9/3/2024

City of Buhl
Tony Jeffries
Clerk/Administrator
300 Jones Ave
Buhl, MN 55713
Email: tjeffries@cityofbuhlmn.com

Re: City of Buhl Water Tower Assessment
AMI Project No: 241117

Mr. Jeffries,

We are pleased to present the results of AMI Consulting Engineers, P.A.'s (AMI) structural inspection of the City of Buhl water tower, located in Buhl, Minnesota. This inspection focuses on evaluating the current condition and remaining service life of the water tower's structure. Also included in this report are recommendations for maintenance, repairs, and future inspections aimed at prolonging the service life of the structure. The following is a summary of the findings and recommended actions.

Existing Construction

The water tower, constructed in 1914, is a product of the Pittsburgh-Des Moines Steel Company. The tower is comprised of a cylindrical tank which is supported by four columns in a square configuration. The top of the tank is approximately 120' above grade. The tower has three levels of cross bracing with two levels of horizontal struts between them. The diagonal cross braces are 1 ⅜" diameter rods. Each column is a built-up lattice consisting of two 15-inch-deep steel channels spaced 10" center-to-center and oriented back-to-back. The channels are connected using 3/8" steel lacing, or diagonally connected bars, riveted to each flange. Horizontal struts and diagonal braces are connected to the columns via riveted bent plates at each strut line. All braces connect using a clevis and cotter pin connection, while struts use a riveted connection. Each column is riveted to a ¾" baseplate which in turn is anchored using two 1 ½" diameter anchor bolts. The columns rest on concrete footings approximately 3'-6" x 3'-6" in size.

At the top of the structure, double angles connect each column's channel to the tank. The angles are riveted to the channel web and welded to the tank wall. The walkway is comprised of riveted steel plate and single angles for the handrail members. The handrails appear to double as a truss member that provides support for the walkway. Several communication antennas are mounted to the tower's handrail.

The water tower is subject to various environmental conditions such as precipitation, UV radiation, and fluctuating temperatures throughout the year. These factors can accelerate coating degradation and corrosion, compromising the tower's integrity over time.

Procedures Used for Inspection

The water tower inspection was performed by a team of two AMI graduate engineers. The team traveled to the site on August 13th, 2024, to begin the assessment. A City of Buhl employee granted the inspection team access to the ladder located on the southwest support of the tower. The inspection team began by establishing a fall protection plan. One team member was to climb the ladder while the other remained on the ground. While climbing the ladder, fall protection harnesses equipped with two retracting fall arrest devices were worn. AMI was unable to complete the inspection on August 13th due to a few loose bolts near the ladder splice point, approximately 90' above grade (Figure 1). This prevented safe access to the tank's walkway. After straps were placed to secure the ladder to the southwest column, AMI returned to finish the inspection on August 21st.

Figure 1. Loose bolts near ladder splice.

Visual observations and ultrasonic thickness (UT) measurements were taken starting at the base of the tower. Ascending from the base, the team took measurements from the ladder at approximately 22'-6", 35'-0", 56'-0", 75'-0", and 90'-0" above grade. These heights corresponded to midpoint and end of each strut level.

The team visually inspected the components of the tower for corrosion, buckled and warped members, and general coating condition. UT scans required the use of a chip hammer and brush to expose steel underneath the coating. Over 150 data points were collected in total. Typically, three data points are averaged for one UT reading. The intent was to obtain a representative sample of data by recording measurements across the entire structure. AMI gathered UT readings for the following elements:

- At each height listed above:
  - Channel webs – (6) readings, (3) per channel
  - Lacing bars – (6) readings, (3) laces per side
- Plus
  - Base plates – (3) readings per base plate
  - Bent plates – (3) readings per plate
  - Double angles at top connections – (5) total readings
  - Column splice plates – (2) readings per plate
  - Strut connection plates – (1) reading

Site Observations

NDT Results:

Table 1 shows the results of UT thickness data obtained from the test locations listed above. Original construction documents are not available, so original thicknesses are assumed based on our knowledge of historical shapes, analysis of the data collected, and the observations made during the inspection. In general, the structural steel is in good condition with negligible section loss and sporadic light surface corrosion. The section loss based on the minimum thickness reported in Table 1 is within the acceptable tolerance for steel plate and structural shapes.

Table 1. Ultrasonic Testing Results.

Element	Approximate Original Thickness (in)	Scan Results (in)		Steel Loss (in)	Percent Loss
		Minimum Thickness	Average Thickness[1]	Based on Min. Thickness	Based on Min. Thickness
Channel Webs	0.400	0.390	0.413	0.010	2.5%
Bent Plates	0.500	0.495	0.514	0.005	1.0%
Base Plates	0.750	0.737	0.759	0.013	1.7%
Lacing Bars	0.375	0.379	0.394	N/A	N/A
Splice Plates	0.375	0.396	0.399	N/A	N/A
Strut Connection Plate	0.375	0.399	0.400	N/A	N/A
Double angles	0.375	0.375	0.408	N/A	N/A

1. Measurements greater than original thicknesses may be attributed to original tolerance limits, which were substandard to modern fabrication tolerances.

Visual Observations:

Again, the structural steel is generally in good condition with negligible section loss and sporadic light surface corrosion. Little to no pack rust was observed during the inspection. AMI noted that the column base plates and the steel near the water tank tend to have more surface corrosion due to greater moisture exposure compared to the rest of the structure. For example, AMI noticed large amounts of vegetation around the electrical box near the southeast footing (Figure 2). The inspection team observed standing water on the base plate and footing near the overgrowth. This is to be expected as it is a common problem for all baseplates.

Figure 2. Dense vegetation surrounding the southeast footing.

Additionally, AMI observed condensation forming on the tank and running onto the steel below. The area between the gusset plates that support the walkway seemed to have more surface corrosion. (Figure 3)

Figure 3. Light corrosion at southwest column-to-tank connection.

AMI documented several locations with loose cross bracing. The bracing was shaken by hand to test tightness, which revealed that some rods are excessively loose. During hot summer days, you would expect the rods to thermally expand and loosen up, but the amount of play observed appeared to be beyond that resulting from thermal expansion alone. When the inspector was near the top of the tower, he could feel the tower react to a moderate wind gust by swaying and then "catching" on the diagonal bracing. Additionally, several cotter pins that are used to positively secure the brace rods pin to the columns were missing (Figure 4). When tightening the cross-bracing rods, it is important not to over tighten the rods because the steel will contract on cold days. Ensure that the contractor performing the work has experience with tension cross bracing and follows the proper industry guidelines.

Figure 4. Typical diagonal brace clevis & cotter pin connection & connection with missing cotter pin.

AMI observed several buckled lace bars near the base of the structure. Steel laces were buckled outward, away from the center of the column (Figure 5). It is unclear when this damage occurred or what caused it in the first place. There did not seem to be any damaged lace bars farther up the columns. The northwest column's baseplate was also bent upward in one corner (Figure 6). This damage probably took place during construction but is not a concern for the longevity of the structure.

Figure 5. Buckled lace near the base of the northwest column

Figure 6. Bent base plate corner on the northwest column.

Only the tops of the concrete foundation are visible without excavation. The visible portion of the concrete foundation supporting the columns is generally in good condition. AMI observed a few hairline cracks, which should be sealed with epoxy to prevent water intrusion.

Overall, the steel coating is in poor condition. Paint cracks were observed over the majority of the structure. Some areas had large areas of chipped paint. (Figure 7) Other areas had smaller holidays where the paint had delaminated from the steel and air pockets have formed underneath the coating. A functional coating system is crucial to protecting the structural steel from corrosion. When selecting a replacement coating, it is best practice to work with a paint manufacturer or an engineer to select the proper paint system and identify the correct surface preparation and application procedures.

Figure 7. Cracked and flaking paint on the southwest column.

Although secondary to the main structure, the existing fixed ladder, cage and walkway handrail should be evaluated for OSHA compliance. OSHA 1910.28(b)(9)(i)(A) states that a cage is still permissible for existing fixed ladders erected before November 19, 2018. Employers may use fixed ladders with cages up until the time a cage, or any ladder section requires replacement, at which time a ladder safety or personal fall arrest system must be installed in accordance with 1910.28(b)(9)(i)(C). For new ladder installations, cages are no longer considered compliant fall protection. Please note that all existing fixed ladders that extend more than 24′ above a lower level must be equipped with a personal fall arrest system of ladder safety system by November 18, 2036. The existing guardrail is not OSHA compliant. Since the existing guardrail is integrated into the structure, a structural engineer should provide recommendations before modifications or alterations are made.

Finally, AMI observed several communications antennas attached to the guardrail at the top of the tower (Figure 8). We cannot say whether these antennas are properly supported. AMI is unaware of any authorization given by an engineer to support antennas from the structure. Best practice is to obtain a letter signed by a professional engineer licensed in the state of Minnesota from the service provider stating that the existing structure can adequately support the loads induced by the antennas.

Figure 8. Several antennas attached to the walkway guardrail.

Conclusions and Recommendations

In summary, the structure is in fair condition but requires repainting and general maintenance. It is our professional opinion that if the structure is continually maintained as outlined in this report, the structure can remain operational for another 40 to 50 years. The following is a summary of our findings and recommended actions.

Based on AMI's assessment of the tower, there is not a need for immediate repairs to the structure. Section loss of the structural steel is negligible, and corrosion is not yet a major issue. AMI recommends that the City of Buhl take the following maintenance steps to maintain the tower's structural integrity.

1. Replace missing cotter pins on the cross-bracing pins within 1 year.
2. Replace buckled lacing bars located on the columns within 1 year.
3. Re-tighten the cross-bracing rods using the existing turnbuckles within 1 year.
4. Clear vegetation around electrical station near the southeast footing (Figure 8) within 1 year. Continue to keep this area clear of vegetation.
5. Sandblast (or similar) and repaint the structure within the next 5 years. Be sure to develop a paint specification with the help of a paint manufacturer or professional engineer. Continue to maintain the new coating in accordance with the paint manufacturers' recommendations.
6. Seal the hairline cracks on the concrete foundation.
7. Perform a visual inspection of the structure conducted by a engineer every 10 years.
8. Repair the loose section of the fixed ladder.
9. Review and address the ladder access and guardrail for OSHA compliance.
10. Install a personal fall arrest system of ladder safety system by November 18, 2036, per current OSHA requirements.
11. Obtain a letter from the antenna service provider stating that the existing structure is adequate to support the antenna loads.

If there are any questions regarding the content of this report, please feel free to contact me via phone or email below. AMI would like to thank you for this inspection opportunity and looks forward to working with you in the future.

Respectfully submitted,

Max Mallinger, EIT
Project Engineer
(715) 718-5711

Reviewed by,

Garrett Larson, PE
Industrial Group Project Manager

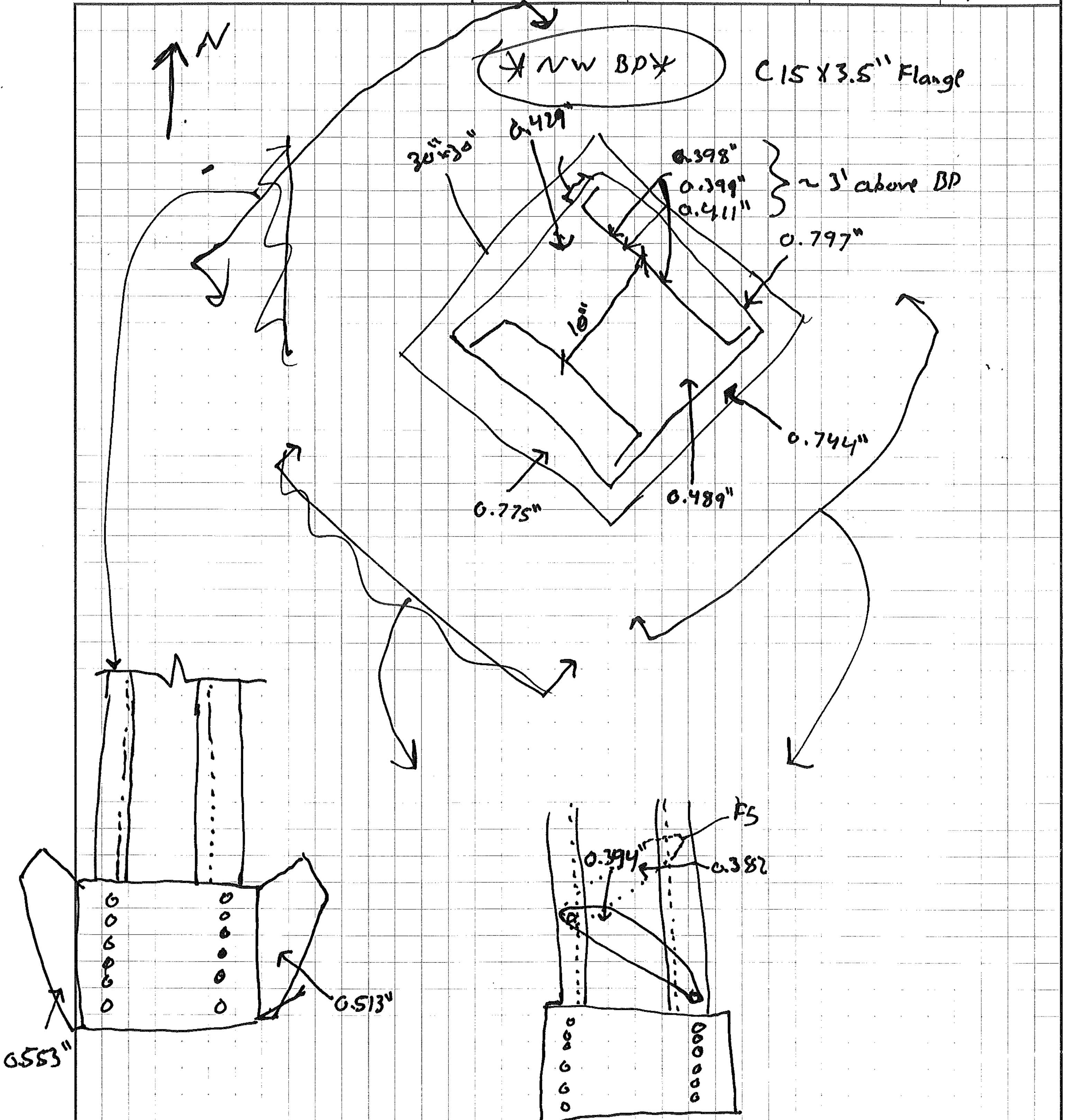
Attachments

- Field Notes
- Raw Ultrasonic Thickness Data

AMI Consulting Engineers P.A.

Project	BUHL WATER TOWER INSPECTION
Description	BASEPLATE UT SCANS - NORTHWEST

Engineer	AMI Proj. No.	Approved	Date
			8/13/24



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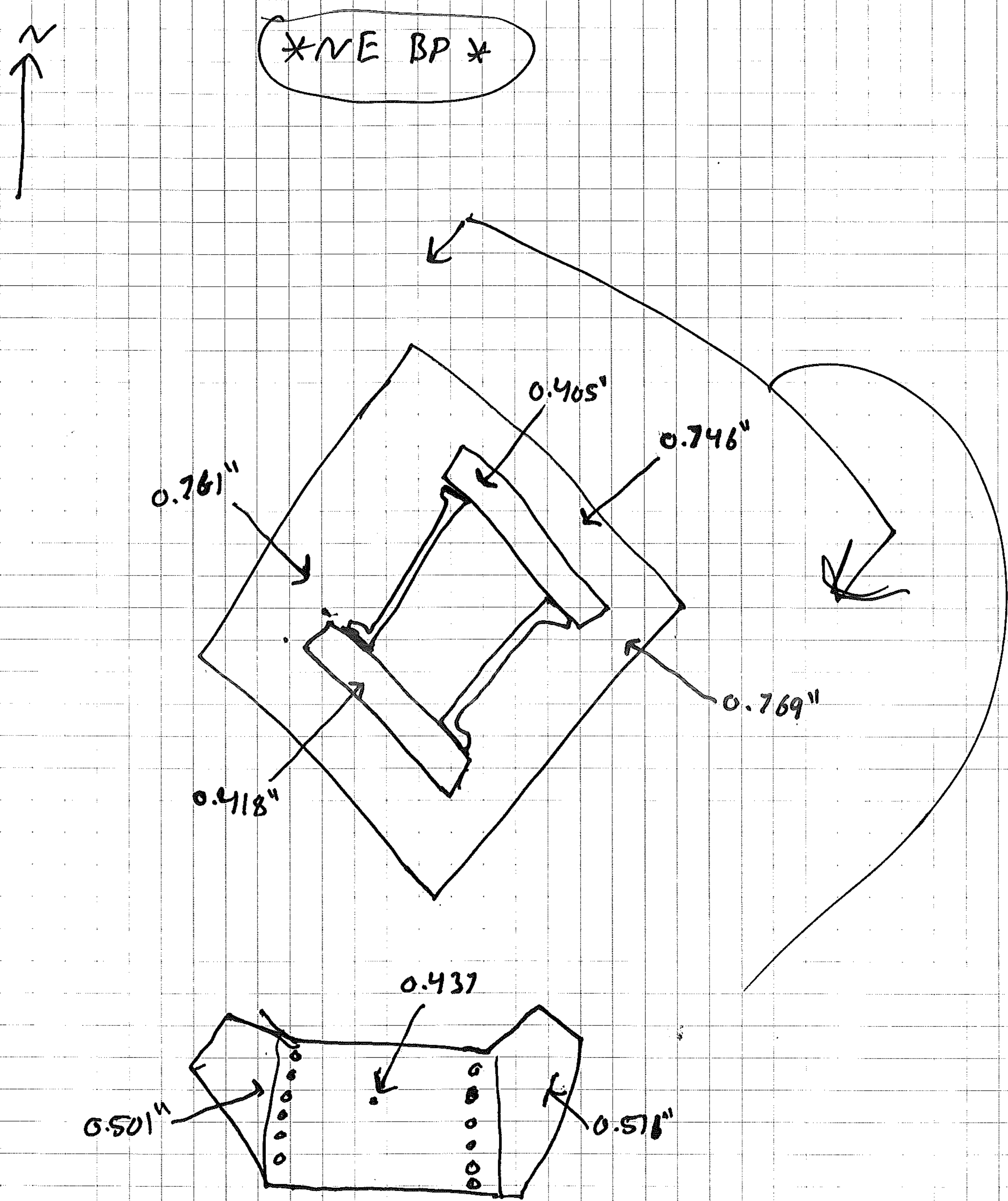
AMI Consulting Engineers P.A.

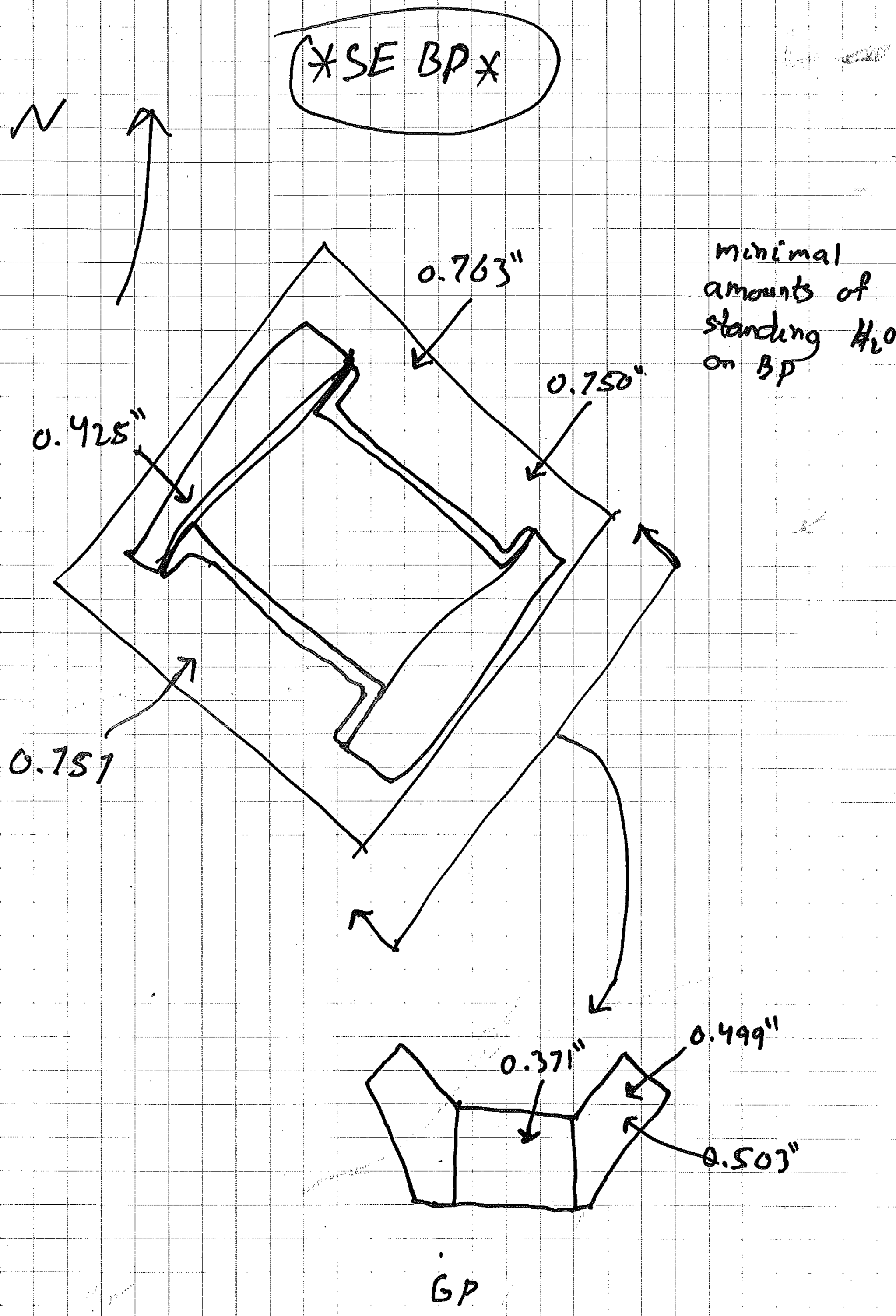
Project	BUHL WATER TOWER INSPECTION
Description	BASEPLATE UT SCANS - NORTHEAST

Engineer	AMI Proj. No.	Approved	Date
			8/13/24



AMI Consulting Engineers P.A.

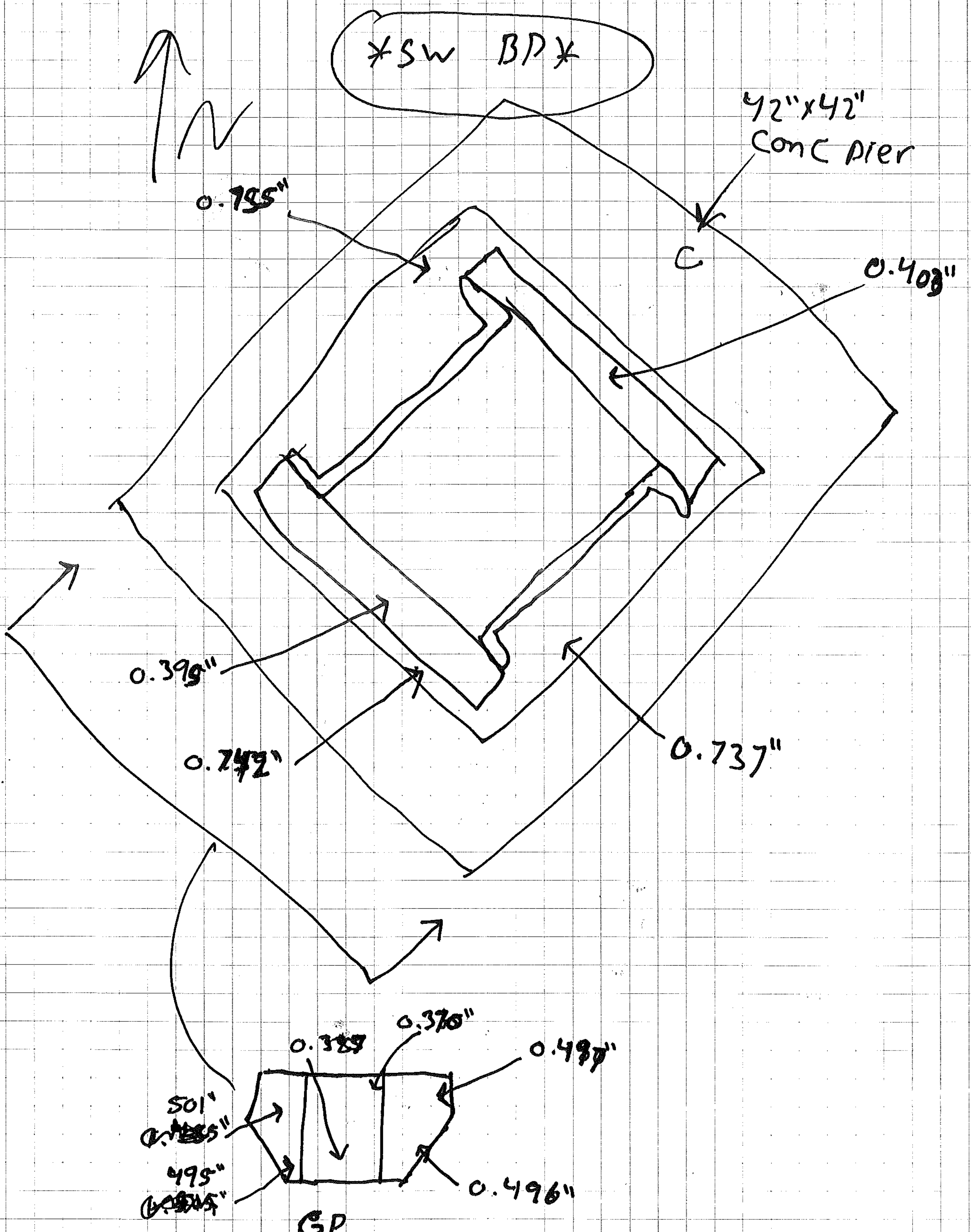
Project	BUHL WATER TOWER INSPECTION		
Description	BASEPLATE UT SCANS - SOUTHEAST		
Engineer	AMI Proj. No.	Approved	Date



AMI Consulting Engineers P.A.

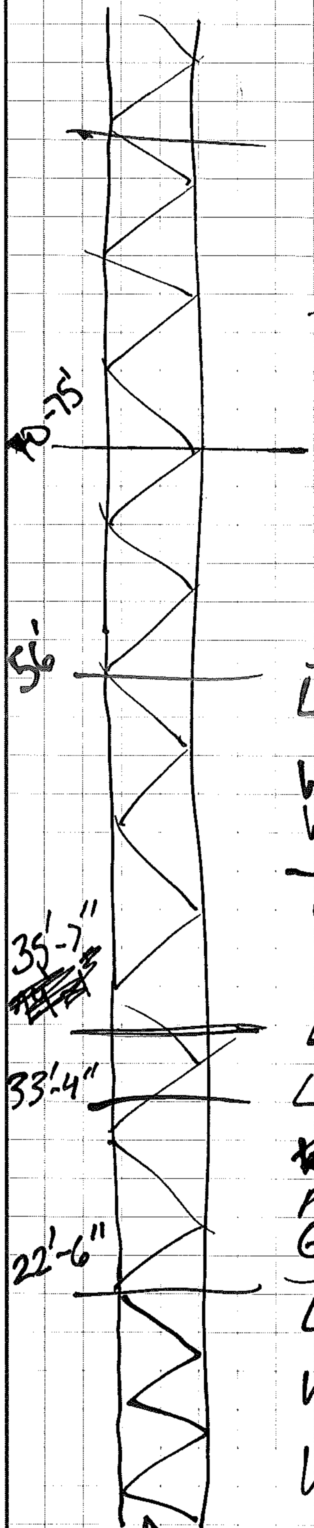
Project	BUHL WATER TOWER INSPECTION
Description	BASEPLATE UT SCANS - SOUTHWEST

Engineer	AMI Proj. No.	Approved	Date
			8/13/24



AMI Consulting Engineers P.A.

PROJECT	BUHL WATER TOWER INSPECTION		
DESCRIPTION	SW SUPPORT UT SCANS		
ENGINEER	AMI PROJ. NO.	APPROVED	DATE
			8/13/24



Lattices: 0.406, 0.412, 0.383, 0.396, 0.402, 0.395
Web L: 0.404, 0.416, 0.405
Web R: 0.417, 0.417, 0.416

Lattices: 0.401, 0.409, 0.401, 0.392, 0.407, 0.398
FRONT PL: 0.380, ~~[illegible]~~ 0.390
Web L: 0.390, 0.395, 0.403
Web R: 0.422, 0.395, 0.408
Gusset: ~~[illegible]~~, 0.512, 0.519   Splice pl: 0.399
Shear tab: 0.400,

Lattices: 0.399, 0.393, 0.399, 0.403, 0.404, 0.400
Web L: 0.406, 0.396, 0.409
Web R: 0.436, 0.431, 0.425

Web R: 0.442, 0.452, 0.458
Web L: 0.409, 0.417, 0.405
Lattices: 0.386, 0.385, 0.397, 0.403, 0.415, 0.406
Loss of coating
~~[illegible]~~   Splice pl: ~~[illegible]~~, 0.403, 0.396
Plate (conn.): 0.396, 0.389
Gussets: 0.551   Shear tab: 0.399

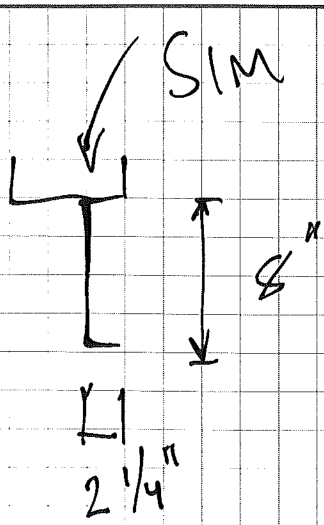
Lattices: 0.391, 0.379, 0.384, 0.393
Web L: 0.415, 0.401, 0.399
Web R: 0.399, 0.422, 0.438

*R & L are as seen from the street

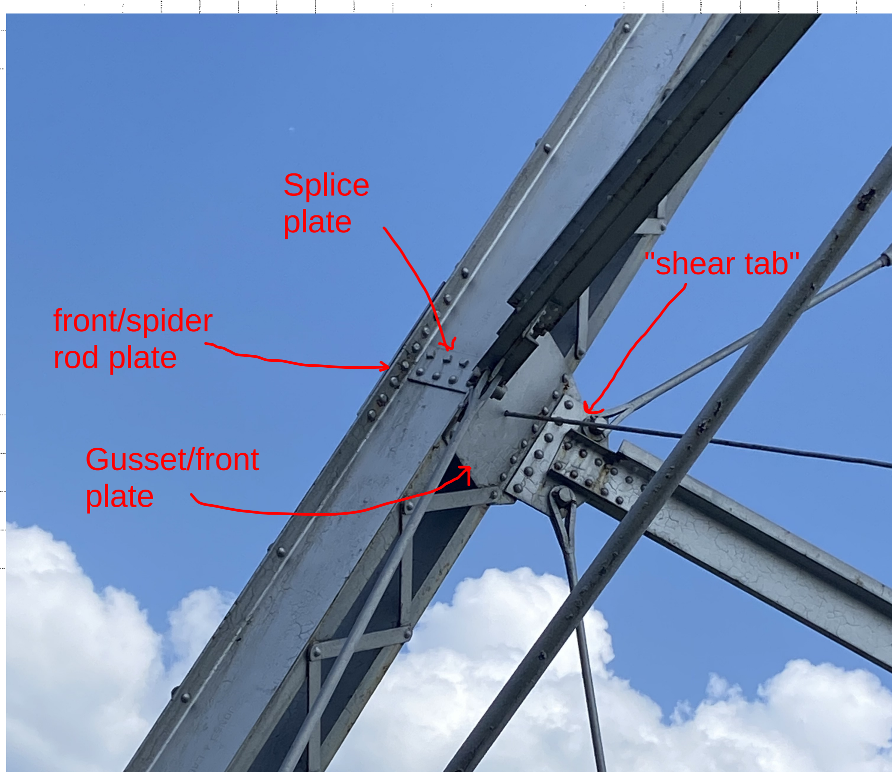
AMI Consulting Engineers P.A.

Project	BUHL WATER TOWER INSPECTION
Description	STRUT MEMBER DIMENSIONS

Engineer	AMI Proj. No.	Approved	Date
			8/13/24



0.268" Web



PROJECT	BUHL WATER TOWER INSPECTION
DESCRIPTION	UT SCANS AT TOP OF TOWER

ENGINEER	AMI PROJ. NO.	APPROVED	DATE
			8/21/24

Catwalk clip angle connections (L4x3 - LLH)

Southwest

0.380, 0.405, 0.425, 0.425, 0.404

Southeast

0.404, 0.404, 0.425, 0.416, 0.401

Northeast

0.375, 0.415, 0.430, 0.407, 0.402

Northwest

0.407, 0.402, 0.414, 0.406, 0.420

	Element - Recorded Measurements (inches)							
	Web	Laces	Gusset	Shear Tab	Base Plate	Splice Plate	Front plate	Angles
	0.398	0.391	0.583	0.399	0.797	0.403	0.396	0.380
	0.399	0.379	0.513	0.400	0.744	0.396	0.389	0.405
	0.411	0.384	0.501		0.775	0.399	0.380	0.425
	0.397	0.393	0.511		0.746		0.390	0.425
	0.427	0.386	0.499		0.781			0.404
	0.390	0.385	0.503		0.769			0.404
	0.439	0.397	0.501		0.763			0.404
	0.403	0.403	0.495		0.750			0.425
	0.408	0.415	0.496		0.751			0.416
	0.395	0.406	0.497		0.755			0.401
	0.412	0.399	0.551		0.742			0.375
	0.400	0.393	0.512		0.737			0.415
	0.413	0.399	0.519					0.430
	0.410	0.403						0.407
	0.401	0.404						0.402
	0.422	0.400						0.407
	0.409	0.401						0.402
	0.416	0.409						0.414
	0.433	0.401						0.408
	0.408	0.392						0.420
	0.420	0.407						
	0.415	0.398						
	0.401	0.406						
	0.399	0.412						
	0.399	0.383						
	0.422	0.396						
	0.438	0.402						
	0.442	0.395						
	0.452	0.386						
	0.458	0.385						
	0.409	0.385						
	0.417	0.394						
	0.405	0.391						
	0.406	0.383						
	0.396	0.390						
	0.409	0.403						
	0.436	0.379						
	0.431	0.383						
	0.425	0.382						
	0.390	0.385						
	0.395	0.394						
	0.403	0.382						
	0.422							
	0.395							
	0.408							
	0.404							
	0.416							
	0.405							
	0.417							
	0.417							
	0.410							
Avg	0.413	0.394	0.514	0.400	0.759	0.399	0.389	0.408
Minimum	0.390	0.379	0.495	0.399	0.737	0.396	0.380	0.375

		UT measured thickness		Steel loss		Percent Loss	
Element	Measured thickness (in)	Min thickness	Avg thickness	Based on Min.	Based on Avg.	Based on Min	Based on Avg.
Web	0.400	0.390	0.413	0.010	0.000	2.50	0.00
Laces	0.375	0.379	0.394	0.000	0.000	0.00	0.00
Gusset	0.500	0.495	0.514	0.005	0.000	1.0	0.00
Shear Tab	0.375	0.399	0.400	0.000	0.000	0.00	0.00
Base Pl	0.750	0.737	0.759	0.013	0.000	1.73	0.00
Splice Pl	0.375	0.396	0.399	0.000	0.000	0.00	0.00
Front pl	0.375	0.380	0.389	0.000	0.000	0.00	0.00
Angles	0.375	0.375	0.408	0.000	0.000	0.00	0.00