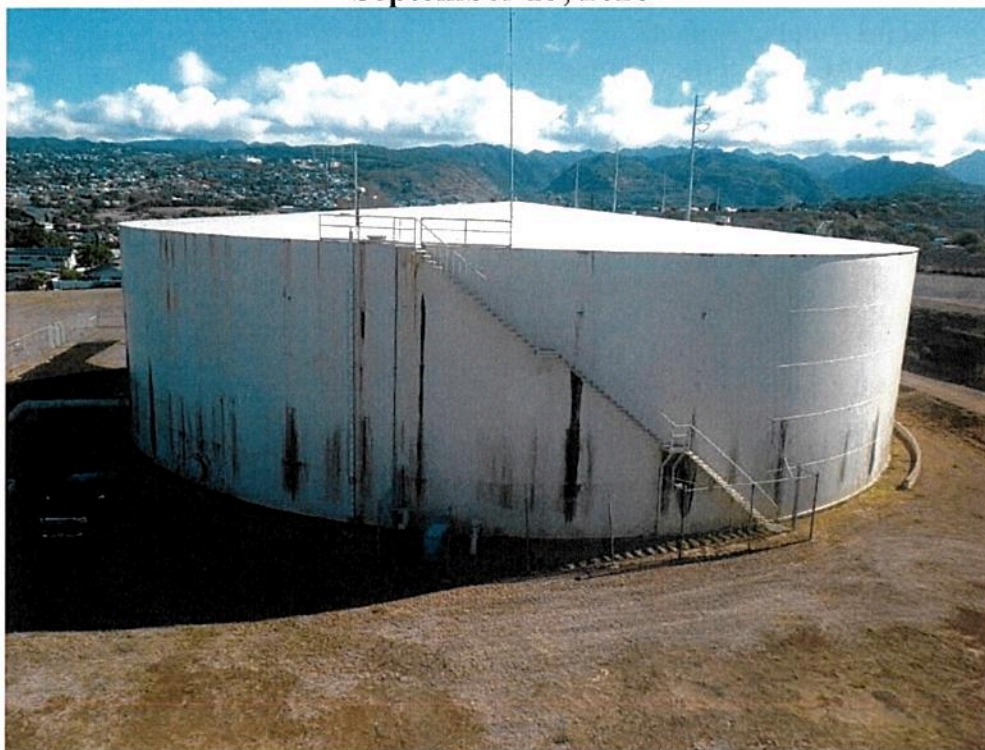




**TANK S-2  
API-653 In-Service Inspection  
September 15, 2020**



**To: NAVFAC  
Honolulu, HI 96819**

**From:**



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

**“Providing Excellence in NDE and Quality  
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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-2, located in Honolulu, Hawaii.

**Tank Data**

Tank ID: S-2  
Built By: Morse Construction Group  
Year Built: 1996  
Product: Potable Water  
Product SPG: 1.00  
Capacity: 125,000 Bbls.  
Size: 165' Diameter x 40' Height

**SYNOPSIS:**

On September 15<sup>th</sup>, 2020 Engineering & Inspections Hawaii performed an API-653; In-Service external inspection of S-2 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. Fifty-seven (57) 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 nineteen (19) areas scattered across the entire peripheral edge of the tank roof and varied in sizes from 1' in length to 20'+ in overall length. Several of the roof attachments were also found to have significant severe corrosion on the nozzles and nozzle to roof connection welds with loss of profile noticeable. The corrosion found on the tank roof was not quantified as to not disturb the anodes and roof material underneath.





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Coating failure and severe active corrosion was noted underneath the Fill/Suction nozzle on the west side of the tank shell.

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-2 was constructed in 1996 by Morse Construction Group and was constructed of A36 carbon steel. The tank was constructed to AWWA D-100 89a Edition code. The tank has a nominal height of 40' and a diameter of 165'. An internal inspection has not been completed on the tank to date. The tank was located inside of a controlled fenced area with Tank S-1 in the immediate area and in similar service.

#### **Surrounding Area:**

Tank S-2 was located inside of a controlled fenced area. The nearest tank (S-1) was approximately 100' to the south. A 3' high brick retaining wall was constructed at the base of the tank on the east side. A large hatch on the north 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. Vegetation growth was noted around the base of the tank covering the projection plate in several areas.

#### **Foundation:**

The tank rested on top of an elevated concrete slab. The concrete sat approximately 6" above grade, except on the east side, where it was generally flush with the ground elevation. Slight cracking and spalling located randomly on the foundation around the tank. No tank grounding was associated with the tank. No leak detection ports were associated with the tank. No evidence of leakage was noted underneath the tank.

#### **Cathodic Protection:**

Cathodic protection anodes were suspended from the tank roof. A rectified cathodic protection system was installed on the tank floor according to NAVFAC Engineering; however, it was not currently being operated.



### **Tank Chime:**

Tank S-2 had a projection plate that extended 3" past the chime weld of the tank shell. The projection plate had thickness readings taken measuring at 0.250" thick. Severe corrosion in the form of knifing and thinning was noted on the east side of the tank near the eastern manway nozzle. Moderate coating failure and active corrosion was also present scattered randomly around the tank projection plate in the form of knifing and thinning. No sealant between the foundation and tank bottom was found.

### **Tank Shell:**

The tank shell was a five-course double butt-welded designed tank where the shell plates were staggered to the right. Discoloring of the tank coating was noted around the entire shell due to micro bacterial growth on the external surfaces. Thirty-two (32) 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. The active corrosion found on the first shell course measured less than 0.250" deep in all locations. The areas of corrosion were measured in varying sizes with several measuring larger than 12" in diameter. The nominal thickness of the first shell course was 1.262". No other significant external corrosion was found on the shell plates on the first shell course or other visible shell plates or their associated connection welds. The external surfaces of the shell were fully coated with several areas of light coating failure present revealing active corrosion on the tank shell plates. 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. The tank's associated data plate was illegible with the markings worn away.

### **Tank Nozzles:**

The Tank has two (2) 30" manways found on the Southwest and Northeast sides of the first shell course. The 24" fill/suction line was found on the west side of the first shell course with moderate active corrosion found on the underside of the nozzle measuring up to 0.250" deep with scaling still present after hand scraping. Light isolated corrosion was observed scattered on the external portions of the tank nozzle bores, flanges, and associated hardware. A low-level alarm 1" nozzle on the North side of the shell was not seal welded to its first isolation valve. 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 North 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.





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### **Fire Suppression:**

The product being stored in S-2 is Potable Water and a fire suppression system is not required.

### **Tank Gauging System:**

A gauge with a visible height board was found on the south side of the tank shell.

### **Tank Stairway, Roof Platform:**

The stairway access to the roof was fully coated with several areas of discoloration found due to active corrosion. All shell attachments were found in full profile. Several of the hardware connections were found with crevice corrosion present between the bolting and the stairway base plates and washers. The roof access platform was a grating base with minor coating failure and active corrosion present.

### **Tank Roof and Appurtenances:**

The roof coating was found generally weathered, chalked, and cracked with numerous areas of localized severe active corrosion found along the peripheral edge of the roof and scattered across all areas of the tank roof, including vent nozzles, roof access hatches, and underneath the handrailing system appurtenances. The severe corrosion found on the tank roof along the edge and on the roof plates were identified on the attached tank roof drawing. The localized corrosion on the tank roof plates were each identified individually by numbering from 1-57 and each location was measured on an X and Y axis with the starting point being the Southwest corner of each roof plate. Nineteen (19) areas of heavy corrosion were noted around the peripheral edge of the tank roof that varied in lengths from 1' to over 20'+. Fifty-seven (57) areas of severe localized corrosion were found scattered across the tank roof plates that varied in overall size from 2" to 20"+ in overall size. The depth of the corrosion was unable to be measured at the risk of putting holes in the tank roof, disturbing the underside of the roof plates and contaminating the water from falling scaling, and disturbing internal anodes hanging from the tank roof. Each area of corrosion was identified with a physical marking and photograph were taken of each location with the corresponding coordinates written and shown in each photograph. The tank roof has two (2) 24" atmospheric vents in place on the north and east sides of the roof with significant corrosion that was noted on the vent nozzle as well as the top plates on the vents. A mesh screen was used as the vent medium and secured by banding. A 24" roof hatch with a diamond plate cover was found on the southwest side of the tank roof with

severe corrosion to the hatch nozzle as well as the roof connection weld and adjacent roof plates; the area was identified as Corrosion Area #31 and written to be removed and lap patched. The scaffold ring in the center of the tank roof has severe active corrosion on its associated reinforcing plate, creating a loss of profile.

### **Recommendations:**

#### **Shell:**

1. Mechanically clean and recoat the scattered areas of active localized corrosion found scattered across the tank shell and projection plate, using an approved coating procedure and specification by NAVFAC.
2. Install a sealant between the projection plate and the tank foundation.
3. Perform weld build-up on the underside of the 24" Fill/Suction nozzle to restore the nozzle to full thickness. An approved P1 to P1 welding procedure should be followed using low hydrogen electrodes, followed by non-destructive testing in accordance with API 653 for nozzle repairs.
4. Remove the vegetation found around the base of the tank.

#### **Roof:**

1. Perform weld build-up on the nineteen (19) areas of external corrosion on the peripheral edge of the tank roof that was identified on the associated inspection drawing.
2. Install lap welded patches over top of the fifty-seven (57) areas of severe localized corrosion scattered across the tank roof plates that were marked, identified, and labeled on the associated inspection drawing of the tank roof. The areas are also identified with photographs attached to the inspection report with the X and Y coordinates starting at the bottom left (southwest) corner of the associated roof plates.
3. Corrosion Area #31 includes the roof hatch nozzle on the southwest side of the tank roof; a lap welded patch should be placed over the entire corroded area after removal of the roof hatch nozzle.
4. Remove and replace the two (2) 24" roof vents and replace with new atmospheric vents. The associated nozzle flanges may need to be replaced as well due to corrosion that was unable to be adequately inspected due to the make-up of the current roof vent and associated vent screens covering the nozzles.
5. Install a new reinforcing plate underneath the scaffolding ring at the center of the tank roof.





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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.

*Based on the satisfactory completion of the In-Service inspection; NAVFAC Potable Water Tank S-2 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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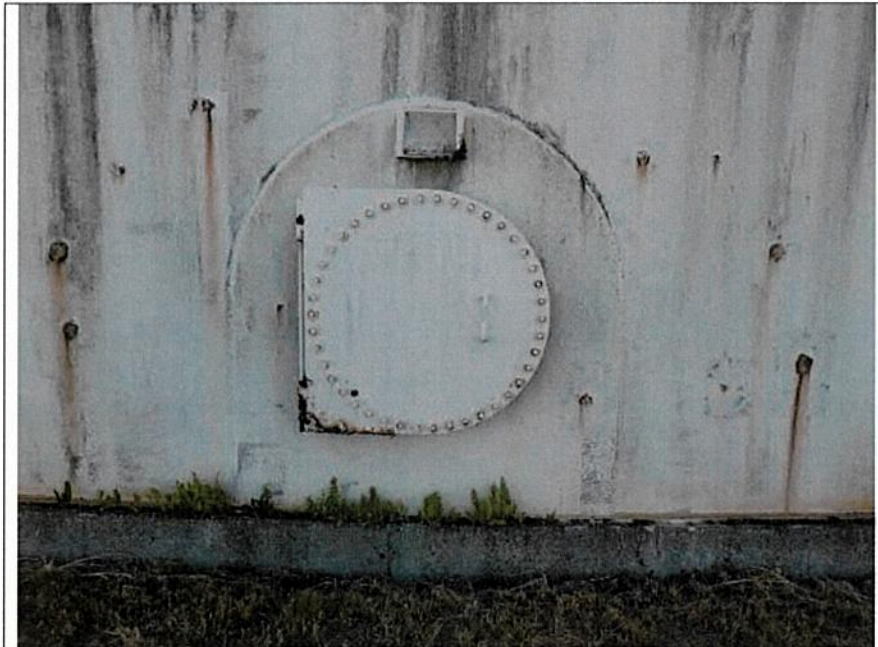


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## Appendix A

### Photographs





**Manway N1 with Data Plate**



**Tank Data Plate**



**Tank identification**



**Localized corrosion on first shell course**





**Corrosion on projection plate and chime area**



**Corrosion on projection plate with knifing noted**





**Localized shell corrosion**



**Localized shell corrosion**

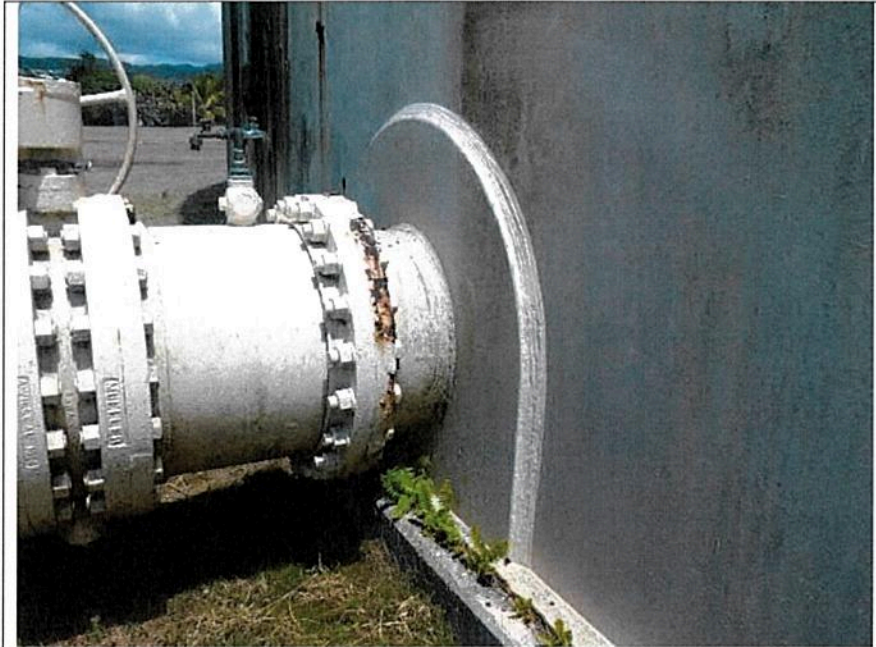




**Knifing of the projection plate and vegetation growth**



**Vegetation growth along east side of tank projection plate**



**Fill/Suction nozzle**



**Underside corrosion of the Fill/Suction Nozzle**





**10" Nozzle**



**1" nozzle without seal weld to block valve**





**Flange corrosion on nozzle (typical)**



**Vegetation growth around tank (typical)**

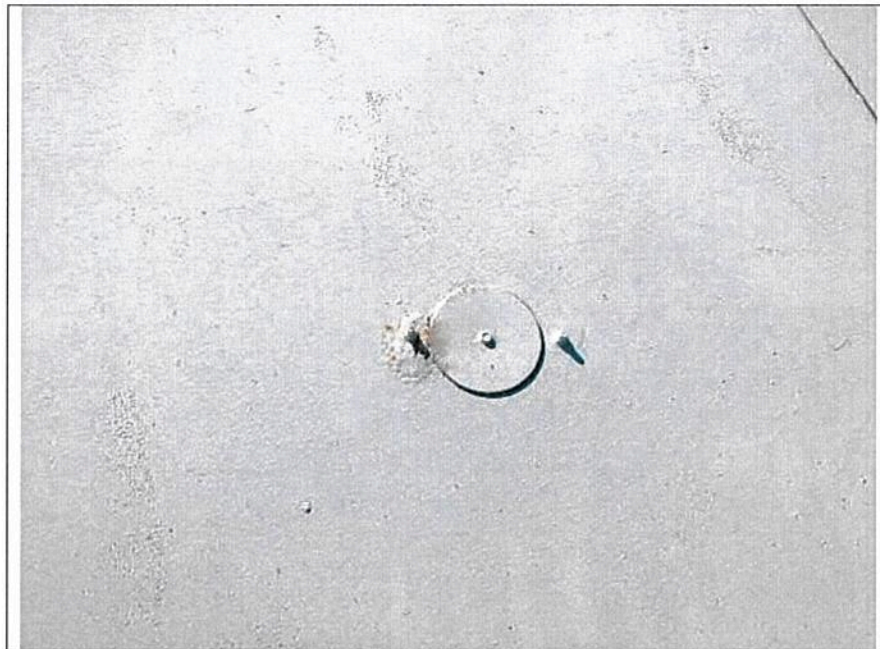


**Corrosion at handrail support of tank roof**



**Roof access hatch and visible board gauge.**





**Roof anode base on tank roof**



**Scaffold ring with corrosion at reinforcing plate**



**24" roof vent nozzle with corrosion on nozzle bore and attached mesh screen**



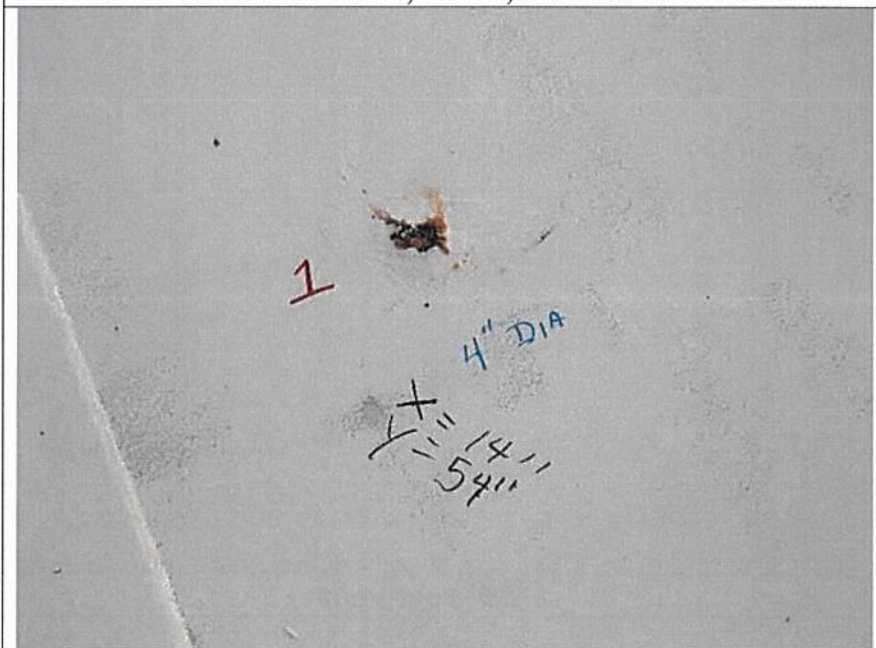
**24" roof vent**

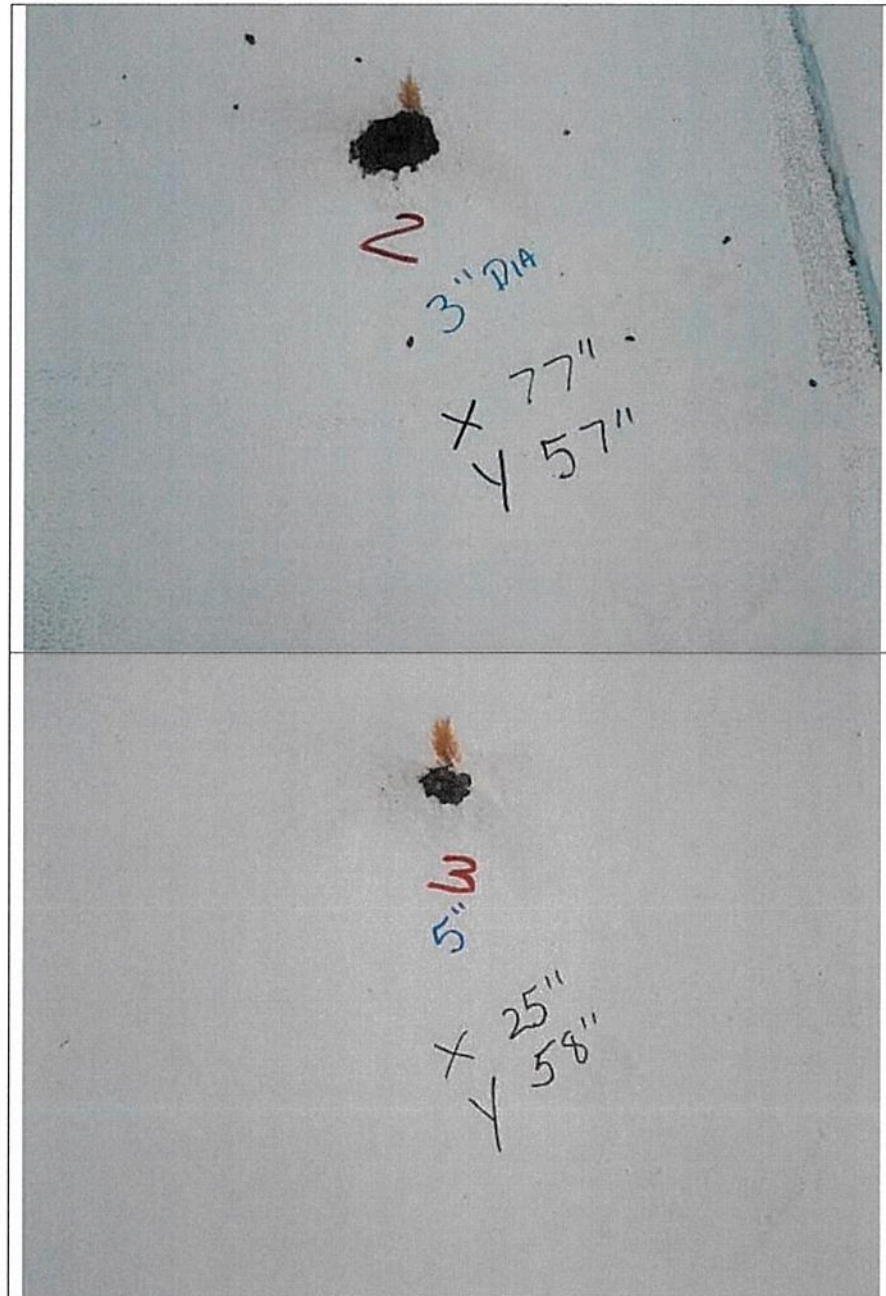




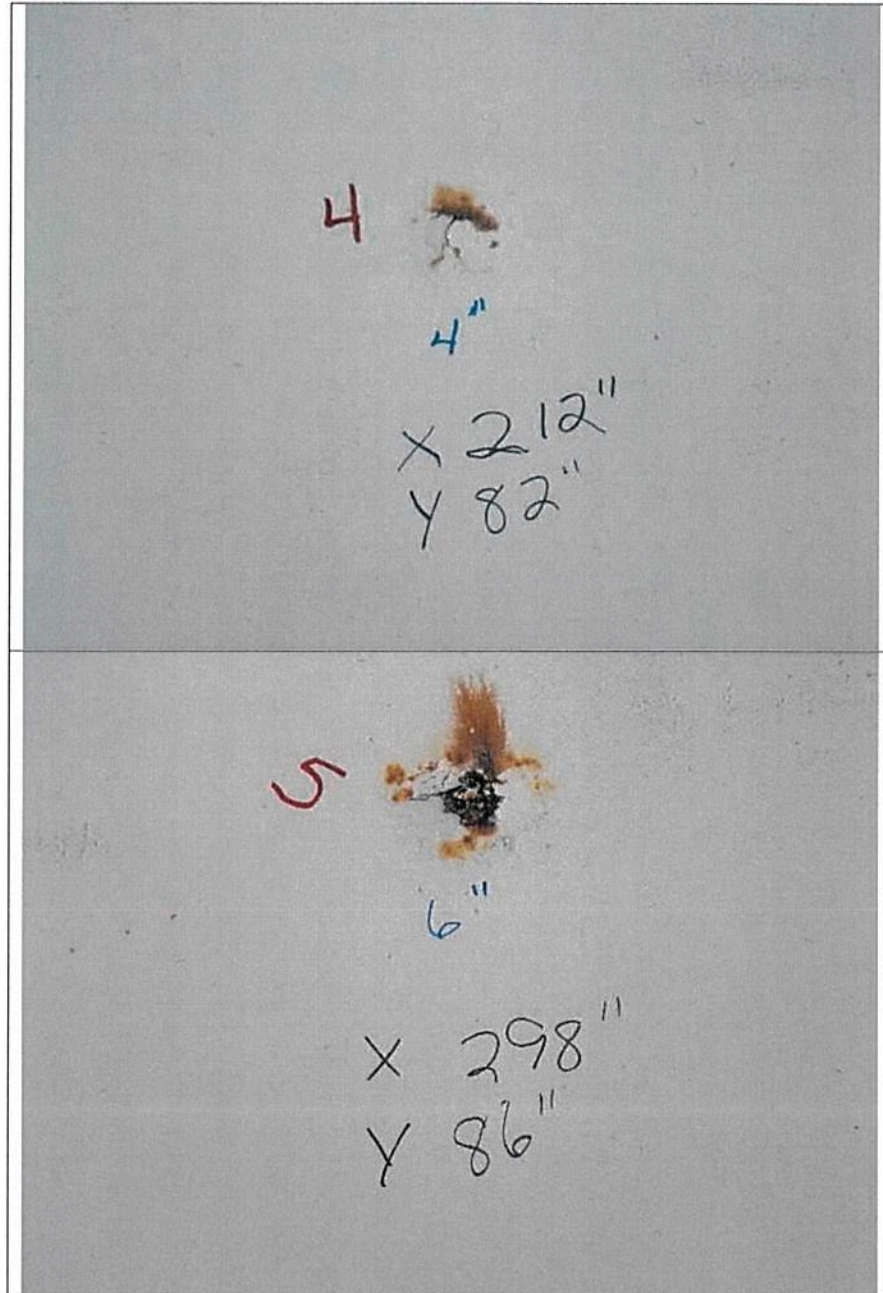
**Corrosion at handrail support at peripheral edge of roof**

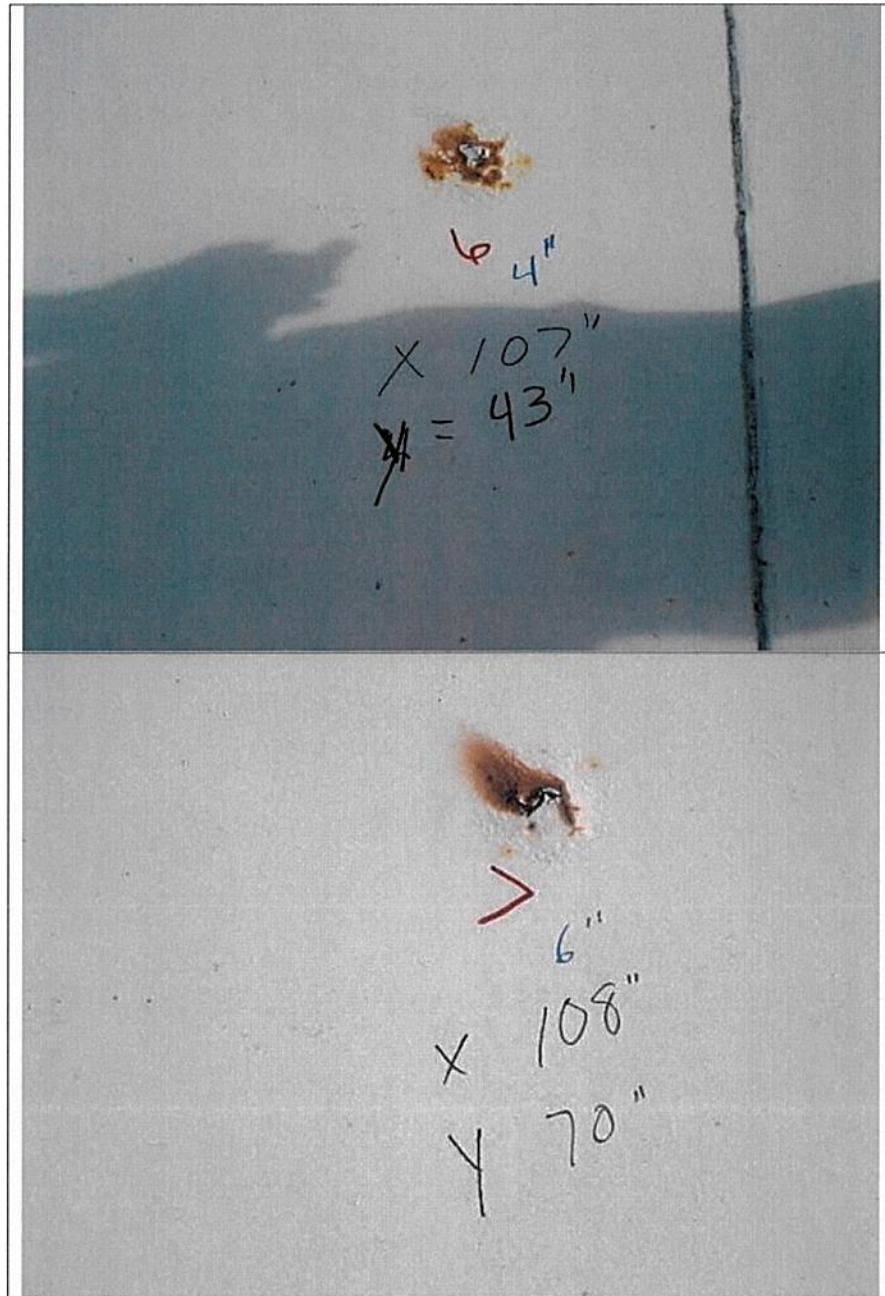
**BELOW ARE ROOF CORROSION AREAS WITH IDENTIFICATION, SIZE, and LOCATION.**



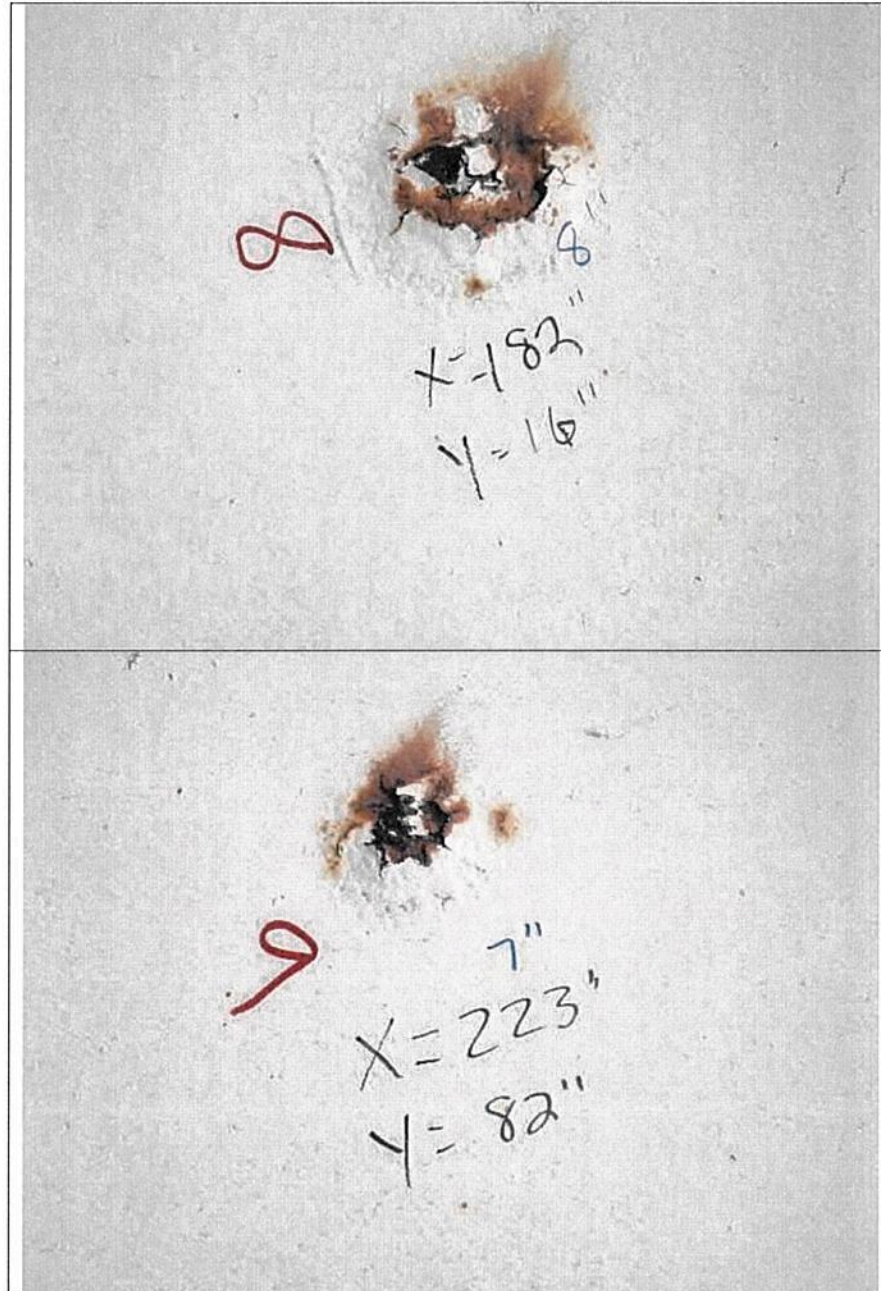


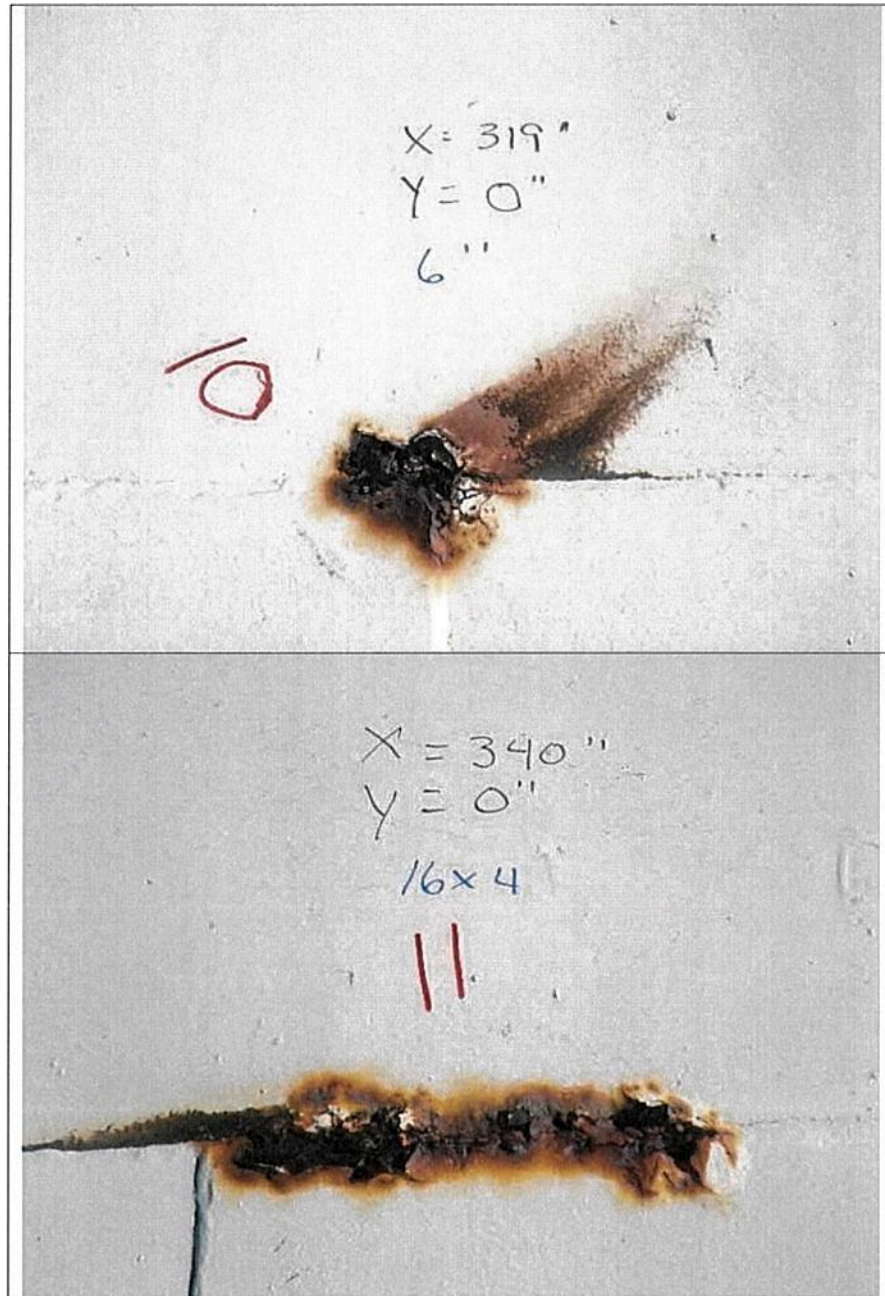




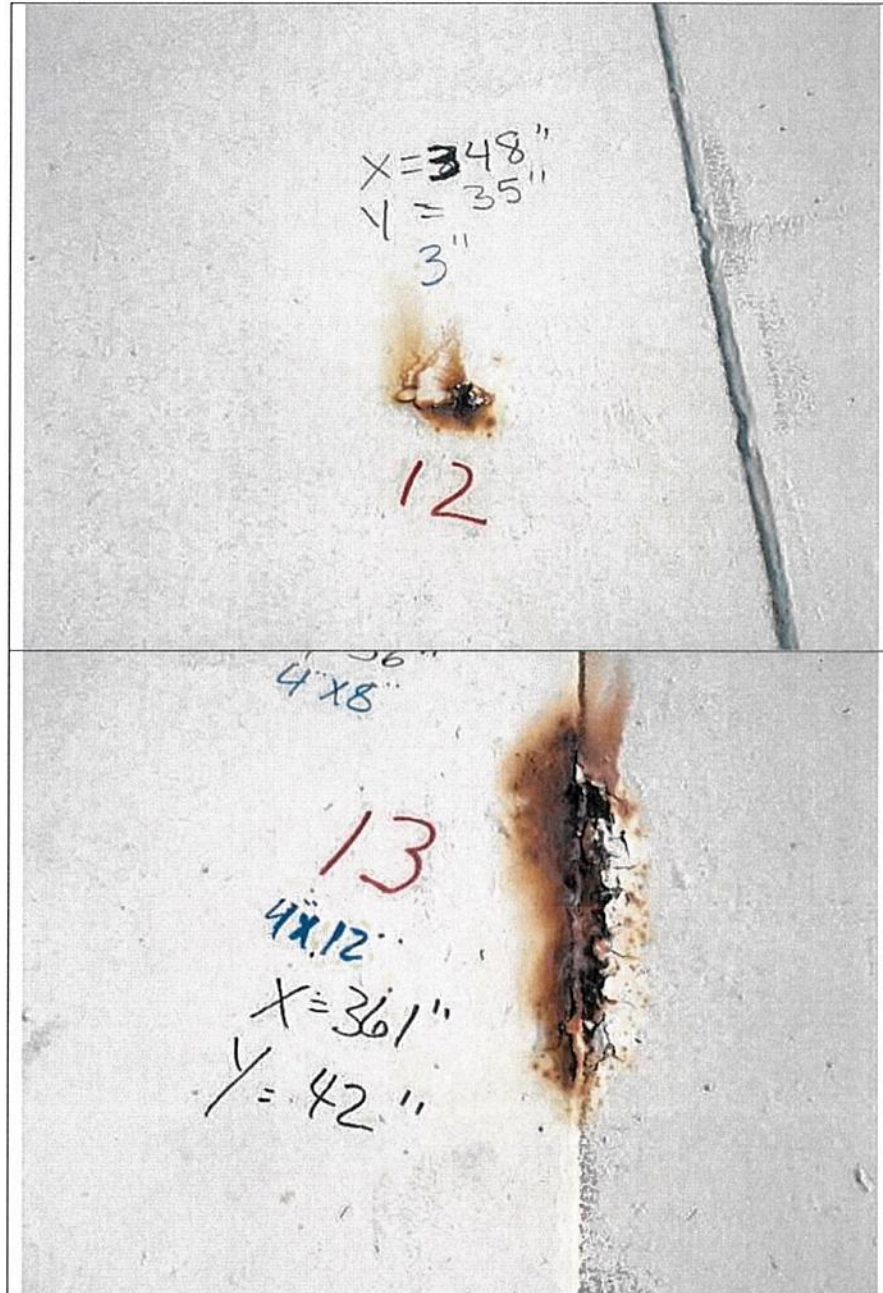


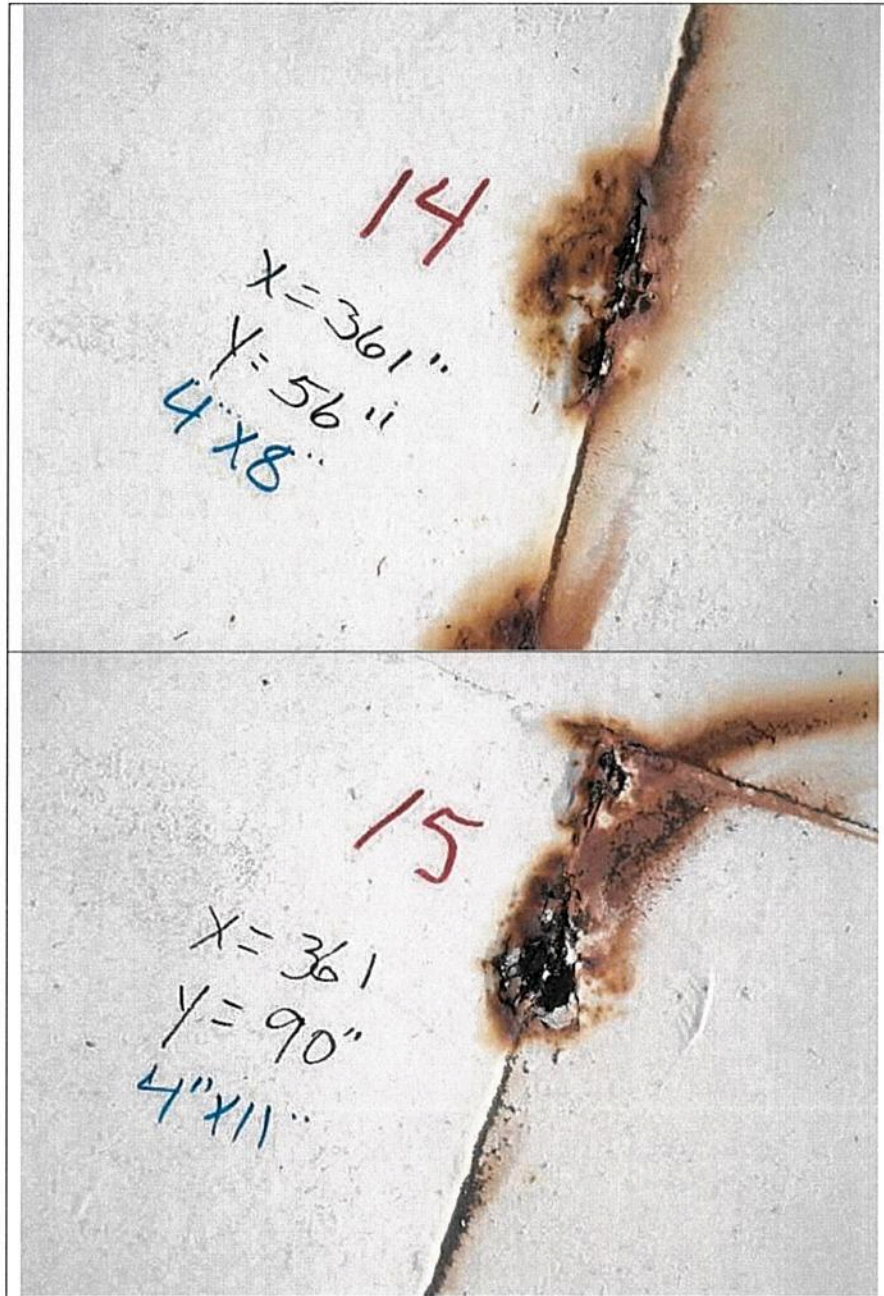




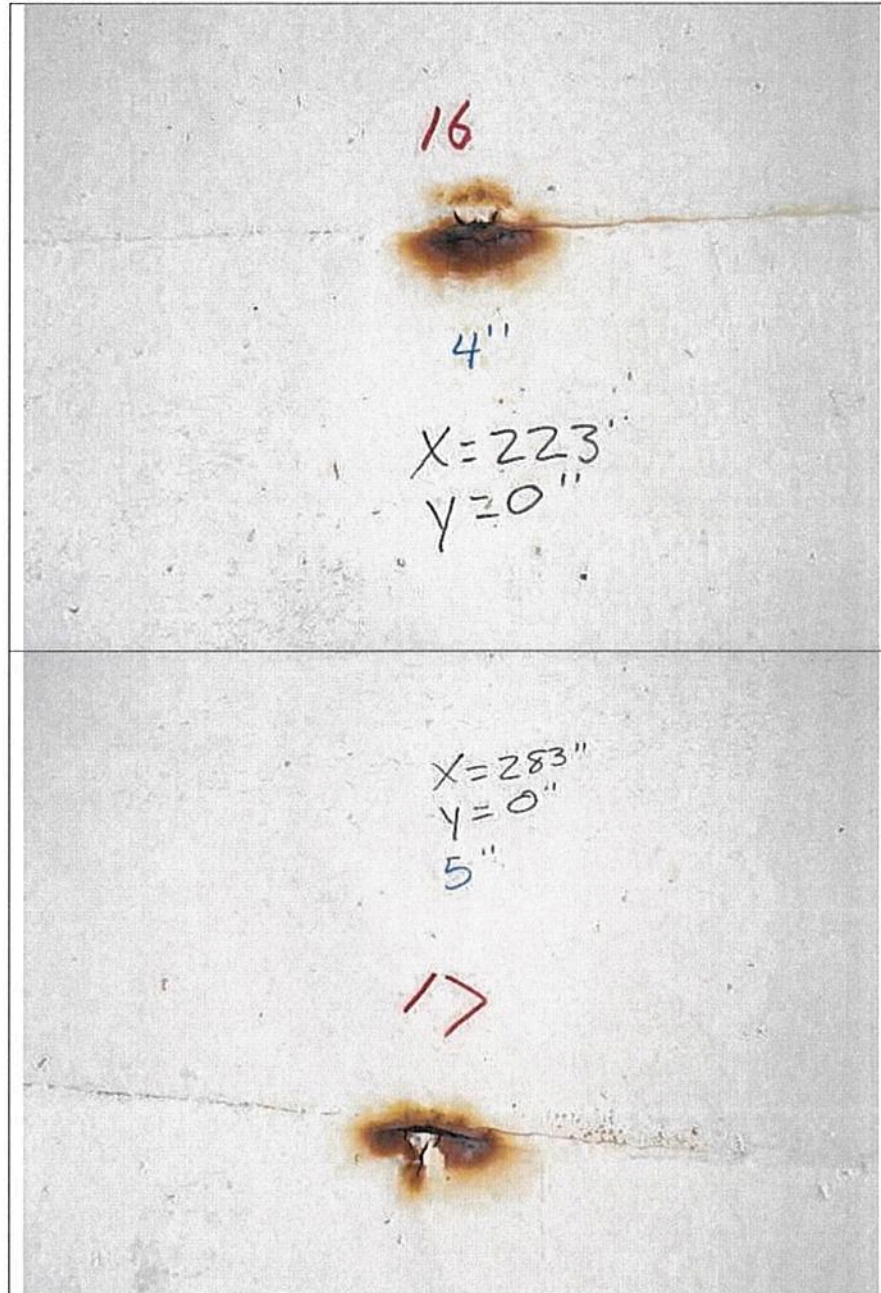


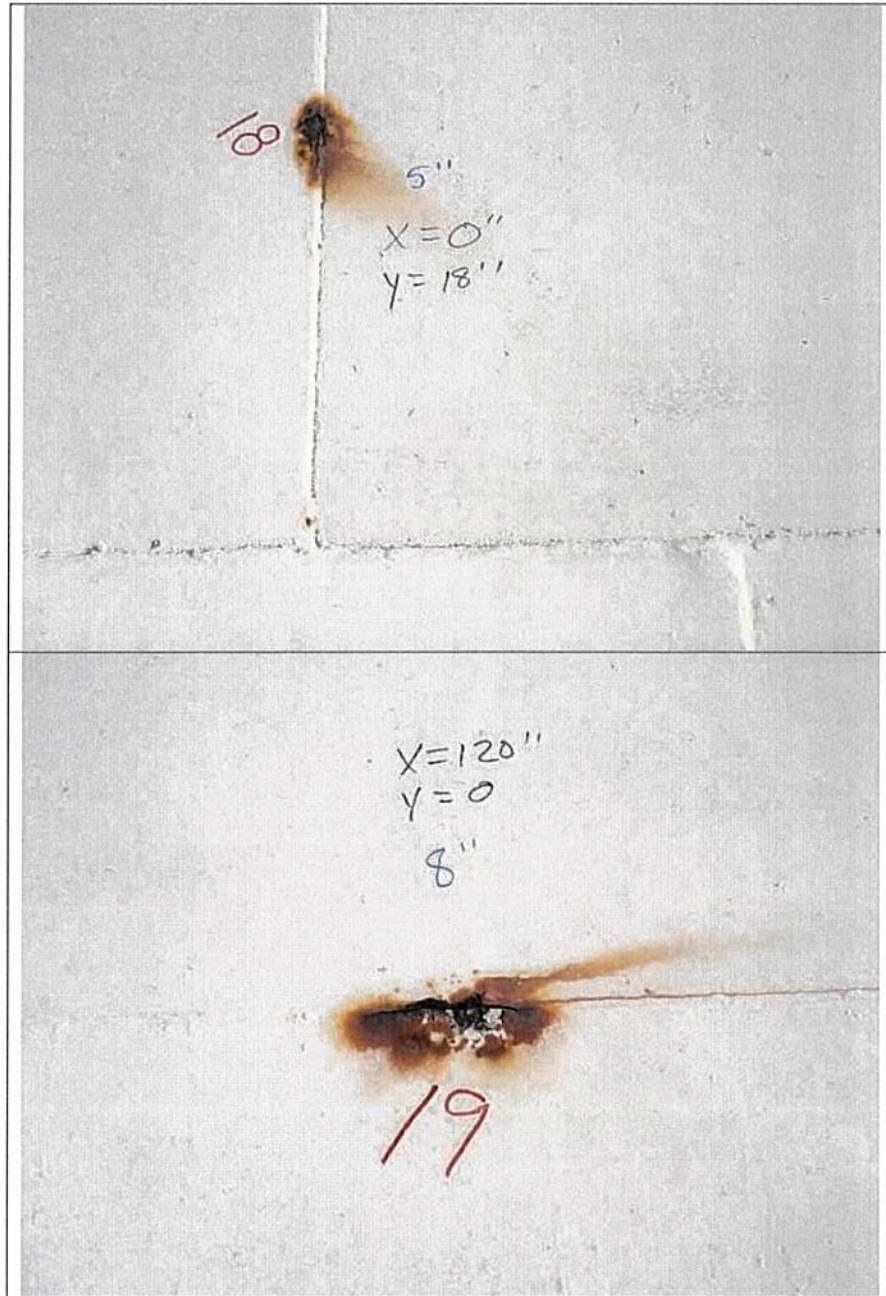






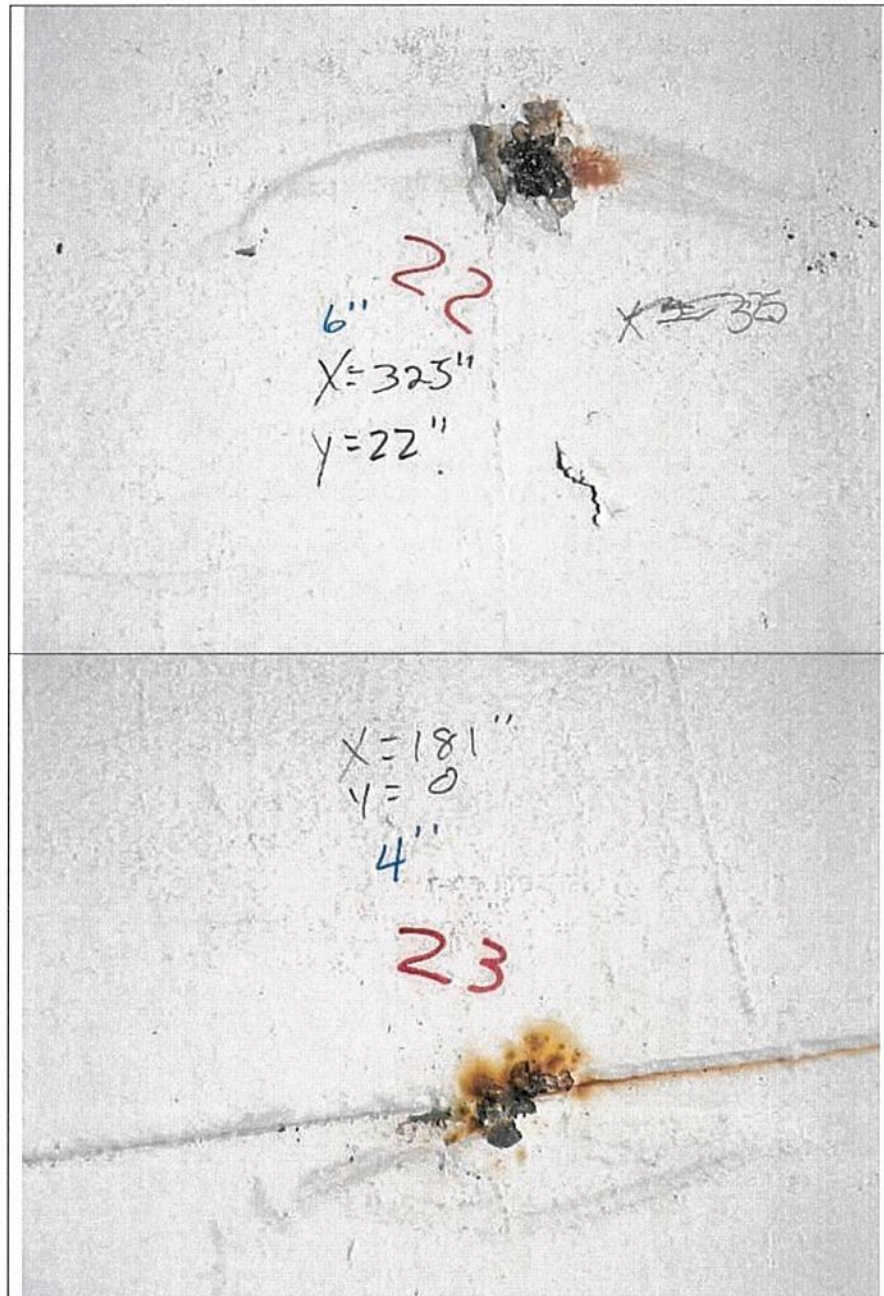




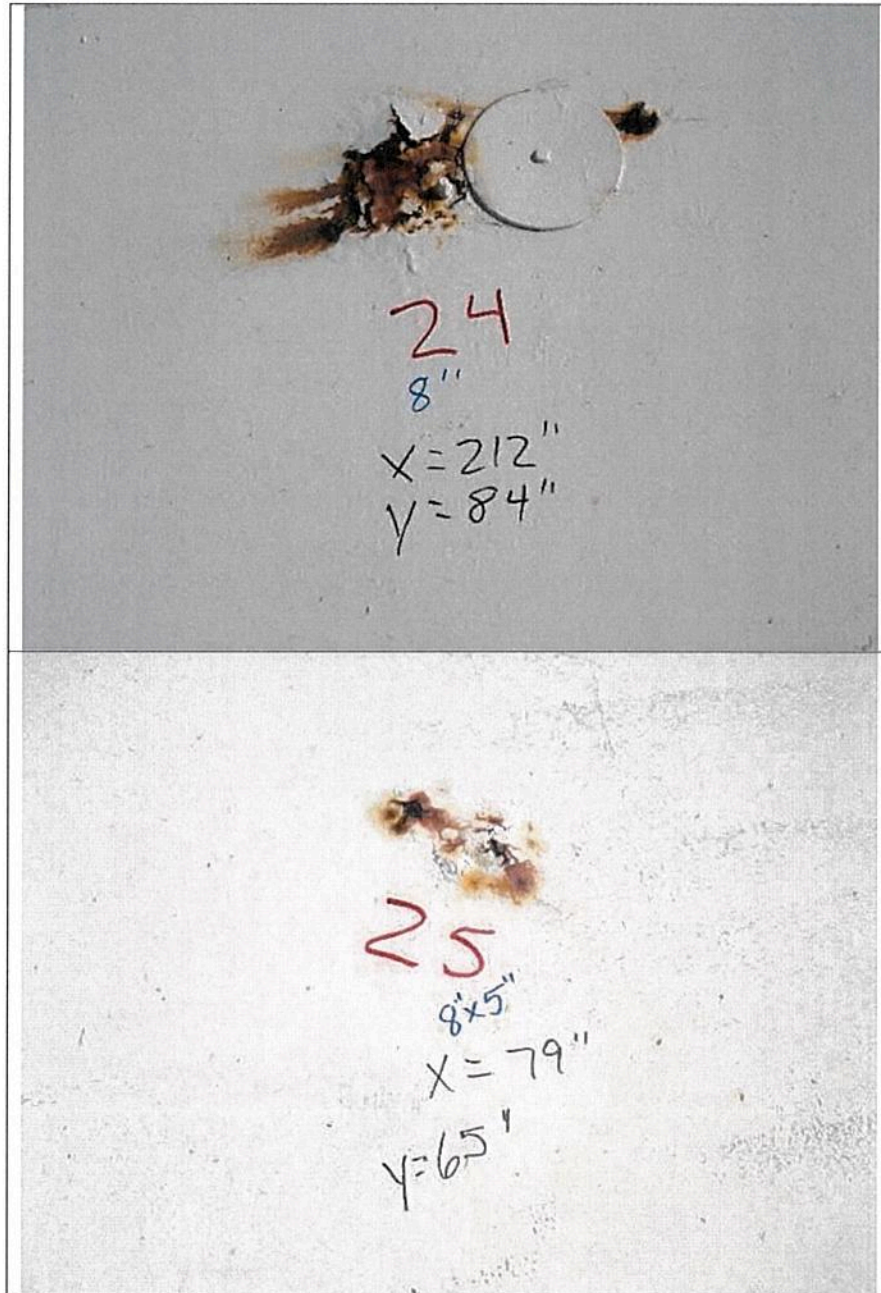


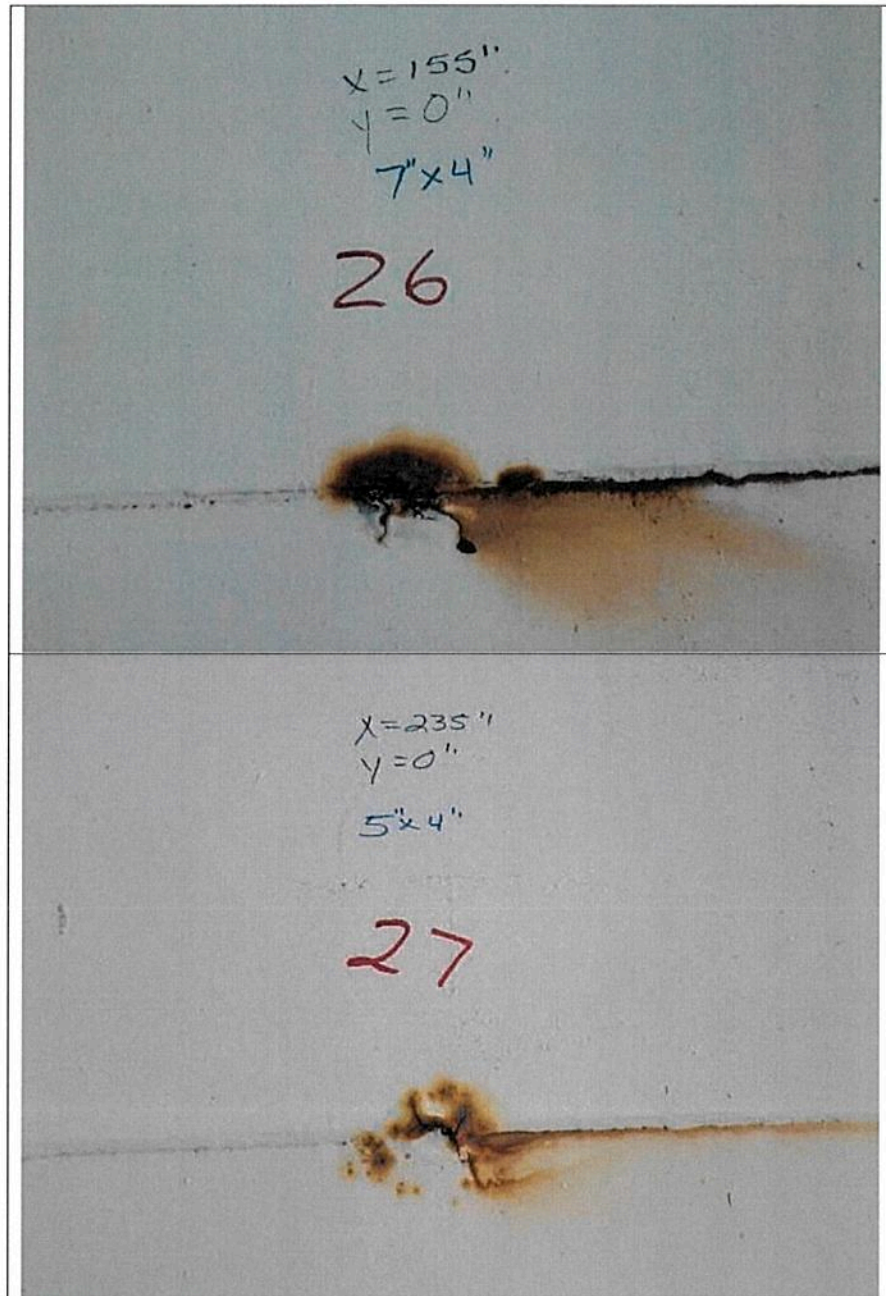




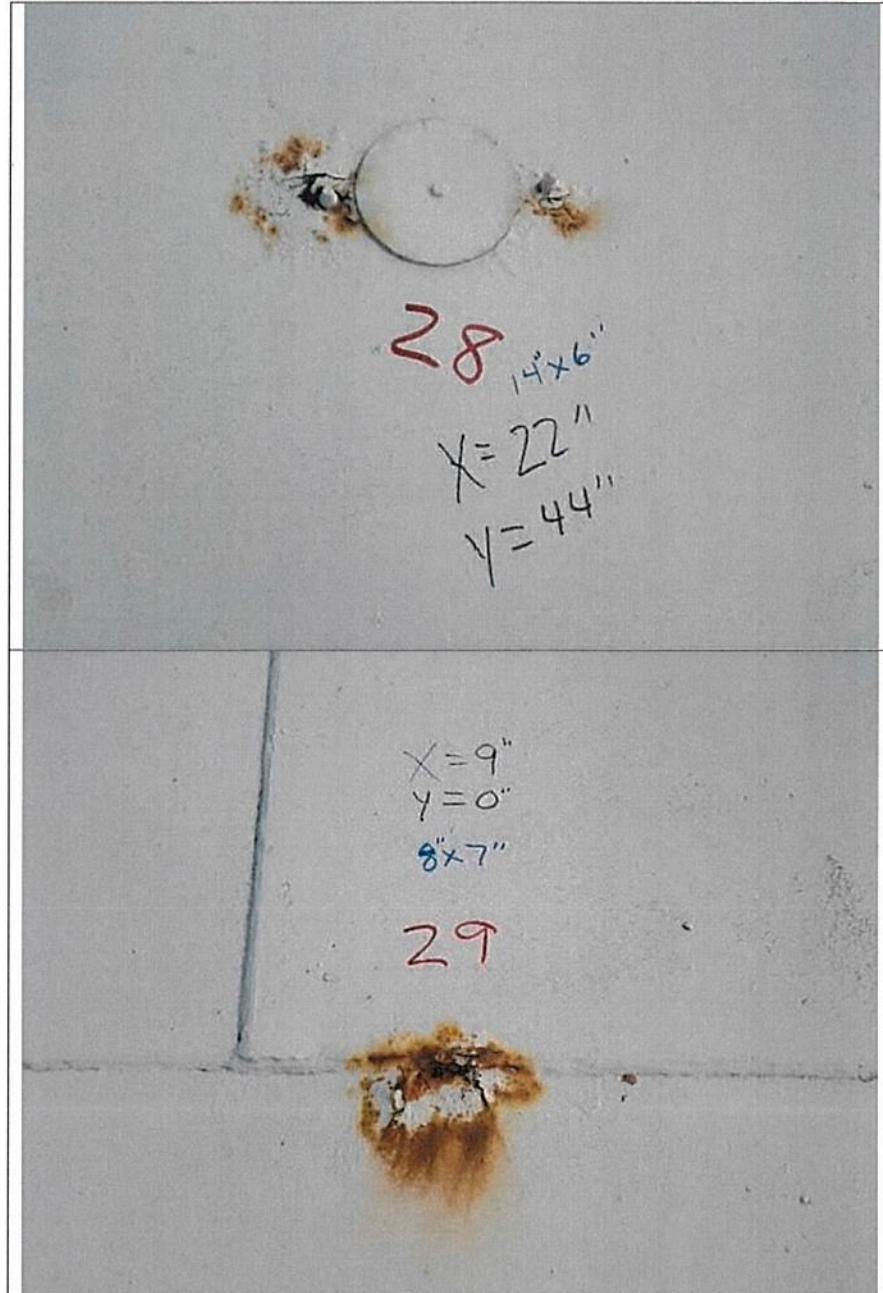


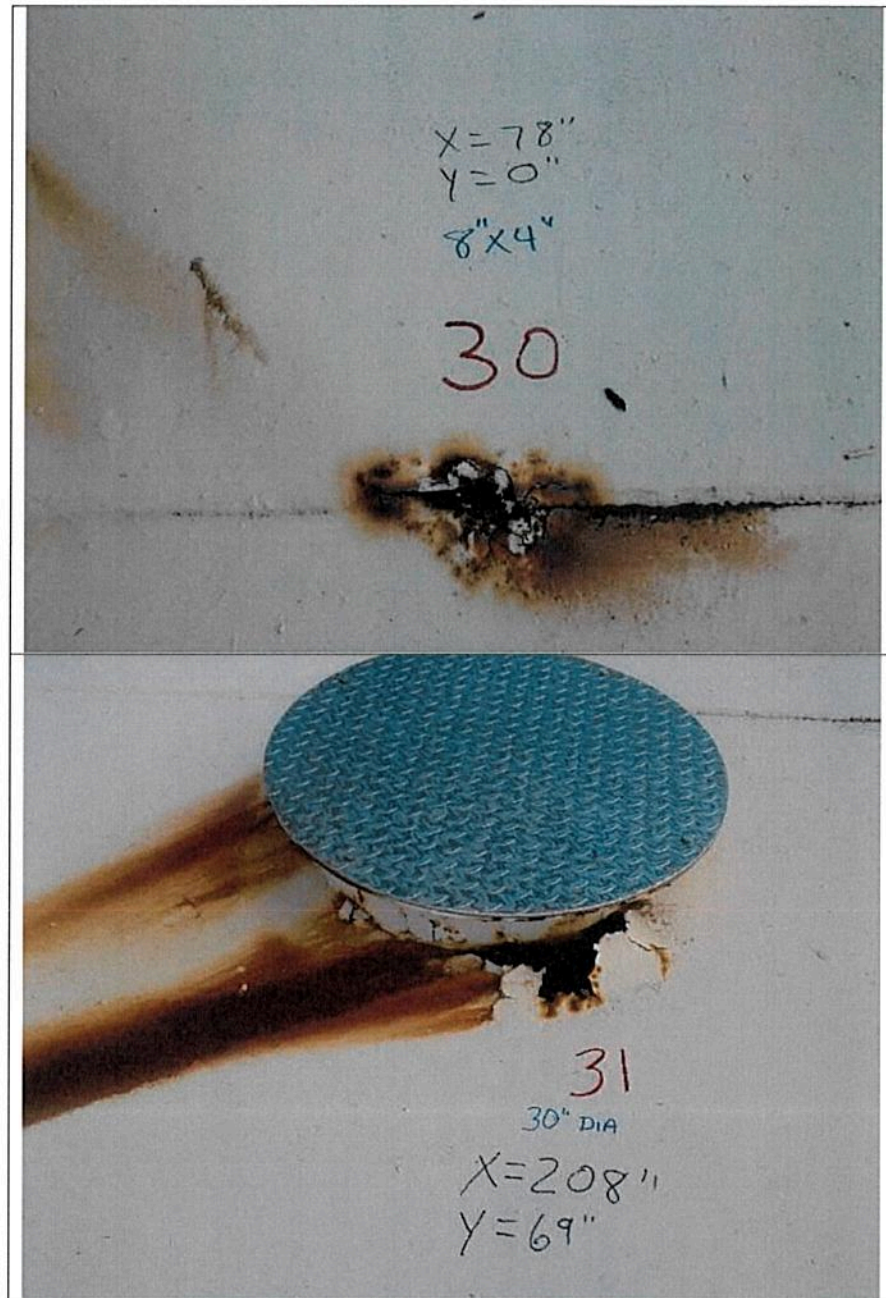




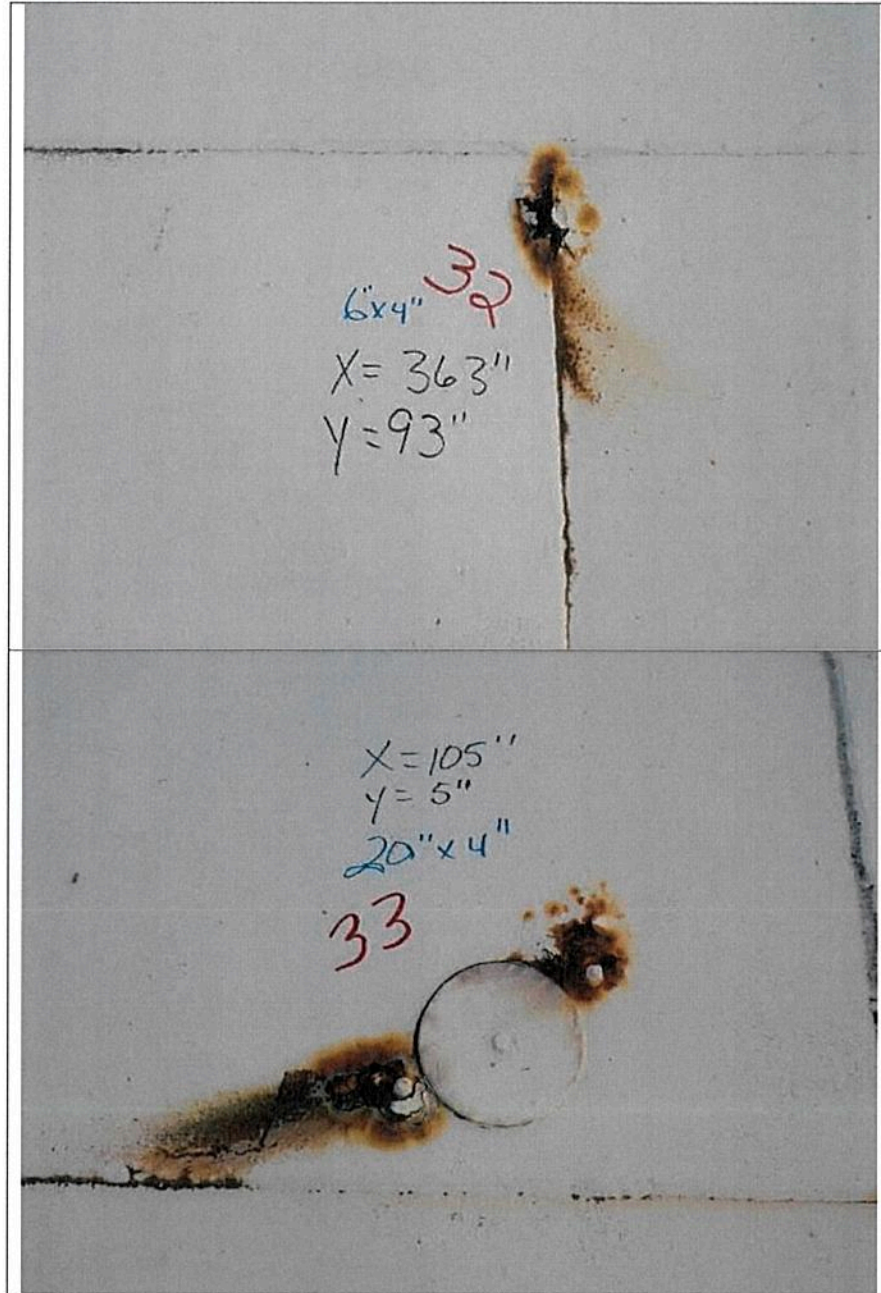


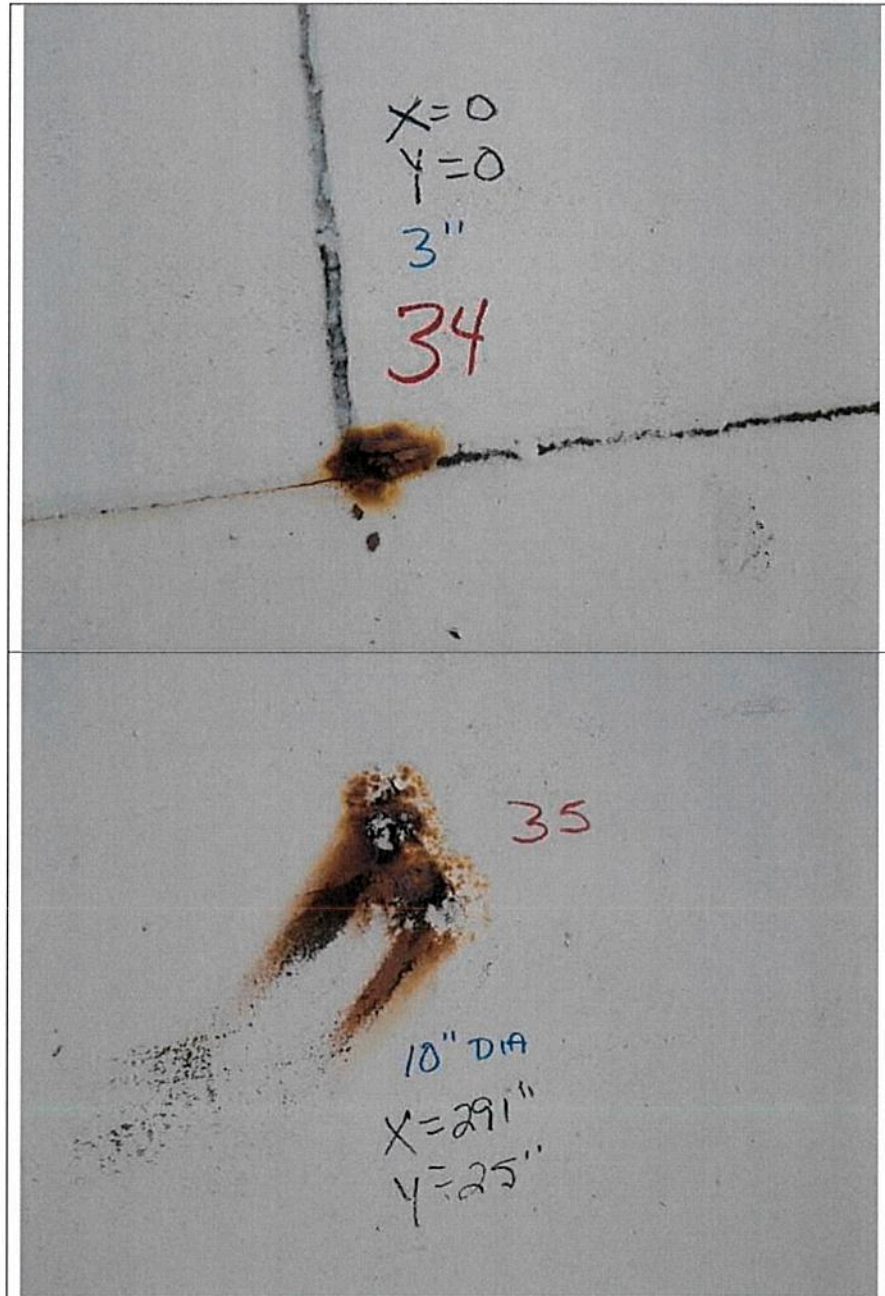




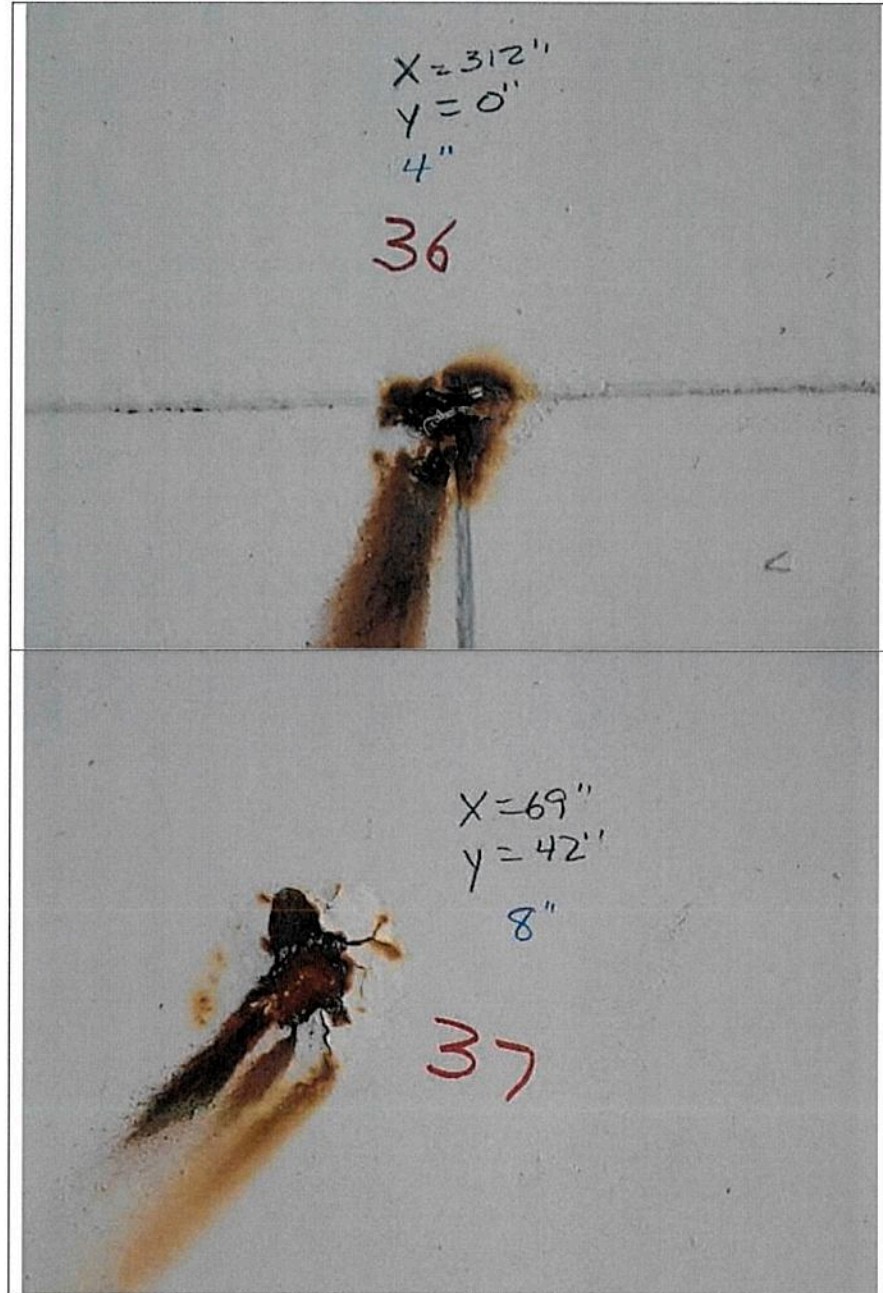


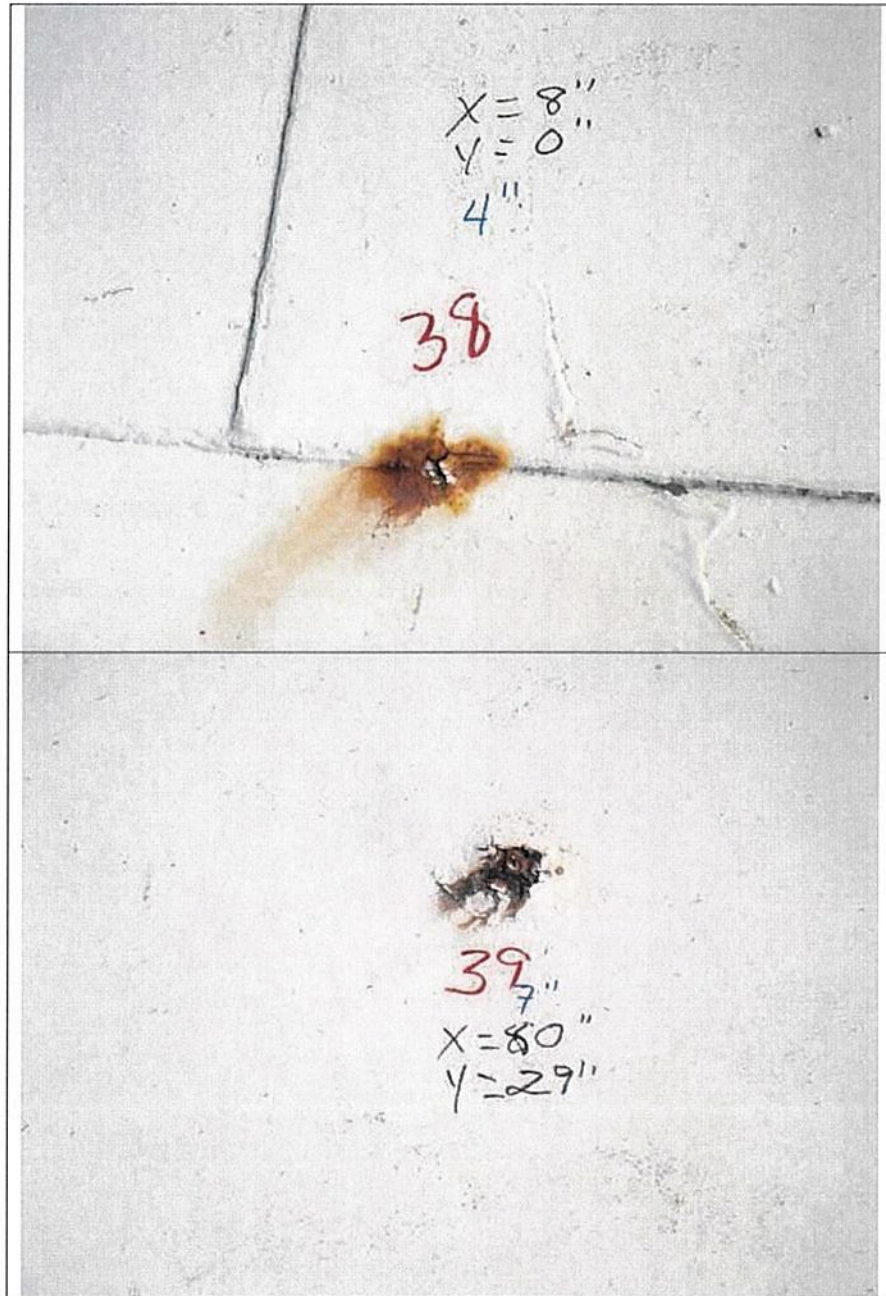




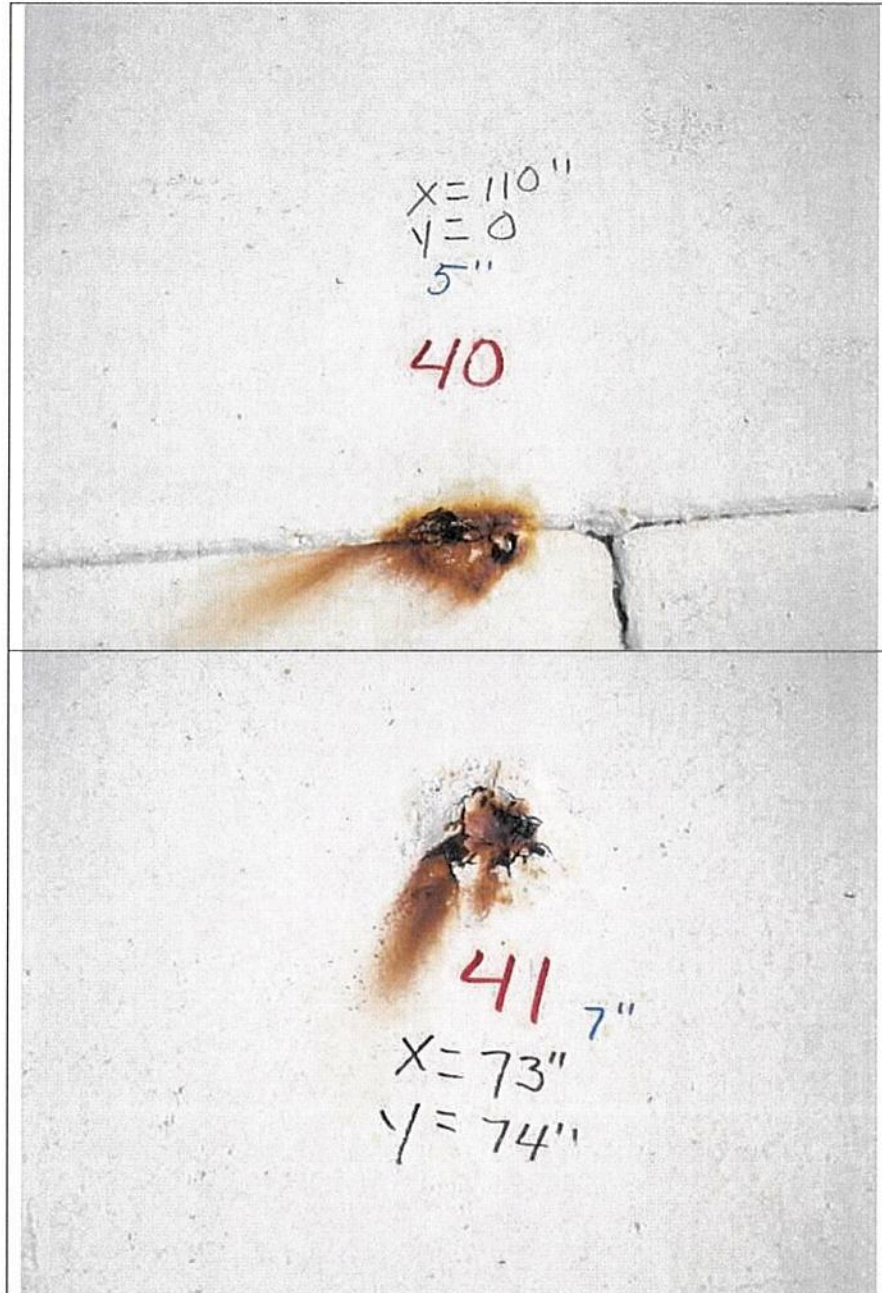


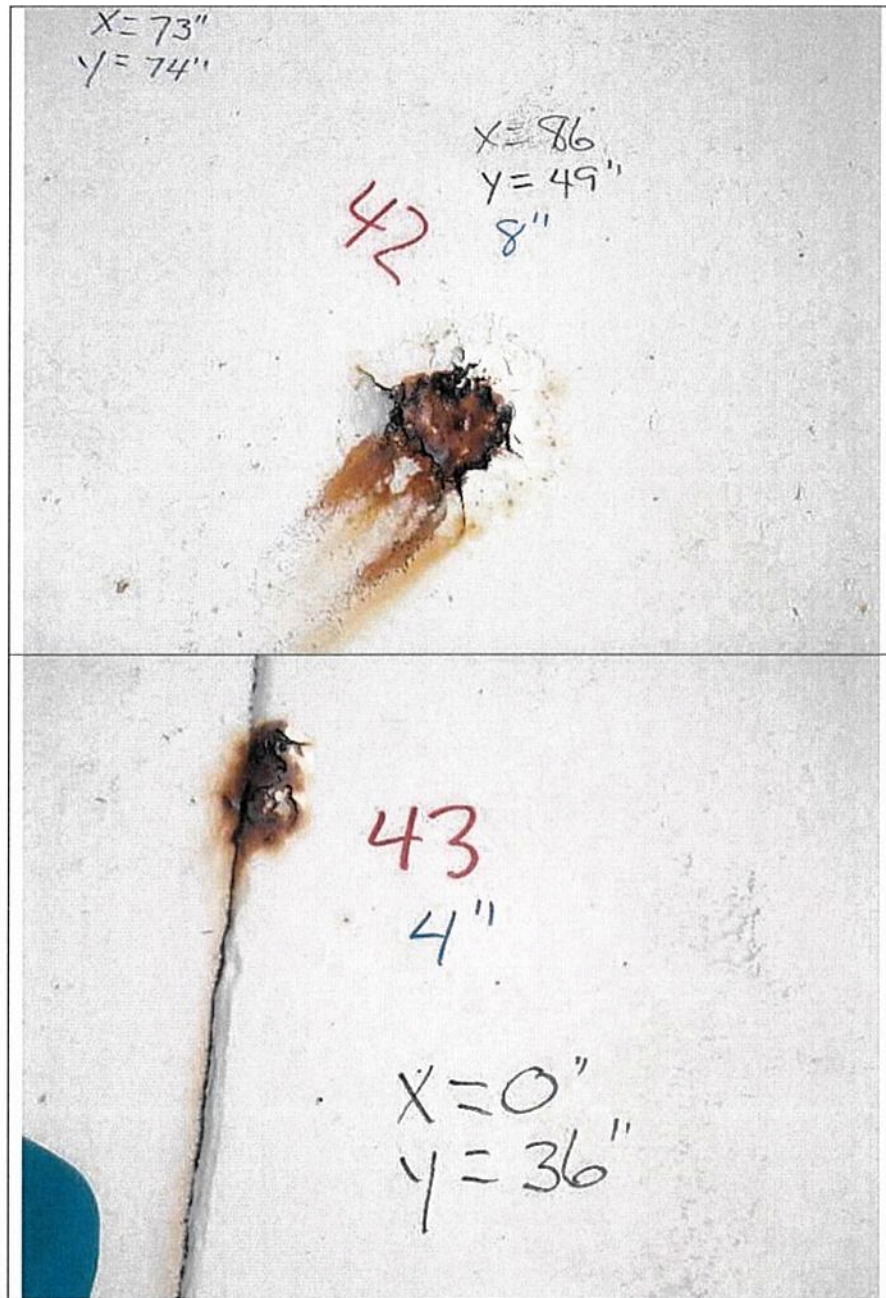




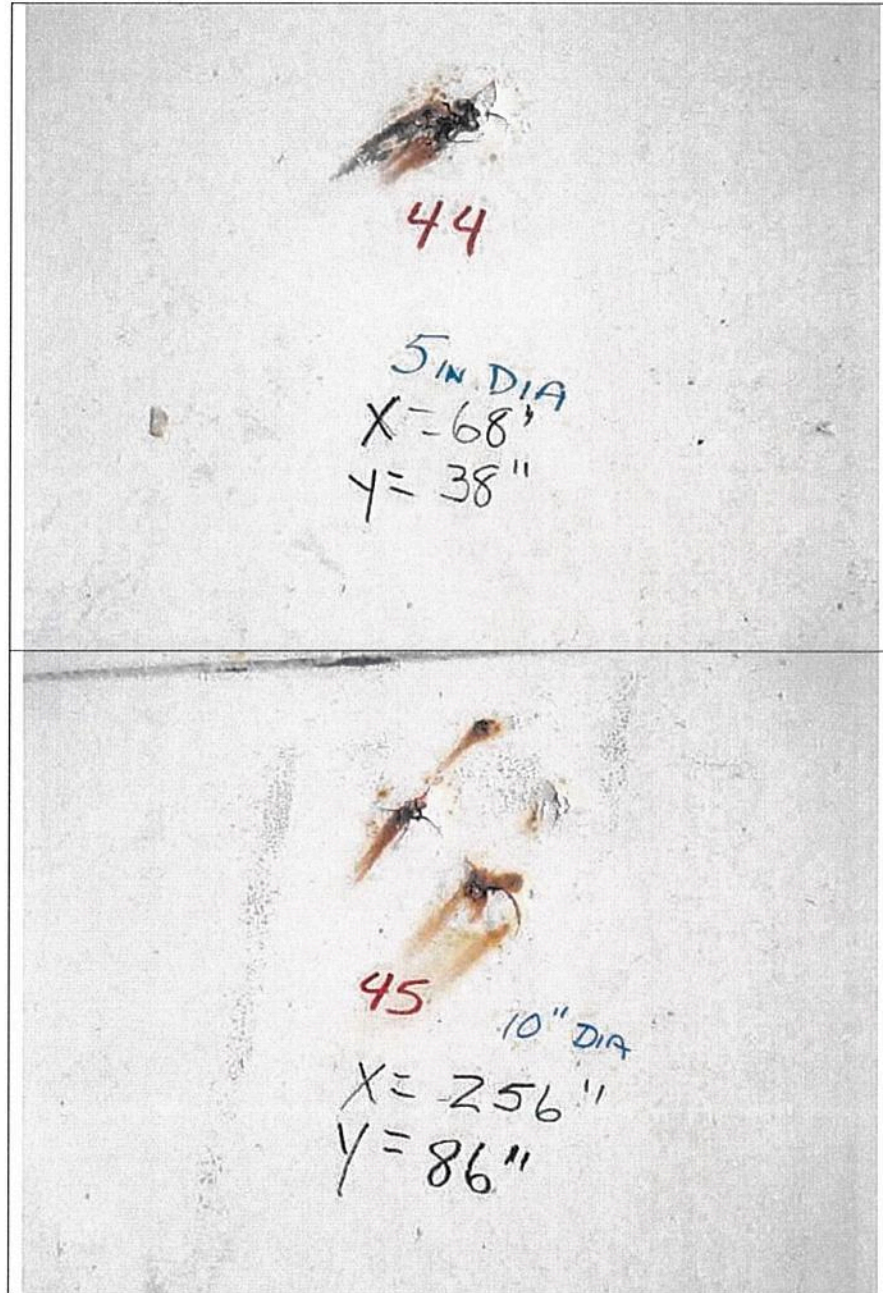


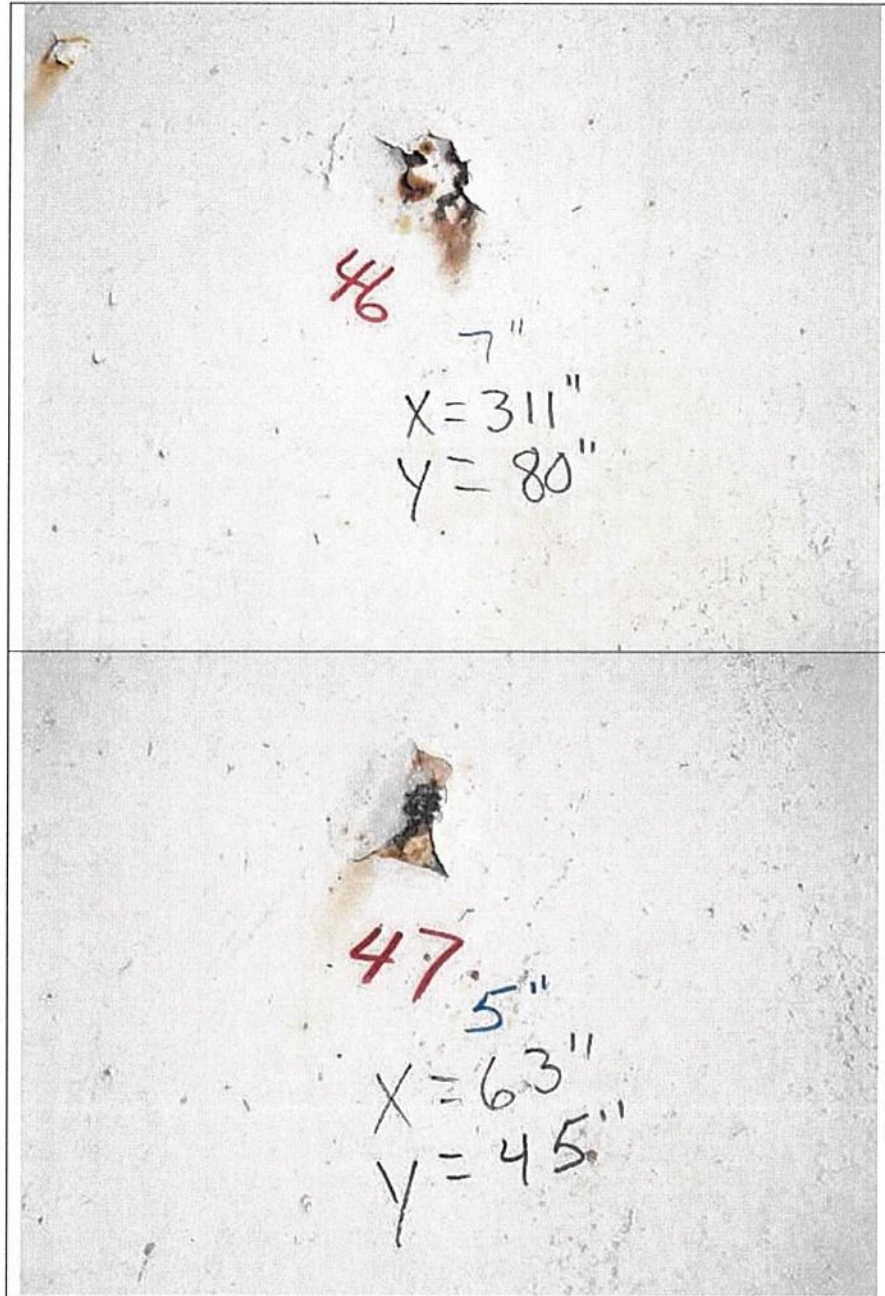




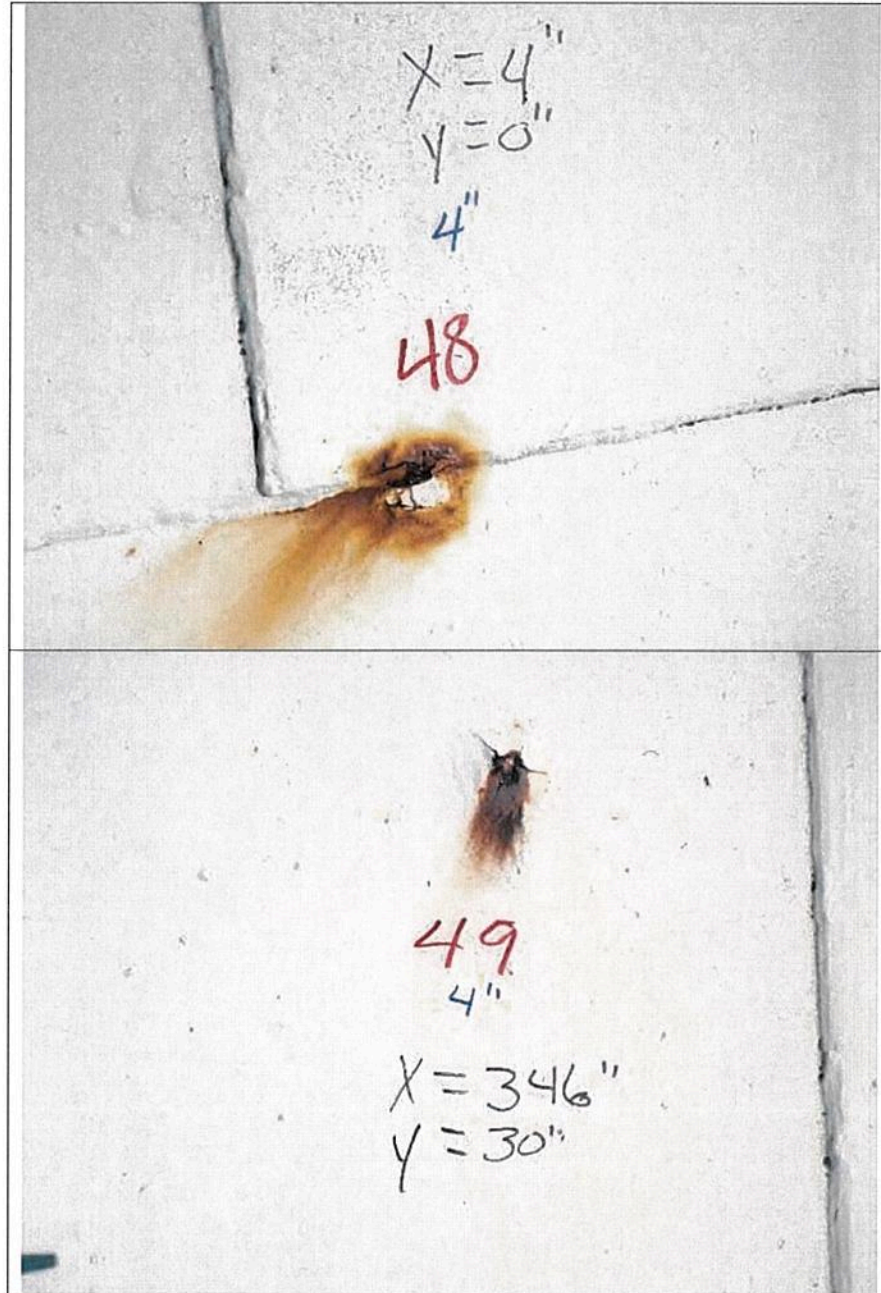


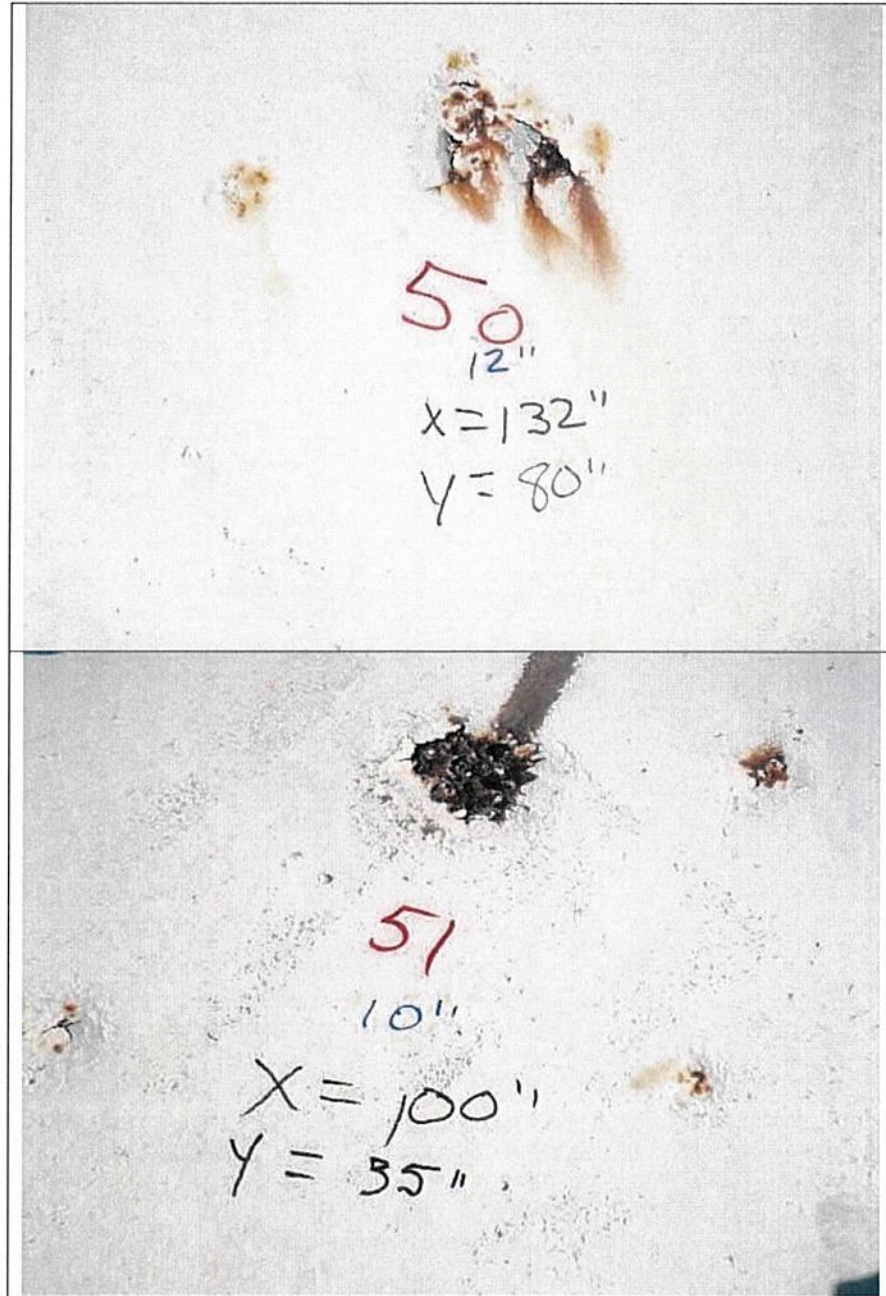




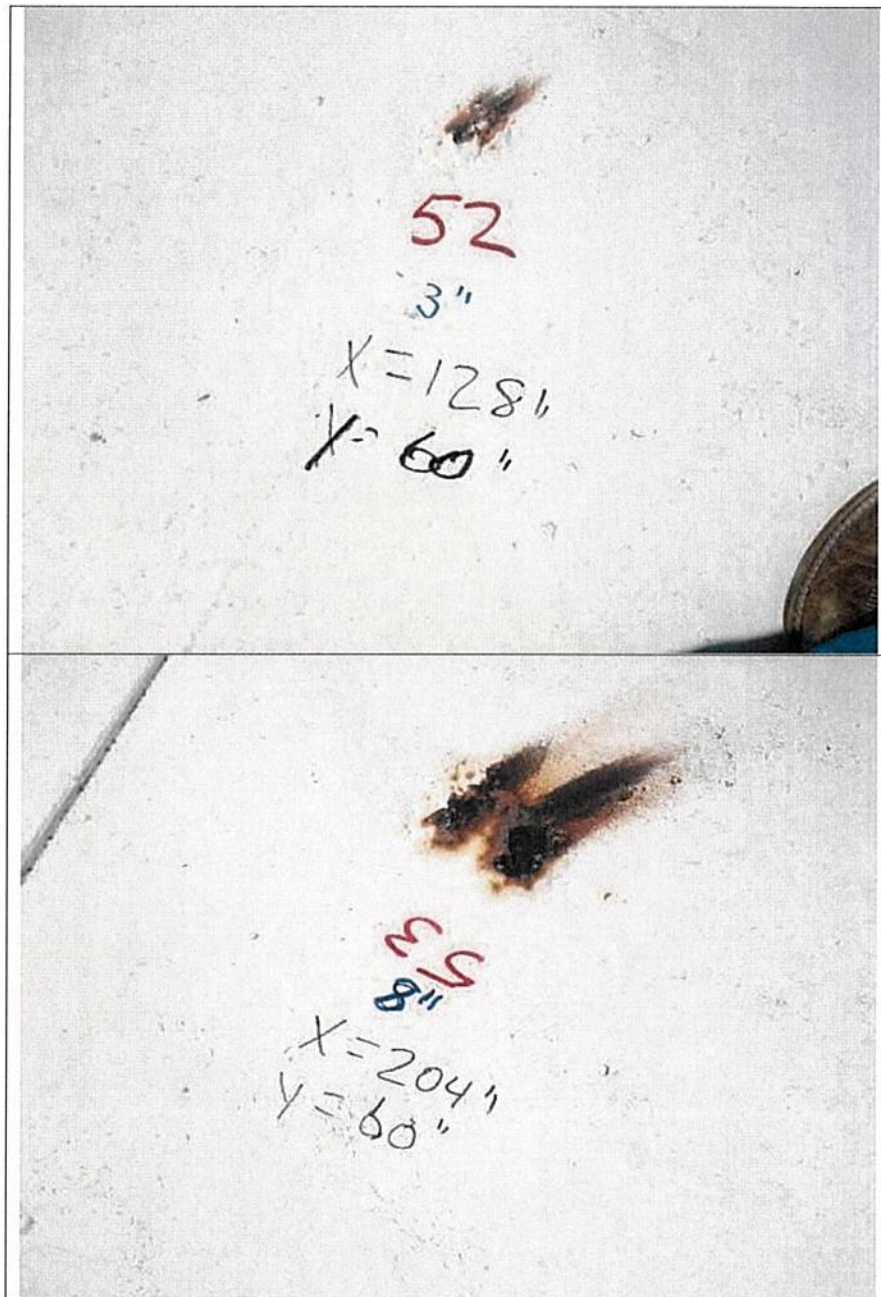


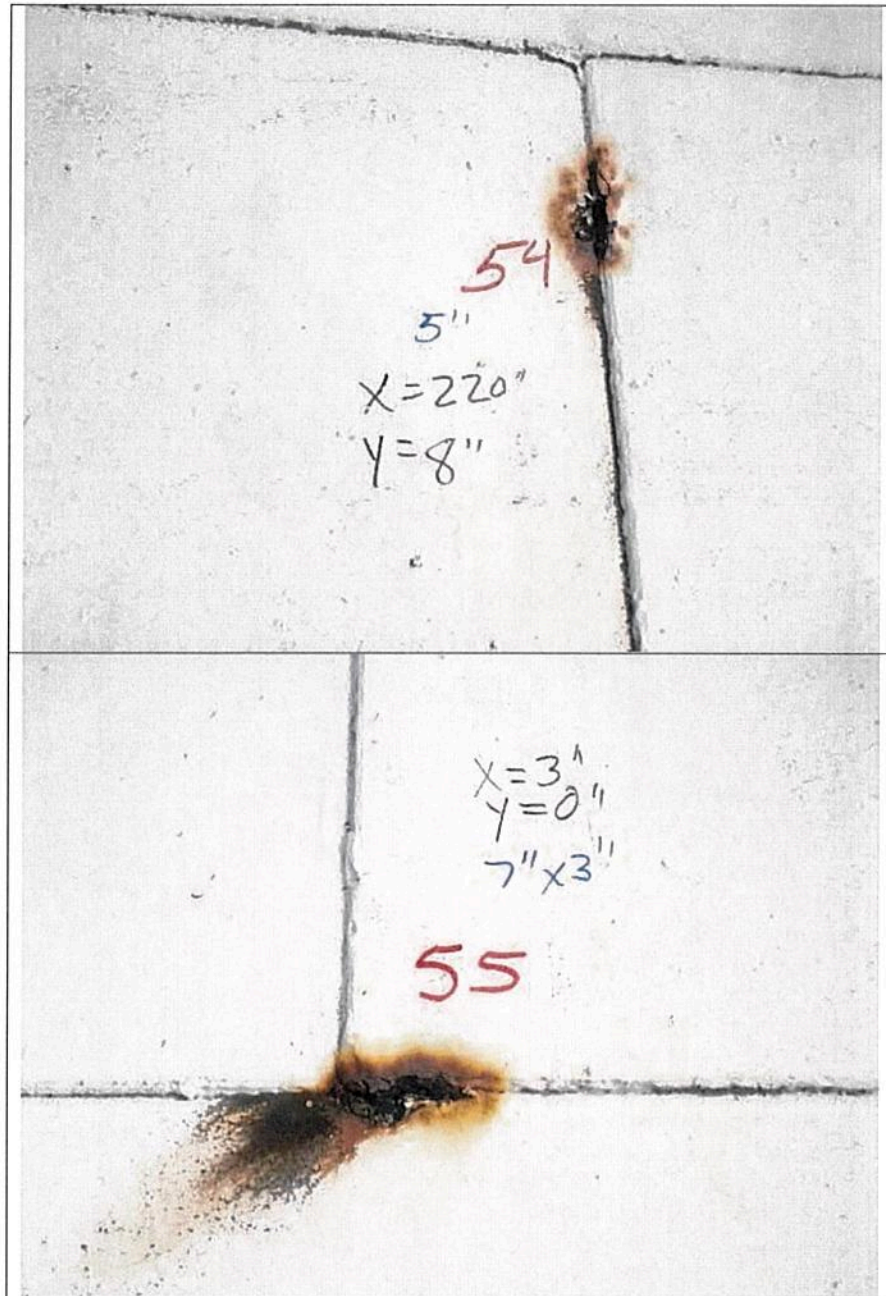




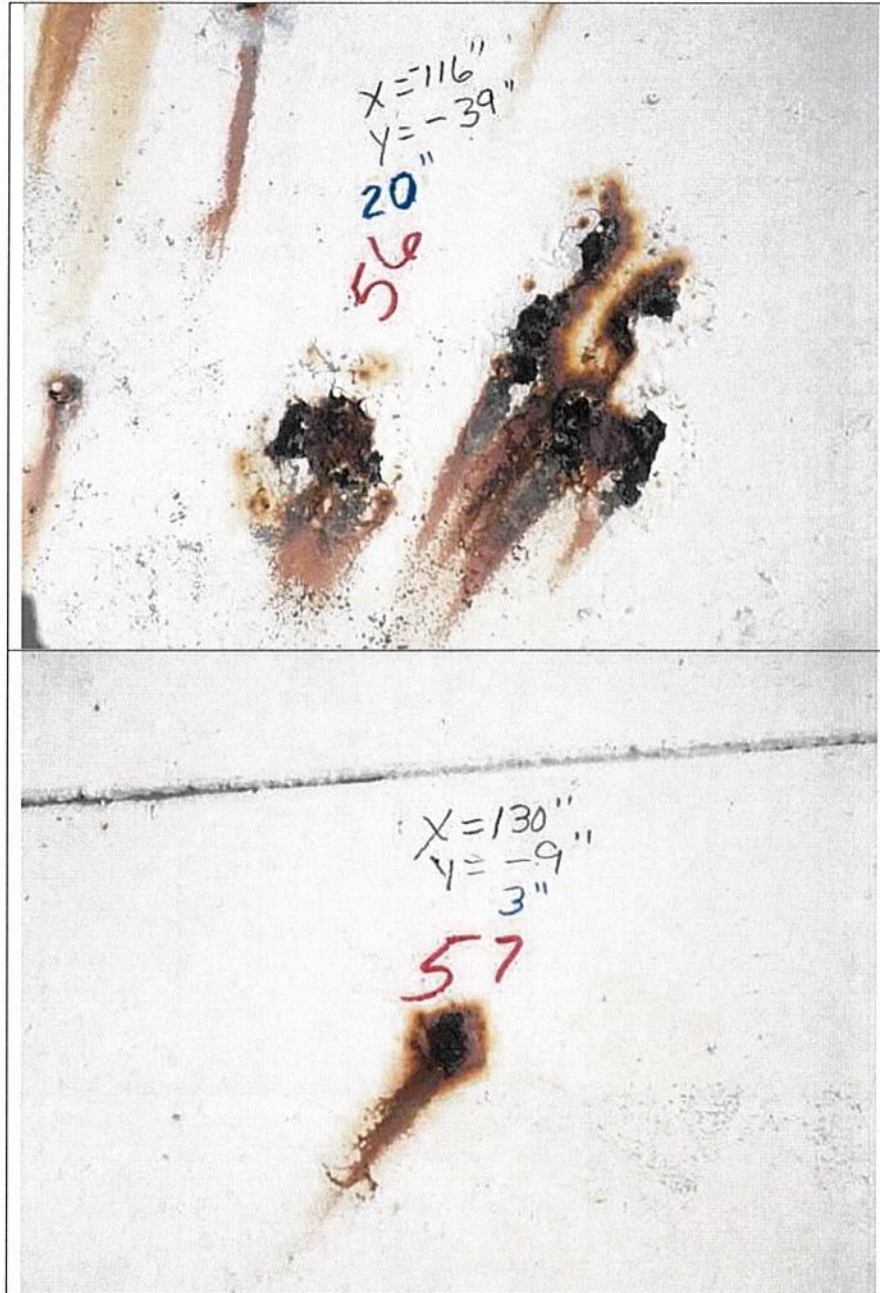


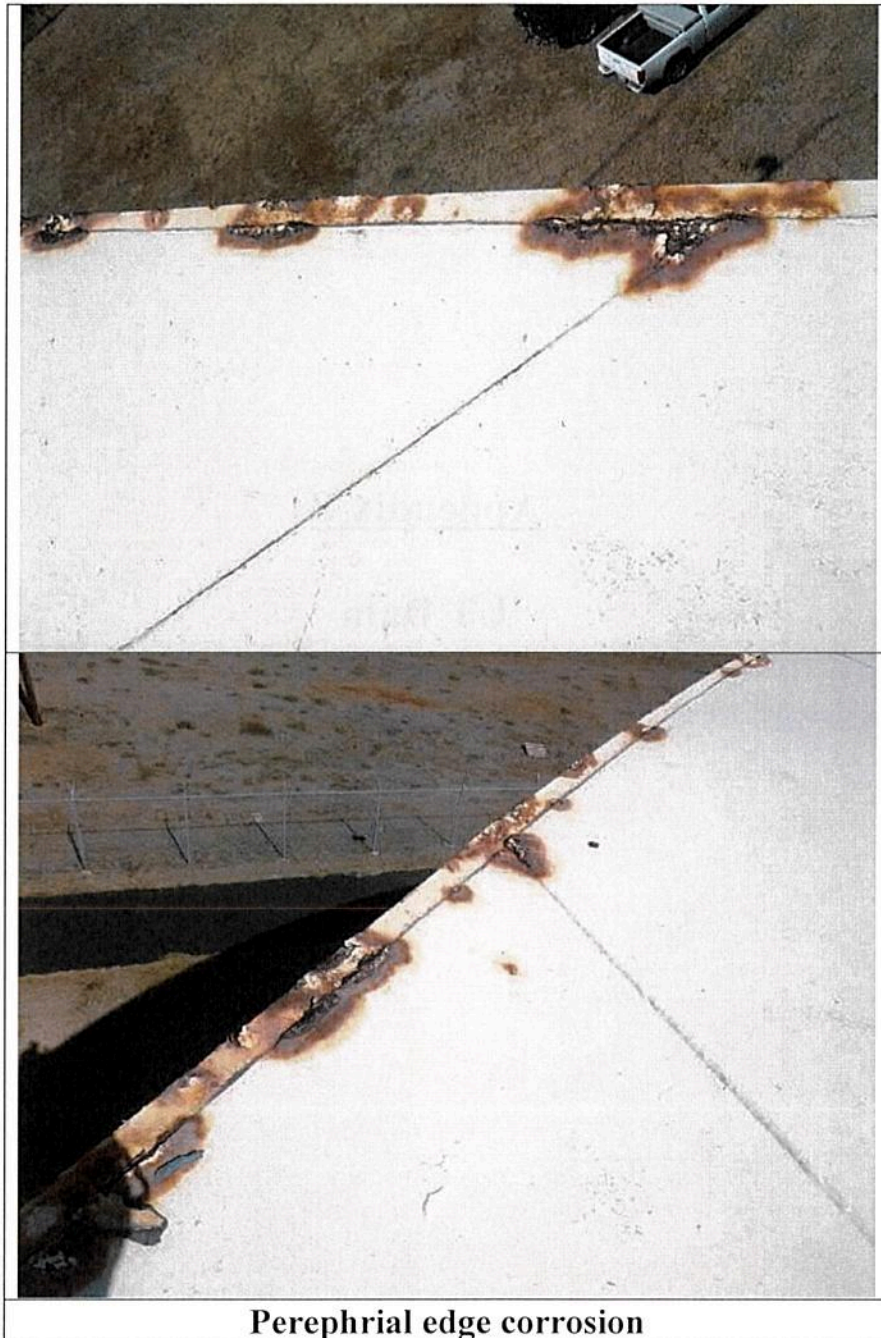
















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## **Appendix B**

### **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 (Southwest)	30"	.635	.634	.635	.661	1.295
N2 Nozzle	10"	.508	.517	.520	.521	1.336
N3 Nozzle	1"	.223	N/A	N/A	N/A	N/A
N4 Manway (Northeast)	30"	.670	.630	.633	.600	1.330
N5 Fill/Suction	24"	.495	.508	.555	.550	1.600



**Appendix B**

UT Measurements Tank Shell 1st Course									
Location	1	2	3	4	5	6	7	8	9
C1 P1	1.295	1.299	1.246	1.291	1.341	1.290	1.299	1.293	1.293
C1 P2	1.295	1.334	1.289	1.294	1.294	1.340	1.333	1.300	1.295
C1 P3 *Sect. Plate	1.432	1.435	1.422	N/A	N/A	N/A	N/A	N/A	N/A
C1 P4	1.200	1.250	1.351	1.395	1.359	1.259	1.390	1.350	1.365
C1 P5	1.288	1.300	1.288	1.277	1.361	1.256	1.290	1.299	1.290
C1 P6	1.329	1.291	1.295	1.295	1.290	1.292	1.298	1.278	1.290
C1 P7	1.298	1.300	1.298	1.292	1.335	1.290	1.286	1.296	1.335
C1 P8	1.293	1.290	1.288	1.328	1.293	1.287	1.294	1.294	1.295
C1 P9	1.299	1.299	1.284	1.300	1.300	1.284	1.337	1.299	1.291
C1 P10	1.292	1.337	1.290	1.283	1.301	1.289	1.291	1.329	1.318
C1 P11	1.295	1.305	1.300	1.290	1.332	1.298	1.290	1.295	1.320
C1 P12	1.290	1.299	1.335	1.296	1.298	1.295	1.337	1.300	1.336
Note: Plate 1 starts at the Southwest 30" 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	1.292	1.335	1.300	1.327	1.336	1.320	1.284	1.322	1.316
C1 P14	1.300	1.323	1.316	1.287	1.287	1.322	1.312	1.298	1.315
C1 P15	1.332	1.289	1.288	1.290	1.290	1.278	1.290	1.315	1.333
C1 P16	1.337	1.340	1.330	1.337	1.339	1.329	1.293	1.335	1.329
C1 P17	1.296	1.347	1.330	1.317	1.374	1.343	1.331	1.352	1.329
C1 P18	1.341	1.329	1.350	1.352	1.335	1.335	1.332	1.361	1.330
C1 P19	1.308	1.302	1.298	1.307	1.330	1.291	1.299	1.297	1.297
C1 P20	1.328	1.338	1.322	1.345	1.340	1.287	1.340	1.316	1.290

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



**Appendix B**

<b>Tank S-2; 6 Inch Drop; Shell Readings</b>					
<b>Location</b>	<b>Starting from Tank Roof to Tank Floor</b>				
<b>C5- 1</b>	.297	<b>C4- 1</b>	.442	<b>C3- 1</b>	.770
<b>2</b>	.298	<b>2</b>	.445	<b>2</b>	.769
<b>3</b>	.297	<b>3</b>	.447	<b>3</b>	.769
<b>4</b>	.296	<b>4</b>	.447	<b>4</b>	.776
<b>5</b>	.298	<b>5</b>	.449	<b>5</b>	.768
<b>6</b>	.298	<b>6</b>	.449	<b>6</b>	.730
<b>7</b>	.298	<b>7</b>	.450	<b>7</b>	.763
<b>8</b>	.297	<b>8</b>	.450	<b>8</b>	.730
<b>9</b>	.298	<b>9</b>	.450	<b>9</b>	.766
<b>10</b>	.299	<b>10</b>	.450	<b>10</b>	.767
<b>11</b>	.298	<b>11</b>	.458	<b>11</b>	.729
<b>12</b>	.298	<b>12</b>	.450	<b>12</b>	.767
<b>13</b>	.297	<b>13</b>	.451	<b>13</b>	.769
<b>14</b>	.297	<b>14</b>	.451	<b>14</b>	.767
<b>15</b>	.296	<b>15</b>	.451	<b>15</b>	.767
<b>16</b>	.296	<b>16</b>	.450	<b>16</b>	.730

Tank S-2; 6 Inch Drop; Shell Readings					
Location		Top to Bottom			
C2- 1	1.008	C1- 1	1.284		
2	1.004	2	1.288		
3	1.004	3	1.292		
4	1.046	4	1.296		
5	1.045	5	1.326		
6	1.008	6	1.295		
7	1.007	7	1.293		
8	1.045	8	1.294		
9	1.010	9	1.293		
10	1.008	10	1.300		
11	1.043	11	1.298		
12	1.044	12	1.297		
13	1.009	13	1.292		
14	1.045	14	1.294		
15	1.042	15	1.262		
16	1.041	16	1.332		

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



**Appendix B**

Tank S-2 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	.168	.178	.174	.161
2	.168	.179	.171	.176
3	.160	.180	.171	.178
4	.173	.178	.173	.174
5	.170	.171	.172	.175
6	.140	.171	.173	.174
7	.171	.196	.173	.175
8	.169	.170	.171	.175
9	.168	.171	.170	.171
10	.172	.170	.170	.170
11	.167	.173	.199	.167
12	.191	.172	.169	.168
13	.165	.173	.172	.171
14	.173	.198	.176	.166
15	.172	.170	.170	.174
16	.200	.182	.182	.193
17	.170	.172	.170	.171
18	.175	.170	.173	.171
19	.187	.171	.177	.168
20	.178	.175	.174	.167

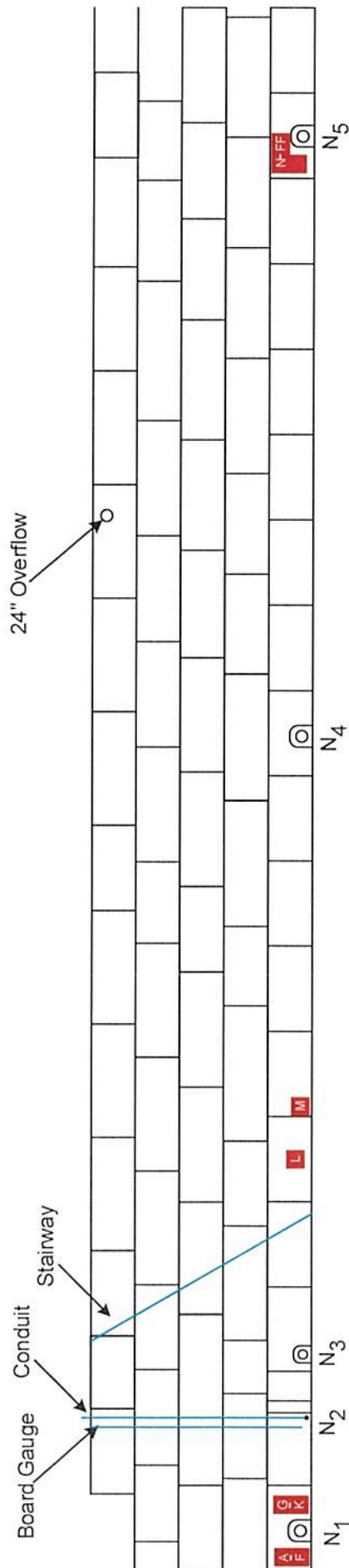


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## Appendix C

### **Drawings**





**A** = Blast and Recoat



**Tank S-2**

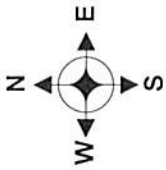
NAVFAC  
Honolulu, HI

Tank Side View  
Plate Layout

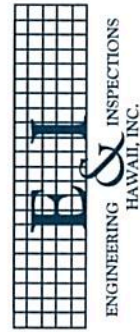
Sept. 2020

### Tank Nozzles

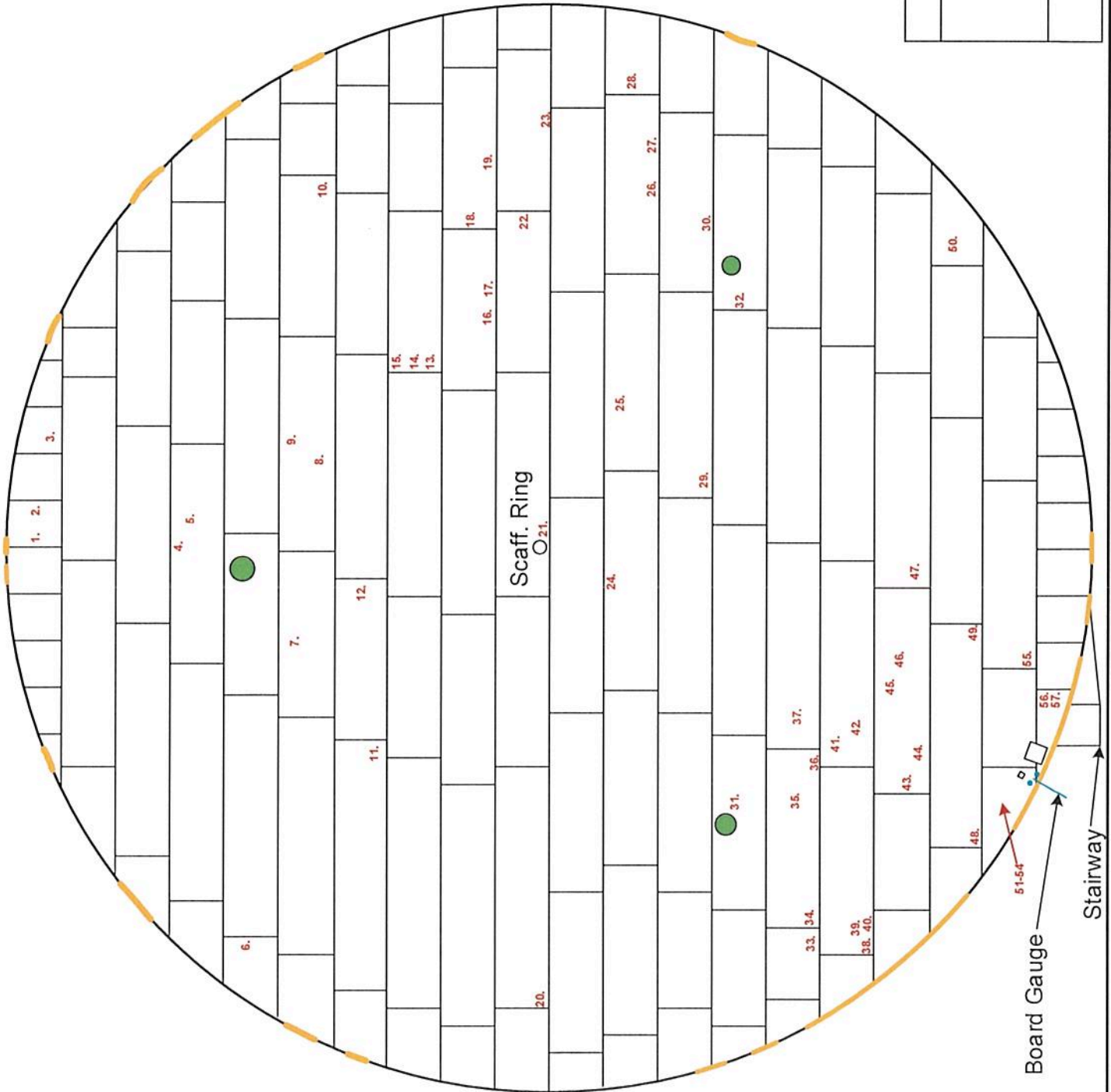
- N<sub>1</sub> = 30" Manway - 22" up
- N<sub>2</sub> = 1" Nozzle - 7" up
- N<sub>3</sub> = 10" Nozzle - 10" up
- N<sub>4</sub> = 30" Manway - 22" up
- N<sub>5</sub> = 24" Fill/Suction - 8" up



- = Replace Vent/Nozzle
- = Patch Peripheral Edge
- = Replace Anode Base
- ##. = Patch Repair Area



<b>Tank S-2</b>
NAVFAC Honolulu, HI
Tank Roof Plate Layout
Sept. 2020







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## **Appendix D**

### **T-Min Calculations**

# Inspection Evaluation Summary

## TANK DATA

Customer: NAVFAC  
 Tank Title: S-2  
 Tank No: Tank 244  
 Work Order #: 20-217  
 Year Built: 1996  
 Years in Service: 24  
 Analyzed By: Daniel Elling

Floor Material: A285M C  
 Shell Material: A285M C  
 Roof Material: A285M C  
 Date: 1/29/2019

## 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	1.200	0.761	0.0026	0.439	169.9 Years
Roof	0.188	0.160	0.090	0.0012	0.070	60.0 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: 0.070

Estimated Remaining Life of the Tank is: 60.0 Years

## Notes

## Recommendations



Minimum Required Thickness																																													
TANK DATA																																													
Customer:	NAVFAC				Floor Material:	A36																																							
Tank Title:	Potable Water				Shell Material:	A36																																							
Tank No:	S-2				Roof Material:	A36																																							
Work Order #:	20-217				Date:	9/14/2020																																							
Year Built:	1996																																												
Prepared By:	Daniel Elling																																												
Definitions/Notations:																																													
<p>H = Height (from 1.1) to maximum liquid level</p> <p>S = Maximum allowable stress value of material</p> <p>CR = Corrosion rate per year</p> <p>E = Joint efficiency</p> <p>D = Diameter of tank</p> <p>G = Highest specific gravity of product</p> <p>tMin = Minimum thickness</p> <p>t = Wall thickness, inches</p> <p>RL = Remainin life in years</p>					<p style="text-align: center;">Parameters</p> <table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td>H</td> <td>See Below</td> <td></td> <td></td> </tr> <tr> <td>S= 1st &amp; 2nd Course</td> <td>36000</td> <td>Yield</td> <td>58,000 Tensile</td> </tr> <tr> <td>S= All Other Courses</td> <td>36000</td> <td>Yield</td> <td>58,000 Tensile</td> </tr> <tr> <td>CR</td> <td>0.0004</td> <td></td> <td></td> </tr> <tr> <td>E</td> <td>0.85</td> <td></td> <td></td> </tr> <tr> <td>D</td> <td>165</td> <td></td> <td></td> </tr> <tr> <td>G</td> <td>1</td> <td></td> <td></td> </tr> <tr> <td>tMin</td> <td>0.25</td> <td></td> <td></td> </tr> <tr> <td>Maximum Fill Height, ft.</td> <td>39</td> <td></td> <td></td> </tr> </table>					H	See Below			S= 1st & 2nd Course	36000	Yield	58,000 Tensile	S= All Other Courses	36000	Yield	58,000 Tensile	CR	0.0004			E	0.85			D	165			G	1			tMin	0.25			Maximum Fill Height, ft.	39		
H	See Below																																												
S= 1st & 2nd Course	36000	Yield	58,000 Tensile																																										
S= All Other Courses	36000	Yield	58,000 Tensile																																										
CR	0.0004																																												
E	0.85																																												
D	165																																												
G	1																																												
tMin	0.25																																												
Maximum Fill Height, ft.	39																																												
Notes:																																													
FLOOR																																													
a. Without Coating					b. With Coating or Leak Detection & Containment																																								
t min = 0.100					t min = 0.050																																								
tMin. Found		tMin.	CR	RL	tMin. Found		tMin.	CR	RL																																				
0.250		0.100	0.0001	NA	0.250		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)					b. All other courses (S=use the smaller of .88Y or .472T)																																								
$t \min = \frac{2.6(H-1)DG}{SE}$																																													
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)					b. All other courses (S=use the smaller of .88Y or .472T)																																								
$t \min = \frac{2.6HDG}{SE}$																																													
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 (lbf/in.2)	Minimum Specified Tensile Strength T (lbf/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
<b>API 650</b>	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
<b>API 12C</b>	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
		Butt (c.)	0.85	
<b>Unknown</b>		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<sub>min</sub>**= Minimum acceptable thickness in in. for each course as calculated from the above formula; however, **t<sub>min</sub> 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/in<sup>2</sup>; 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.