
8	.300	8	.645	8	.830
9	.301	9	.646	9	.804
10	.301	10	.648	10	.805
11	.300	11	.646	11	.804
12	.300	12	.646	12	.804
13	.300	13	.645	13	.804
14	.299	14	.646	14	.805
15	.298	15	.646	15	.804
16	.299	16	.646	16	.805

Tank S-1; 6 Inch Drop; Shell Readings					
Location		Top to Bottom			
C2- 1	1.174	C1- 1	1.350		
2	1.182	2	1.381		
3	1.183	3	1.351		
4	1.185	4	1.358		
5	1.189	5	1.361		
6	1.195	6	1.361		
7	1.198	7	1.365		
8	1.200	8	1.368		
9	1.198	9	1.370		
10	1.201	10	1.376		
11	1.203	11	1.406		
12	1.163	12	1.369		
13	1.166	13	1.402		
14	1.167	14	1.372		
15	1.167	15	1.370		
16	1.163	16	1.404		

Course 1-5; 96" (8'-0")

Appendix B

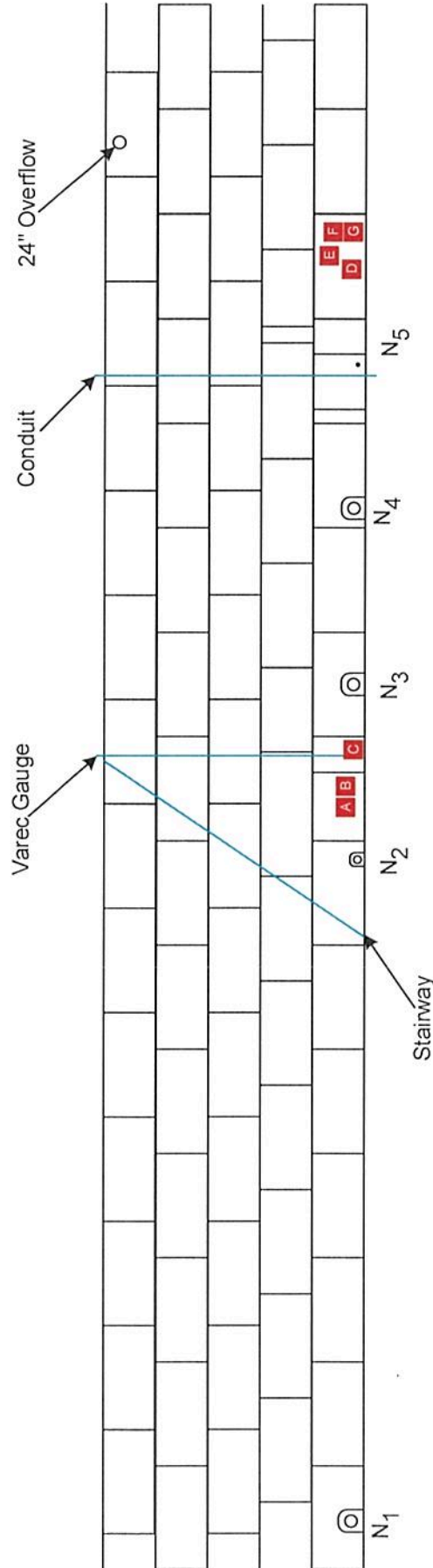
Tank S-1 Roof Readings; Center of tank going, North, South, East and West.				
Reading	North To Center	West To Center	South To Center	East To Center
1	.176	.174	.174	.165
2	.175	.176	.181	.167
3	.184	.185	.156	.165
4	.189	.190	.169	.140
5	.210	.200	.182	.166
6	.162	.164	.174	.180
7	.188	.189	.197	.190
8	.194	.195	.195	.176
9	.189	.189	.176	.181
10	.177	.176	.178	.178
11	.200	.201	.178	.178
12	.172	.174	.180	.176
13	.173	.173	.175	.195
14	.176	.178	.190	.194
15	.159	.160	.180	.174
16	.181	.181	.166	.182
17	.178	.178	.141	.168
18	.160	.160	.165	.181
19	.177	.178	.167	.180
20	.174	.175	.164	.174



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Appendix C

Drawings



A = Blast and Recoat



Tank S-1

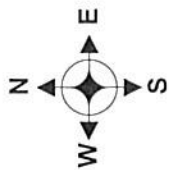
NAVFAC
Honolulu, HI

Tank Side View
Plate Layout

Sept. 2020

Tank Nozzles

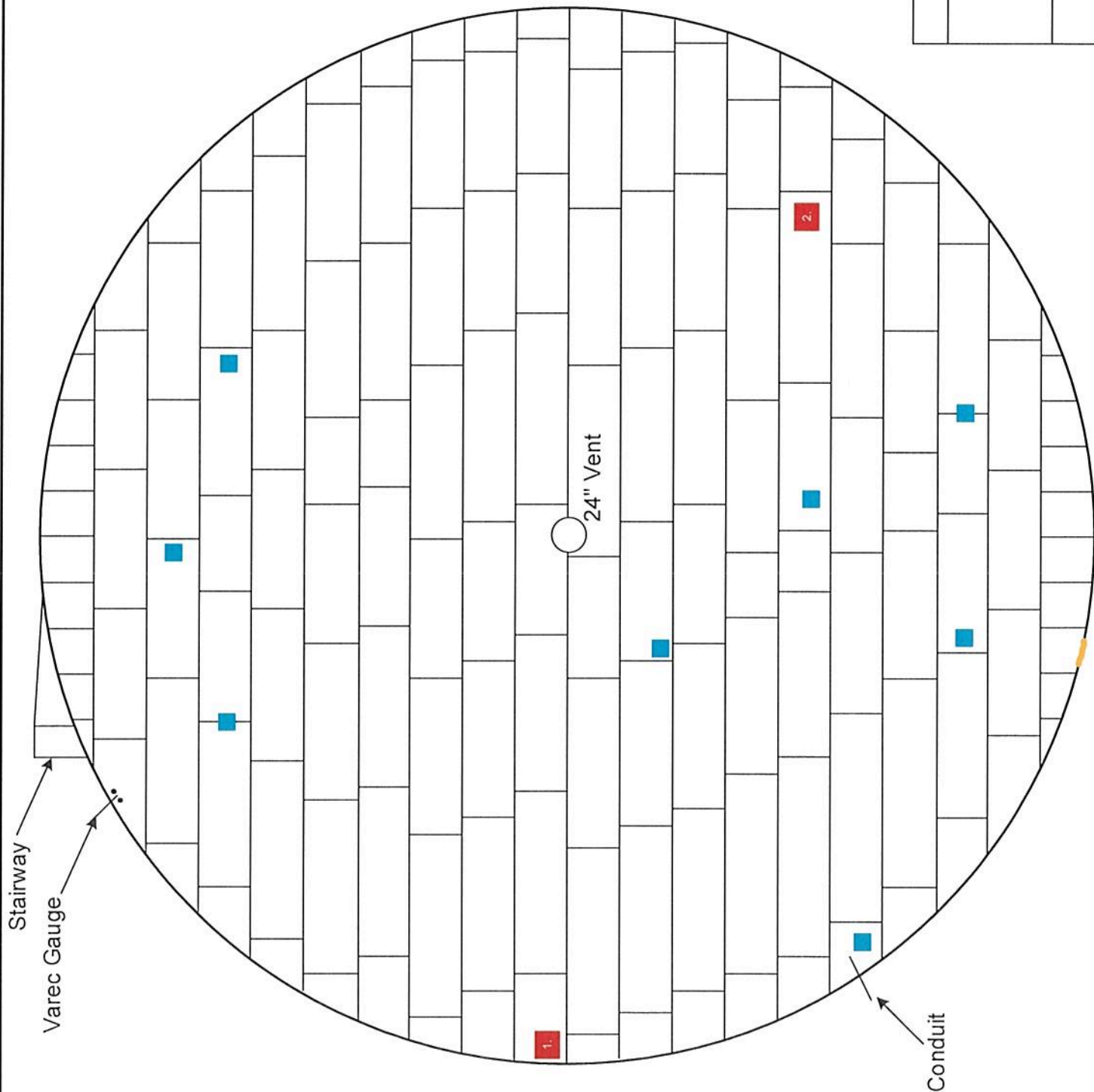
- N₁ = 24" Manway - 18" up
- N₂ = 10" Nozzle - 10" up
- N₃ = 24" Manway - 18" up
- N₄ = 24" Fill/Suction - 20" up
- N₅ = 1" Nozzle - 7" up



- = WBU Peripheral Edge
- = Replace Anode Base
- = Patch Repair Area



Tank S-1
NAVFAC Honolulu, HI
Tank Roof Plate Layout





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Appendix D

T-Min Calculations

Inspection Evaluation Summary

TANK DATA

Customer: NAVFAC
 Tank Title: Potable Water
 Tank No: S-1
 Work Order #: 20-217
 Year Built: 1996
 Years in Service: 24
 Analyzed By: Daniel Elling

Floor Material: A36
 Shell Material: A36
 Roof Material: A36
 Date: 9/14/2020

Definitions/Notes:

Corrosion Rate (CR) = (T Nominal - T Actual)/ Years of Service
 Remaining Corrosion Allowance (RCA) = (T Actual - T min)
 Estimated Remaining Life = (RCA/ Corrosion Rate (CR))

Controlling Thickness: The actual lowest recorded thickness for a specific area of the tank.
 or the averaged thickness of L of a corroded area.

Summary

Section	Previous Thickness	Controlling Thickness	Minimum Required Thickness	Corrosion Rate	RCA	Estimated Remaining Life
Shell	1.262	1.250	0.761	0.0005	0.489	978.0 Years
Roof	0.188	0.140	0.090	0.0020	0.050	25.0 Years

Based upon the inspection results and current available data the tank Is Suitable
 for continued use in accordance with the referenced code sections.

The lowest (governing) Remaining Corrosion Allowance for the Tank is: 0.050

Estimated Remaining Life of the Tank is: 25.0 Years

Notes

Minimum Required Thickness																															
TANK DATA																															
Customer: <u>NAVFAC</u>						Floor Material: <u>A36</u>																									
Tank Title: <u>Potable Water</u>						Shell Material: <u>A36</u>																									
Tank No: <u>S1</u>						Roof Material: <u>A36</u>																									
Work Order #: <u>20-217</u>						Date: <u>9/14/2020</u>																									
Year Built: <u>1996</u>																															
Prepared By: <u>Daniel Elling</u>																															
Definitions/Notations:																															
H = Height (from 1.1) to maximum liquid level S = Maximum allowable stress value of material CR = Corrosion rate per year E = Joint efficiency D = Diameter of tank G = Highest specific gravity of product tMin = Minimum thickness t = Wall thickness, inches RL = Remainin life in years					Parameters <table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 50%;">H</td> <td style="width: 50%;">See Below</td> </tr> <tr> <td>S= 1st & 2nd Course</td> <td>36000 Yield</td> </tr> <tr> <td>S= All Other Courses</td> <td>36000 Yield</td> </tr> <tr> <td>CR</td> <td>0.0004</td> </tr> <tr> <td>E</td> <td>0.85</td> </tr> <tr> <td>D</td> <td>165</td> </tr> <tr> <td>G</td> <td>1</td> </tr> <tr> <td>tMin</td> <td>0.761</td> </tr> <tr> <td>Maximum Fill Height, ft.</td> <td>37.5</td> </tr> </table> <table border="1" style="width: 100%; border-collapse: collapse; margin-top: 10px;"> <tr> <td style="width: 50%;"></td> <td style="width: 50%;">58,000 Tensile</td> </tr> <tr> <td></td> <td>58,000 Tensile</td> </tr> </table>					H	See Below	S= 1st & 2nd Course	36000 Yield	S= All Other Courses	36000 Yield	CR	0.0004	E	0.85	D	165	G	1	tMin	0.761	Maximum Fill Height, ft.	37.5		58,000 Tensile		58,000 Tensile
H	See Below																														
S= 1st & 2nd Course	36000 Yield																														
S= All Other Courses	36000 Yield																														
CR	0.0004																														
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G	1																														
tMin	0.761																														
Maximum Fill Height, ft.	37.5																														
	58,000 Tensile																														
	58,000 Tensile																														
Notes:																															
FLOOR																															
a. Without Coating t min = 0.100 <table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <th style="width: 20%;">tMin. Found</th> <th style="width: 20%;">tMin.</th> <th style="width: 20%;">CR</th> <th style="width: 20%;">RL</th> </tr> <tr> <td>0.761</td> <td>0.100</td> <td>0.0001</td> <td>NA</td> </tr> </table>					tMin. Found	tMin.	CR	RL	0.761	0.100	0.0001	NA	b. With Coating or Leak Detection & Containment t min = 0.050 <table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <th style="width: 20%;">tMin. Found</th> <th style="width: 20%;">tMin.</th> <th style="width: 20%;">CR</th> <th style="width: 20%;">RL</th> </tr> <tr> <td>0.761</td> <td>0.050</td> <td>0.0001</td> <td>NA</td> </tr> </table>					tMin. Found	tMin.	CR	RL	0.761	0.050	0.0001	NA						
tMin. Found	tMin.	CR	RL																												
0.761	0.100	0.0001	NA																												
tMin. Found	tMin.	CR	RL																												
0.761	0.050	0.0001	NA																												
Remaining Life in years is :					NA																										
GENERAL CORRODED SHELL																															
a. 1st two courses (S=use the smaller of .80Y or .429T) $t \min = \frac{2.6(H-1)DG}{SE}$					b. All other courses (S=use the smaller of .88Y or .472T)																										
Shell: Calculated from formulas below, but shall not be less than .100" for any tank course.																															
H	D	G	S	E	t min	H	D	G	S	E	t min																				
1.	37.5	165	1	24882	0.85	0.740																									
2.	29.5	165	1	24882	0.85	0.578																									
3.	21.5	165	1	27376	0.85	0.378																									
4.	13.5	165	1	27376	0.85	0.230																									
5.	5.5	165	1	27376	0.85	0.083																									
LOCALLY THINNED SHELL																															
a. 1st two courses (S=use the smaller of .80Y or .429T) $t \min = \frac{2.6HDG}{SE}$					b. All other courses (S=use the smaller of .88Y or .472T)																										
Shell: Calculated from formulas below, but shall not be less than .100" for any tank course.																															
H	D	G	S	E	t min	H	D	G	S	E	t min																				
1.	37.5	165	1	24882	0.85	0.761																									
2.	29.5	165	1	24882	0.85	0.598																									
3.	21.5	165	1	27376	0.85	0.396																									
4.	13.5	165	1	27376	0.85	0.249																									
5.	5.5	165	1	27376	0.85	0.101																									

API STANDARD 653

Table 4-1 Maximum Allowable Shell Stresses
(Not For Use For Reconstructed Tanks, see Note 6)

Material Specification and Grade	Minimum Specified Yield Stress, Y (lb/in.2)	Minimum Specified Tensile Strength T (lb/in.2)	Allowable Product Stress, S(lbf/in.2)(7)		Allowable Hydrostatic Test Stress, St(lbf/in.2)(7)	
			Lower Two Courses	Upper Courses	Lower Two Courses	Upper Courses
			ASTM Specifications			
A283-C	30,000	55,000	23,600	26,000	26,000	27,000
A285-C	30,000	55,000	23,600	26,000	26,000	27,000
A36	36,000	58,000	24,900	27,400	27,400	30,100
A131-A, B, CS	34,000	58,000	24,900	27,400	27,400	30,100
A131-EH 36	51,000	71,000	30,500	33,500	33,500	36,800
A573-58	32,000	58,000	24,900	27,400	27,400	28,800
A573-65	35,000	65,000	27,900	30,700	30,700	31,500
A573-70	42,000	70,000	30,000	33,000	33,000	36,300
A516-55	30,000	55,000	23,600	26,000	26,000	27,000
A516-60	32,000	60,000	25,600	28,200	28,200	28,800
A516-65	35,000	65,000	27,900	30,700	30,700	31,500
A516-70	38,000	70,000	30,000	33,000	33,000	34,200
A662-B	40,000	65,000	27,900	30,700	30,700	33,700
A662-C	43,000	70,000	30,000	33,000	33,000	36,300
A537- Class 1	50,000	70,000	30,000	33,000	33,000	36,300
A537- Class 2	60,000	80,000	34,300	37,800	37,800	41,500
A633-C, D	50,000	70,000	30,000	33,000	33,000	36,300
A678-A	50,000	70,000	30,000	33,000	33,000	36,300
A678-B	60,000	80,000	34,300	37,800	37,800	41,500
A737-B	50,000	70,000	30,000	33,000	33,000	36,300
A841	50,000	70,000	30,000	33,000	33,000	36,300
A10 (1)	30,000	55,000	23,600	26,000	26,000	27,000
A7 (1)	33,000	60,000	25,700	28,300	28,300	29,700
A442-55 (1)	30,000	55,000	23,600	26,000	26,000	27,000
A442-60 (1)	32,000	60,000	25,600	28,200	28,200	28,800
CSA Specifications						
G40.21M, 260W	37,700	59,500	25,500	28,100	28,100	30,900
G40.21M, 300W	43,500	65,300	28,000	30,800	30,800	33,900
G40.21M, 350W	50,800	65,300	28,000	30,800	30,800	33,900
G40.21M, 350WT	50,800	69,600	29,900	32,900	32,900	36,100
Unknown (2)	30,000	55,000	23,600	26,000	26,000	27,000
Riveted Tanks:						
A7, A9, or A10 (1.3)	NA	NA	21,000	21,000	21,000	21,000
Known (4)	Y	T	Note 4	Note 4	Note 4	Note 4
Unknown (5)	NA	NA	21,000	21,000	21,000	21,000
Notes:			maximum allowable shell stress for both product and hydrostatic test conditions are listed under column for Allowable Product Stress, S.			
1. ASTM A7, A9, A10, and A442 are obsolete ASTM material specifications previously listed in API Standards 12C and 650.						
2. The yield stress and tensile strength values shown are per API 653 for welded AST material of unknown origin.			5. This provision is for riveted tanks, constructed of unknown grades of material, evaluated per 4.3.4.2 of this standard.			
3. This provision is for riveted tanks, constructed of any grade of material, evaluated per 4.3.4.1 of this standard.			6. The allowable stresses for reconstructed tanks are tabulated in API Std 650, Table 3-2 or calculated per 8.4 of this standard.			
4. This provision is for riveted tanks, constructed of known grades of material evaluated per 4.3.4.2 of this standard. For all courses, the			7. The allowable stresses are calculated per 4.3.3.1 of this standard, unless otherwise noted. The calculated allowable stresses are rounded to the nearest 100 lbf/in.2.			

API STANDARD 653

Table 4-2--Joint Efficiencies for Welded Joints

Standard	Edition & Year	Type of Joint	Joint Efficiency E	Applicability or Limits
API 650	7th & Later	Butt	1.00	Basic Standard
	(1980-Present)	Butt	0.85	Appendix A -Spot RT
		Butt	0.70	Appendix A -No RT
		Butt	0.85	Basic Standard
	(1961-1978)	Butt	1.00	Appendices D&G
API 12C	14th & 15th	Butt	0.85	
	(1957-1958)			
	3rd-13th	Lap (a.)	0.75	3/8" max. t
	(1940-1956)	Butt (c.)	0.85	
	1st & 2nd	Lap (a.)	0.07	7/16" max. t
	(1936-1939)	Lap (b.)	.050 + k/5	1/4" max. t
Unknown		Butt (c.)	0.85	
		Lap (a.)	0.70	7/16" max. t
		Lap (b.)	0.50 + k/5	1/4" max. t
		Butt (c.)	0.70	
		Lap (d.)	0.35	

- Notes:**
- a. Full double lap-welded.
 - b. Full fillet weld with at least 25% intermittent full fillet opposite side; k=% of intermittent weld expressed in decimal form.
 - c. Single butt-welded joints with a back-up bar were permitted from the years of 1936 to 1940 and 1948 to 1954.
 - d. Single lap-welded only.

API STANDARD 653 General Notes:

Shell: Calculated from formulas below, but shall not be less than .100" for any tank course.

Floor: .100" for tank bottom/foundation design with no means for detection and containment of a bottom leak.

.050" for tank bottom/foundation design with means to provide detection and containment of a bottom leak.

.050" for tank bottom with reinforced lining >.05" thick in accordance with API RP 652.

Roof: .090" average thickness in any 100" square area.

Minimum Shell Thickness Formula: $t_{min} = \frac{2.6(H-1)DG}{SE}$ (for entire shell course)
 $t_{min} = \frac{2.6HDG}{SE}$ (for locally thinned area)

t_{min}= Minimum acceptable thickness in in. for each course as calculated from the above formula; however, **t_{min} shall not be less than 0.100" for any tank course.**

H= Height from bottom of shell course in consideration to maximum liquid level when evaluating an entire shell course, in ft.; or

= Height from the bottom of localized corrosion are, length L (see API 653 4.3.2.1) from the lowest point of the bottom of L to the locally thinned area to the maximum liquid level, in ft.; or

= Height from the lowest point within any location of interest to the maximum liquid level in ft.

G= Highest specific gravity of product.

D= Diameter of tank.

S= Maximum allowable stress in lbf/in²; use the smaller of .80Y or .429T for bottom and second course; use the smaller of .88Y or .472T for all other courses. Allowable stresses are shown in table 4-1

(API 653) for materials listed in the current and previous editions of API 12C and API std. 650.

E= Joint Efficiency.