5-1-2008

Field Testing and Evaluation of Electroslag Welds on the Commodore Barry Bridge

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Final Report

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Prepared for:
DMJM Harris
Philadelphia, PA

ATLSS Report No. 08-04
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FIELD TESTING AND EVALUATION OF ELECTROSLAG WELDS ON THE COMMODORE BARRY BRIDGE

Final Report

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1. Introduction

The Commodore Barry Bridge is cantilever truss bridge and spans the Delaware River connecting Bridgeport, New Jersey and Chester, Pennsylvania. The bridge has a main span of 1,644 feet and side spans of 822 feet, and carries five lanes of traffic. Originally opened to traffic in 1974, the bridge is owned by the Delaware River Port Authority (DRPA).

This work is part of an inspection and evaluation of eight electroslag welds that have previously been identified as having the potential for crack growth. Lehigh University's ATLSS Center was contracted by the firm of DMJM Harris of Philadelphia, the prime consultant, to perform instrumentation and monitoring of selected truss members to measure the in-situ stresses at the selected welded connections.

2. Instrumentation Plan and Data Acquisition

The following section describes the sensors and instrumentation plan used during the controlled-load testing and long-term monitoring program. Detailed instrumentation plans can be found in Appendix A.

2.1 Strain Gages

Strain gages were placed at locations known to be fatigue sensitive and/or to provide insight into the global load distribution characteristics and general behavior of the bridge.

All strain gages installed in the field were model LWK-06-W250B-350 produced by Measurements Group Inc. These gages are uniaxial weldable resistance-type strain gages with a gage length of 0.25 inches. The gage resistance is 350 ohms and an excitation voltage of 10 volts was used.

Weldable-type strain gages were selected due to the ease of installation in a variety of weather conditions. The "welds" are point or spot resistance welds about the size of a pin prick. The probe is powered by a battery and only touches the foil that the strain gage is mounted on by the manufacturer. This fuses the foil to the steel surface. It takes forty or more of these small "welds" to attach the gage to the steel surface. There are no arc strikes or heat affected zones that are discernible. There is no preheat or any other preparation involved other than the preparation of the local metal surface by grinding and then cleaning before the gage is attached to the component with the welding unit. There has never been an instance of adverse behavior associated with the use of weldable strain gages including their installation on extremely brittle material such as A615 Gr75 steel reinforcing bars. Figure 2.1 shows a photograph of the installation of a weldable strain gage at Weld A_448.

Figure 2.1 – Installation of weldable strain gage adjacent to Weld A_448

2.2 Data Acquisition

Two Campbell Scientific CR9000 data loggers were used for the collection of data during the long-term monitoring. The CR9000 data logger is a high speed, multi-channel 16-bit data acquisition system. This data logger was configured with digital and analog filters to assure noise-free signals. Real-time data were viewed while on site by connecting the logger directly to a laptop computer. This was done to ensure that all sensors were functioning properly.

One CR9000 data logger was located at Panel Point 6 on the west side of the bridge (north truss). The other data logger was located at Panel Point 66 on the east side of the bridge (south truss). Each data logger was enclosed in a weather-tight box, as seen in Figure 2.2. Figure 2.3 contains a photograph of the inside of the box. In addition to the CR9000 data logger, there were communications equipment and a power supply inside the box.

Figure 2.2 – Weather-tight box containing data acquisition system located on the west-bound walkway at Panel Point 6

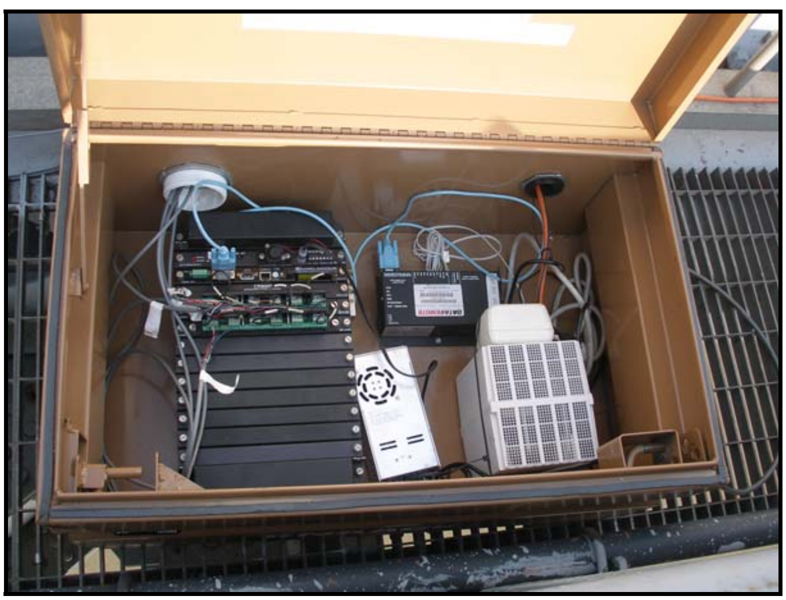


Figure 2.3 – Interior of weather-tight box containing data acquisition system

Remote communications with the data logger was established using a wireless modem. Data download was performed nightly via a server located in the ATLSS laboratory in Bethlehem, PA. This link was also used to upload new programs as needed.

2.3 Instrumented Members

Field-measured stresses were measured at the following eight welds:

1. 244
2. 273
3. 291
4. 302

Pennsylvania back span

5. 44
6. 418
7. 444
8. 448

New Jersey back span

Shown in Figure 2.4 is a view of the Pennsylvania back span of the bridge indicating the instrumented truss members. Note that all four of the truss members are on the upstream truss.

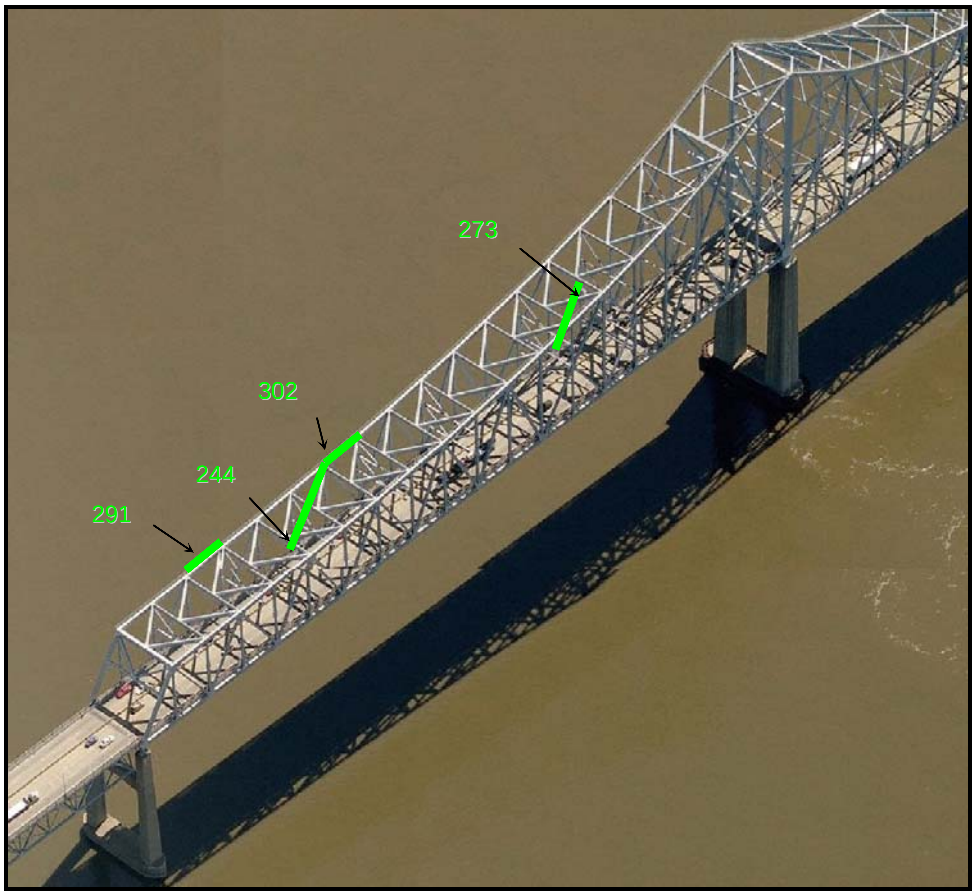


Figure 2.4 – View of Pennsylvania back span looking upstream showing instrumented truss members *(green = upstream; yellow = downstream)*

Figure 2.5 shows a photograph of the New Jersey back span of the truss. Three of the instrumented truss members are on the down stream truss (418, 444, and 448). The fourth instrumented truss member is on the upstream truss (44).

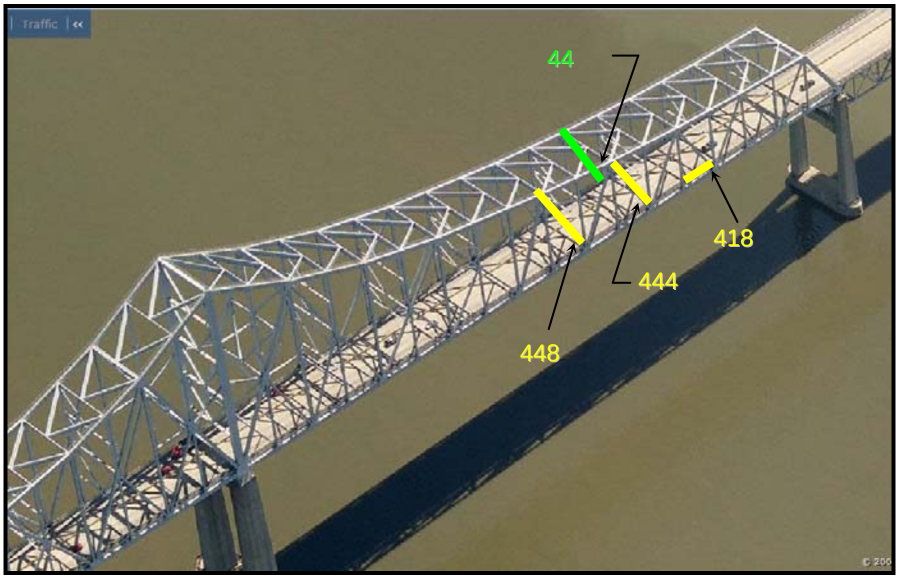


Figure 2.5 – View of New Jersey back span looking upstream showing instrumented truss members *(green = upstream; yellow = downstream)*

At each location, two strain gages were installed on the thinner of the two joined plates. Each gage was oriented longitudinally with respect to the truss member, and located 1 inch from the side of the plate, and 1 inch from the edge of the weld (see Appendix A for further detail).

3. Test Program – Summary

In order to measure the in-situ live load stresses in the truss members of interest, a long-term monitoring program was implemented. There were two periods of monitoring.

3.1 Phase 1 Monitoring

Phase 1 monitoring commenced on October 17, 2007 and ran until November 28, 2007. During this period, stress time-history data were not collected continuously. Data were only recorded when the measured stress at selected gages exceeded predefined triggers. The trigger gage and trigger value are selected solely to reduce the amount of time-history data recorded during the monitoring period. These data can be used to validate the highest stress cycles recorded in the stress range histogram (which is recorded constantly over the monitoring period). Once the strain value for the "trigger" gage reached the predefined limit, the logger began recording data for a predefined period of time. It should be noted that the trigger value of stress is not meant to be correlated to a stress caused by a particular vehicle. The value is selected so an appropriate quantity of data is recorded. Data were sampled at a rate of 50 Hz.

Simultaneously, stress-range histograms were developed continuously at each location monitored using the rainflow cycle-counting method. For each strain gage, this method considers 10 minutes of time-history data at a time and pairs up peaks in the response in this 10 minute segment to determine a tally of stress range cycles (number and magnitude). Every 10 minutes, the "tally" is updated, while the time-history data used to develop the tally is discarded. This process continued for the duration of the long-term monitoring period. Using these histograms, estimates of the effective stress-range and number of cycles can be made. Utilizing these results and knowing the detail category at the sensor location, and making the assumption that the stresses measured during the monitoring period are representative of the life of the bridge, an estimate of the remaining fatigue life can be made. A complete description of this procedure including a description of the rainflow cycle-counting algorithm is presented in Appendix B.

Unfortunately, there was a large amount of spurious signals (i.e., noise) in the data which corrupted the data. These spurious signals are believed to be the result of electromagnetic interference. Though manual review of the data is still possible, the noise precluded the use of algorithms used to reduce and analyze the data. For this reason, a second phase of monitoring was performed.

3.2 Phase 2 Monitoring

Phase 2 monitoring began on November 28, 2007 and ran until December 7, 2007, at which point the equipment was removed from the bridge. During this period, data were collected from all sensors continuously at a rate of 10 Hz. A reduced sampling rate was used since the response of the bridge was observed to be significantly slower than initially assumed. The rainflow cycle counting was carried out after the data had been collected using a PC running MATLAB. Digital signal processing techniques were used to remove spurious signals from the data that were observed in the first period of monitoring. The reliability of the Phase 2 data set is believed to be improved over the Phase 1 data. Therefore, this data has been used to construct the stress-range histograms presented in this report. All further references to field measured data in this report refers to data collected during Phase 2.

4. Results of Long-term Monitoring

This section of the report presents the results of the long-term monitoring phase of this project.

4.1 Pennsylvania Back Span

Eight strain gages (four welds) were installed on Pennsylvania back span members. The measured stress range histograms are presented in Table 4.1. The maximum recorded stress ranges, S_{Rmax}, are shown at the bottom of the table. The histogram shown is presented with all cycles (not truncated).

Stress Range (ksi)		Number of Cycles							
Min	Max	A_244	B_244	A_273	B_273	A_291	B_291	A_302	B_302
0.00	0.25	354,175	357,572	495,999	504,554	405,940	419,762	466,277	491,246
0.25	0.50	10,862	11,380	7,173	7,239	7,129	6,842	3,664	4,895
0.50	0.75	3,789	3,412	2,720	2,733	3,008	2,793	1,717	2,111
0.75	1.00	1,866	2,091	604	637	1,587	1,325	871	1,066
1.00	1.25	1,163	861	153	131	606	426	350	472
1.25	1.50	193	133	38	32	205	122	130	207
1.50	1.75	36	31	4	7	63	37	52	67
1.75	2.00	6	7	3	6	41	16	19	44
2.00	2.25	1	2	1	1	20	7	7	13
2.25	2.50	0	0	0	0	8	1	8	12
2.50	2.75	0	0	0	0	1	0	1	1
2.75	3.00	0	0	0	0	0	0	0	1
3.00	3.25	0	0	0	0	0	0	0	0
3.25	3.50	0	0	0	0	0	0	0	0
3.50	3.75	0	0	0	0	0	0	0	0
3.75	4.00	0	0	0	0	0	0	0	0
4.00	4.25	0	0	0	0	0	0	0	0
4.25	4.50	0	0	0	0	0	0	0	0
4.50	4.75	0	0	0	0	0	0	0	0
4.75	5.00	0	0	0	0	0	0	0	0
	S_{Rmax} (ksi) =	2.25	2.25	2.25	2.25	2.75	2.50	2.75	3.00

Table 4.1 – Stress-range histogram for Pennsylvania back span members

4.2 New Jersey Back Span

Eight strain gages (four welds) were installed on New Jersey back span members. The measured stress range histograms are presented in Table 4.2. The maximum recorded stress ranges, S_{Rmax}, are shown at the bottom of the table. The histogram shown is presented with all cycles (not truncated). Note that the data from strain gages A_448 and B_448 are not included in this table due to excessive noise in the data. A manual review of the available data indicates that the stress ranges are low and on the order of the other strain gaged members.

Stress Range (ksi)		Number of Cycles					
Min	Max	A_44	B_44	A_418	B_418	A_444	B_444
0.00	0.25	357,844	364,660	488,200	493,156	355,623	369,753
0.25	0.50	10,827	10,222	7,447	3,704	11,557	10,101
0.50	0.75	4,241	3,230	2,202	406	3,748	2,735
0.75	1.00	1,694	2,015	519	53	1,928	1,232
1.00	1.25	1,741	958	85	19	1,136	186
1.25	1.50	535	143	6	1	213	51
1.50	1.75	111	26	2	0	54	27
1.75	2.00	35	8	0	0	13	9
2.00	2.25	1	1	0	0	15	8
2.25	2.50	1	0	0	0	6	1
2.50	2.75	0	0	0	0	2	0
2.75	3.00	0	0	0	0	2	0
3.00	3.25	0	0	0	0	1	0
3.25	3.50	0	0	0	0	1	0
3.50	3.75	0	0	0	0	0	0
3.75	4.00	0	0	0	0	0	0
4.00	4.25	0	0	0	0	0	0
4.25	4.50	0	0	0	0	0	0
4.50	4.75	0	0	0	0	0	0
4.75	5.00	0	0	0	0	0	0
	S_{Rmax} (ksi) =	2.50	2.25	1.75	1.50	3.50	2.50

Table 4.2 – Stress-range histogram for New Jersey back span members

5. Ultrasonic Testing Results

This section of the report presents a review of the current and past ultrasonic testing (UT) on the eight electroslag welds under investigation. Since the original Weidlinger investigation in 1988 [1], three UT inspections have been performed on the eight electroslag welds identified by Weidlinger.

The first UT inspection was performed by WTTI in 1999 [2] under the direction of Drexel University. The second inspection was performed by Pennoni Associates in 2006 [3]. Finally, in conjunction with the field testing discussed in this report, a third UT inspection was performed by Bureau Veritas North America in 2007 [4]. The inspection reports for each of these three inspections are included in Appendix C.

A summary of the three inspections is presented in Table 5.1. For each inspection, all defects found are listed along with the dB indication rating and flaw length. It can be seen that there is significant discrepancy between the 1999 inspection and the subsequent inspections. However, there is good agreement between the 2006 and 2007 inspections.

The results from the latest UT inspection are used for the subsequent fracture mechanics analysis presented in Section 6. In the 1988 Weidlinger study, a calibration between flaw size and dB indication rating was made by physically measuring flaws in core samples removed from the bridge. The calibration is presented in graphical form in Figure 5.1.

It can be seen that some welds have multiple flaws. For the purposes of the fracture mechanics analysis, the most severe flaw in each weld is considered. These flaw sizes are presented in Table 5.2.

Weld No.	Flaw No.	1999 (WTTI)		2006 (Pennoni)		2007 (BV)	
		dB rating	length (in)	dB rating	length (in)	dB rating	length (in)
44	1	6	0.25	9	0.25	10	1
	2	8	0.25	2	0.5	10	0.75
	3	8	0.25			10	0.25
	4	10	0.25				
244	1	9	2	4	1.25	5	1.25
	2	9	5	4	0.5	5	0.5
	3	3	3.5				
273	1	6	6.5	10	1.25	10	1.12
	2	10	0.75				
	3	10	0.75				
	4	8	4.25				
444	1	3	0.125	15	0.125	15	0.125
	2	6	0.125				
	3	10	0.125				
448	1	6	0.25	14	0.125	14	0.125
	2	6	0.25				
	3	6	0.25				
	4	10	0.125				
291	1	10	0.125	none		none	
	2	10	0.125				
	3	10	0.125				
	4	10	0.125				
	5	4	0.125				
	6	10	0.125				
	7	6	0.125				
	8	4	1				
	9	4	0.125				
	10	10	0.25				
302	1	6	2.5	13	3	13	3
	2	6	10	11	8	11	8
418	1	3	0.25	11	0.5	11	5
	2	0	0.25	7	0.5	7	5

Table 5.1 – Summary of UT results for the eight welds under investigation, red shading denotes rejectable flaw, green denotes acceptable flaw

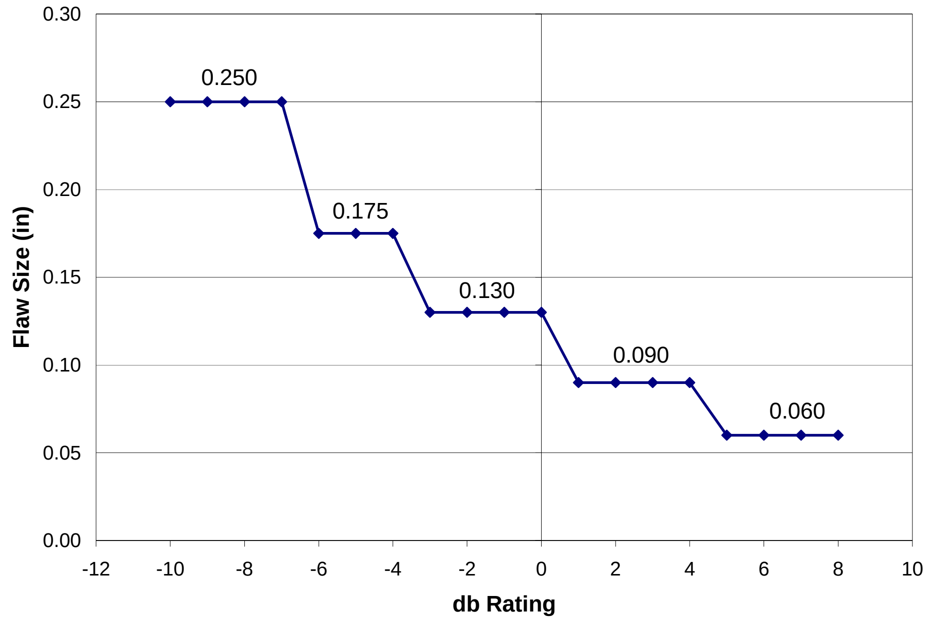


Figure 5.1 – Calibration curve relating dB indication rating to flaw size (from Figure C-3 of Weidlinger report [1])

Weld No.	Length (in)	Depth (in)
44	1	0.06
244	1.25	0.06
273	1.12	0.06
444	0.125	0.06
448	0.125	0.06
291	-	-
302	8	0.06
418	5	0.06

Table 5.2 – Assumed worst-case flaws considered for fracture mechanics analysis

6. Fracture Mechanics Evaluation

The full penetration welded detail with thickness transition is considered a fatigue Category B per AASHTO, with a CAFL of 16 ksi. However, AASHTO requires that the weld soundness be established by NDT. Per the latest UT inspection, only one of these welds (number 244) has rejectable flaws and therefore cannot be considered Category B.

The peak stress range observed at any strain gage was 3.5 ksi, significantly less than this CAFL. Therefore, for all welds other than 244, fatigue cracking is not expected per the AASTHO requirements.

To evaluate Weld 244, a fracture mechanics approach is used. Using the measured stress range histograms and the estimated flaw size based on the results of the UT inspection, the potential for fatigue crack growth is evaluated. Though only Weld 244 has rejectable flaw, other welds have acceptable flaws. The fracture mechanics approach is used to evaluate these welds as well.

The range of stress intensity at the crack tip is calculated using standard fracture mechanics equation [5]:

$$\Delta K = F_s F_w F_e F_g S_R \sqrt{\pi a} \qquad \text{(Eqn. 6.1)}$$

Where:

- F_s = free surface correction factor
- F_w = back free surface correction factor
- F_e = crack shape correction factor
- F_g = non-uniform stress correction factor
- S_R = stress range (ksi)
- a = crack size (in)
- ΔK = applied range of stress intensity at the crack tip (ksi√in)

Fatigue crack growth can be expected if the applied range of stress intensity, ΔK, exceeds the fatigue threshold intensity, known as ΔK_{th}. A conservative lower bound for the steel used on this bridge of 2.75 ksi√in is considered. For each weld tested, an estimate of ΔK will be made and compared to ΔK_{th}.

No surface cracks were found in any of the welds under investigation. Therefore, the flaws are embedded within the weld. It has been conservatively assumed that the flaw are located within a plane perpendicular to the applied stress. The lengths and depths of the flaws were estimated using the results from the UT inspection and a calibration between UT dB reading and flaw size performed in the 1988 Weidlinger report.

An embedded elliptical crack model is considered for this evaluation. The cracks have been idealized as shown in Figure 6.1. Note that the plate thickness is equal to 2w. The dimension "b" is taken from the 2007 UT inspection report (noted as flaw length on the report). The dimension "a" is determined by the calibration chart provided in the 1988 Weidlinger report, which plots UT dB indication on the horizontal axis and flaw size in inches on the vertical axis. This relation was determined from core samples taken from welds that were evaluated with UT in the field. The size of the flaws were obtained by examining the cores. For simplicity, the flaws have been assumed to exist at mid-thickness.

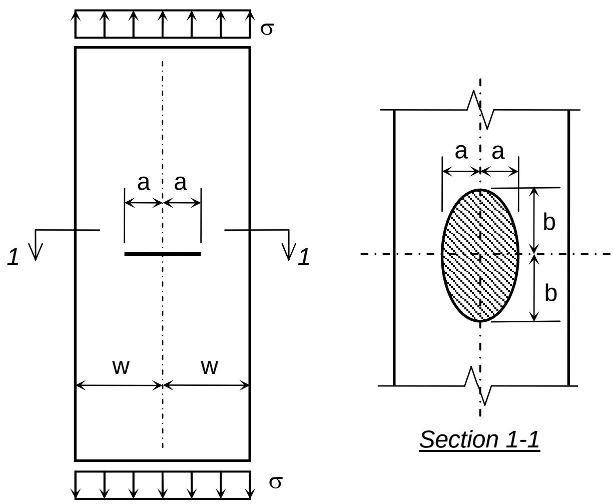


Figure 6.1 – Illustration of fracture mechanics model used to evaluate weld flaws (embedded elliptical crack)

Based on the model shown above, the correction factors can be calculated as follows:

$F_s = 1.0$ (free surface correction factor)

$F_g = 1.0$ (non-uniform stress correction factor)

$$F_w = \sqrt{\sec\left(\frac{\pi a}{2w}\right)} \quad \text{(back free surface correction factor)} \qquad \text{(Eqn. 6.2)}$$

$$F_e = \frac{1}{E(k)} \quad \text{(crack shape correction factor)} \qquad \text{(Eqn. 6.3)}$$

E(k) is equal to the complete elliptic integral of the second kind. It should be noted that the equation for F_e is given for the end of the minor axis of the ellipse, yielding the maximum value of ΔK. It is given by:

$$E(k) = \int_0^{\pi/2} \sqrt{1 - k^2 \sin^2 \varphi}\, d\varphi \qquad \text{(Eqn. 6.4)}$$

or expressed as a power series:

$$E(k) = \frac{\pi}{2} \sum_{n=0}^{\infty} \left[\frac{(2n)!}{2^{2n} n!^2} \right]^2 \frac{k^{2n}}{1 - 2n} \qquad \text{(Eqn. 6.5)}$$

where,

$$k = 1 - \left(\frac{a}{b} \right)^2 \qquad \text{(Eqn. 6.6)}$$

The above equations were used to calculate the applied ΔK at each weld. The results are summarized in Table 6.1 below. As a very conservative assumption, all cycles were assumed to be equal to the maximum measured stress range (i.e., all measured cycles at the maximum value),

Weld No.	t = 2w (in)	a (in)	b (in)	$S_{R,max}$ (ksi)	k	F_e	F_w	ΔK (ksi√in)
44	1.125	0.03	0.5	2.50	0.996	0.987	1.002	0.76
244	1.125	0.03	0.625	2.25	0.998	0.991	1.002	0.69
273	1.625	0.03	0.56	2.25	0.997	0.989	1.001	0.68
444	1.125	0.03	0.0625	3.50	0.770	0.768	1.002	0.83
448	1.5	0.03	0.0625	3.50	0.770	0.768	1.001	0.83
291	1.25	*No discernible flaws from UT evaluation*						
302	1.375	0.03	4	2.75	1.000	0.997	1.001	0.84
418	1.5	0.03	2.5	1.75	1.000	0.997	1.001	0.54

Table 6.1 – Summary of calculated ΔK values for each weld.
($S_{R,max}$ for Weld 448 set equal to maximum observed stress range from other welds)

As noted in the table, the applied stress intensities, ΔK, calculated assuming all cycles have a magnitude equal to the maximum measured stress range are significantly less than the threshold stress intensity, ΔK_{th} of 2.75 ksi√in. In fact, the maximum ΔK is equal to 0.84 ksi√in, or 30% of the threshold. At Weld 244 (the only weld with rejectable discontinuities), ΔK is equal to 0.69 ksi√in (25% of the threshold). As a result, fatigue crack growth is not expected at any of the eight welds.

7. Findings

The measured stress ranges at all strain gaged locations are low. The full penetration welded detail with thickness transition is considered a fatigue Category B per AASHTO, with a CAFL of 16 ksi. However, AASHTO requires that the weld soundness be established by NDT. Only one of these welds (Weld 244) has rejectable flaws and therefore cannot be considered Category B.

The peak stress range observed at any strain gage was 3.5 ksi, significantly less than this CAFL. Therefore, for all welds other than 244, fatigue cracking is not expected per the AASTHO requirements.

The effect on the fatigue performance of the weldments in question as a result of the presence of flaws has been evaluated using a fracture mechanics approach. This analysis has shown that in all cases, the applied stress range intensity (ΔK) is significantly less than the threshold (ΔK_{th}). In the worst case, ($\Delta K / \Delta K_{th}$) was 30%. At Weld 244 (the only weld with rejectable discontinuites) ($\Delta K / \Delta K_{th}$) was 25%.

Therefore, fatigue crack growth is not expected at any of the eight weldments under the current traffic loading conditions. Future field evaluations should be performed to evaluate the effect of a potential increase in traffic load.

8. Recommendations

Based on the results and findings presented above, the following recommendations are made:

1. Each of the eight critical welds identified above should be UT tested during the next biannual cycle of inspection in 2008 or the following cycle in 2010.

2. If there is no significant change in the UT results, further UT testing need not be repeated in the future, except as noted in recommendation number 3 below. A decrease in a dB reading of more than 4 dB or a dB reading of less than +5dB should be considered a significant change.

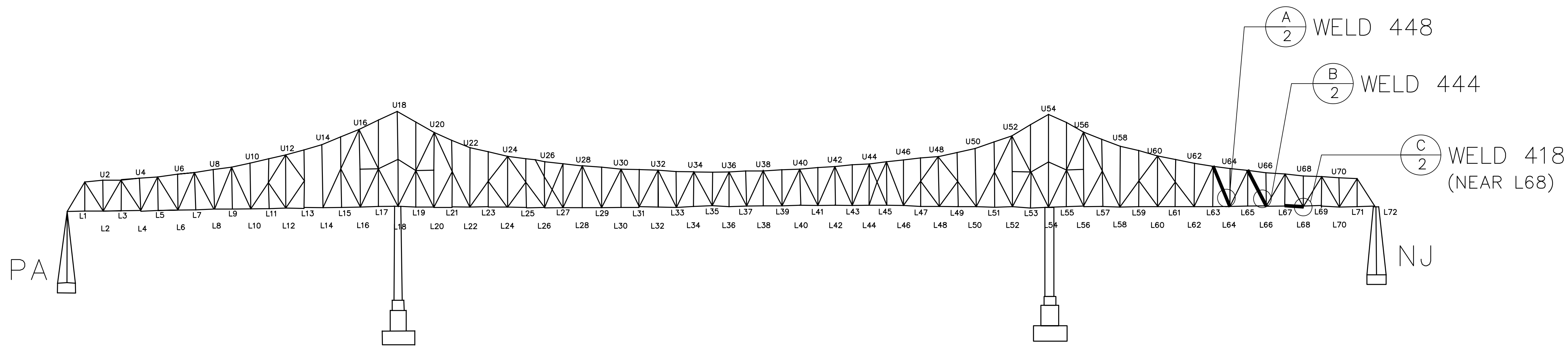
3. Field monitoring of stresses and UT testing of each of the eight critical welds should be repeated when the ADTT increases by more than 50% from its current value (4,000), when the posted or maximum legal load for the bridge is increased, or in 20 years, whichever occurs first.

9. References

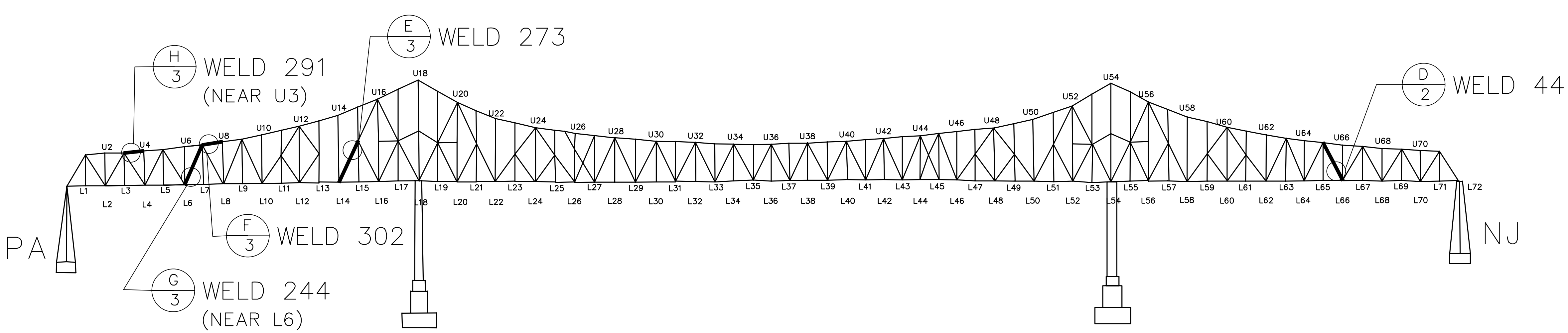
1. Weidlinger Associates, "Commodore Barry Bridge, Electroslag Welds Investigation, Final Report," May 1988.
2. Welder Training and Testing Institute, Inc., "Report of Ultrasonic Testing of Welds, Commodore Barry Bridge," August 1999.
3. Pennoni Associates, Inc., "Ultrasonic Examination Report, Commodore Barry Bridge," September 2006.
4. Bureau Veritas North America, Inc., "Ultrasonic Inspection Report of Structural Steel, Commodore Barry Bridge," October 2007.
5. Zettlemoyer, N. and Fisher, John W., "Stress Gradient and Crack Shape Effects on Stress Intensity at Welded Details," Welding Research Supplement, August 1978.

APPENDIX A

Instrumentation Plans



SOUTH TRUSS



NORTH TRUSS

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PROJECT:

COMMODORE BARRY BRIDGE

SHEET NOTES:

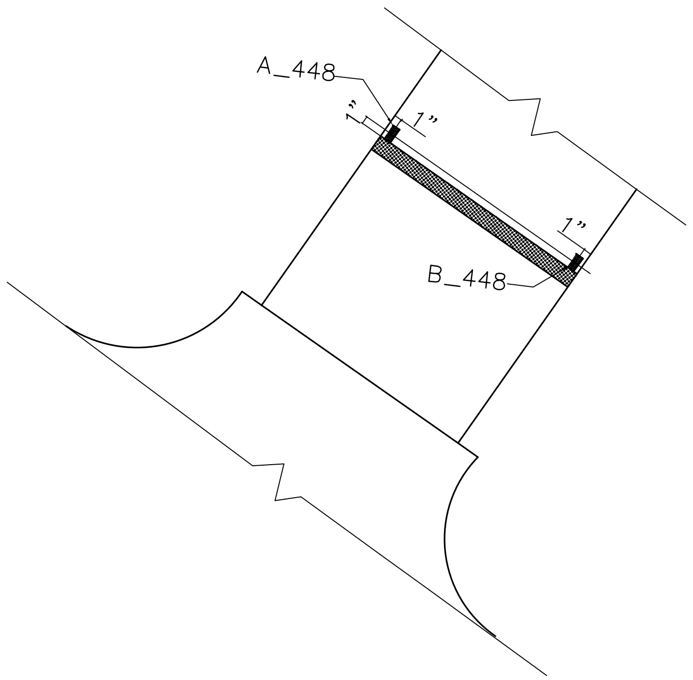
NO.	DESCRIPTION	DATE	BY
2	REPORT	1/10/08	ICH
1	INITIAL SUBMITTAL	10/19/07	ICH

DESIGNED BY:	ICH/BTY
DRAWN BY:	CB
CHECKED BY:	ICH
SCALE:	NTS
DATE:	10/19/07
PROJECT NO.:	
SHEET TITLE:	

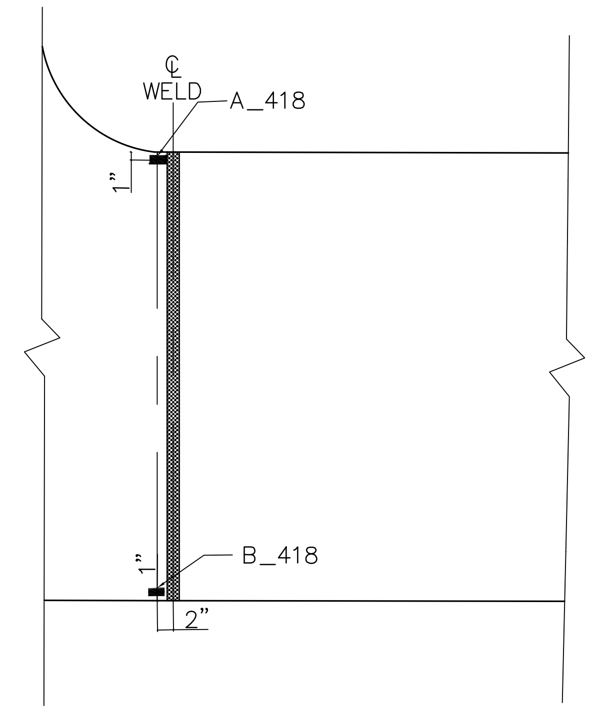
TRUSS ELEVATIONS

SHEET NO.:

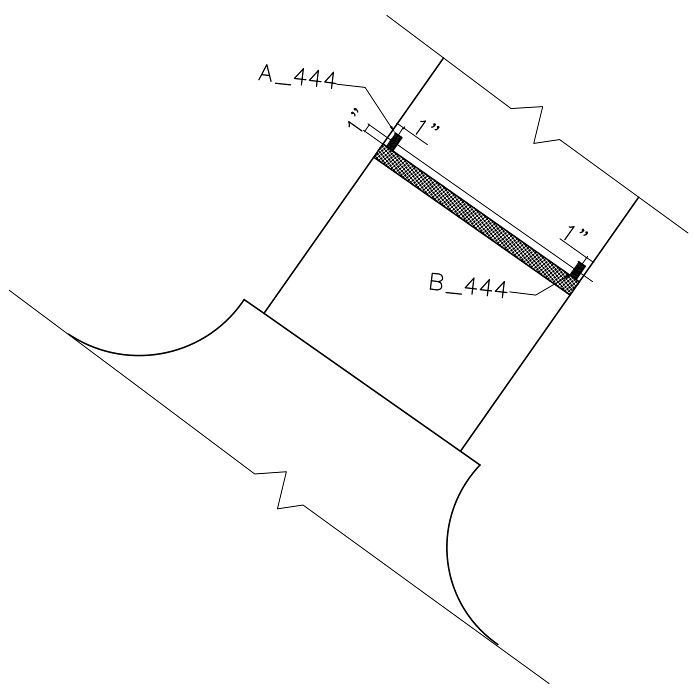
1 OF 3



A / 1 WELD 448
(INBOARD)



C / 1 WELD 418
(INBOARD)



B / 1 WELD 444
(INBOARD)

D / 1 WELD 44
(INBOARD)

ATLSS
ADVANCED TECHNOLOGY FOR
LARGE STRUCTURAL SYSTEMS
117 ATLSS Drive
Lehigh University
Bethlehem, PA 18015
610-758-3535 FAX 610-758-6842

PROJECT:

COMMODORE BARRY BRIDGE

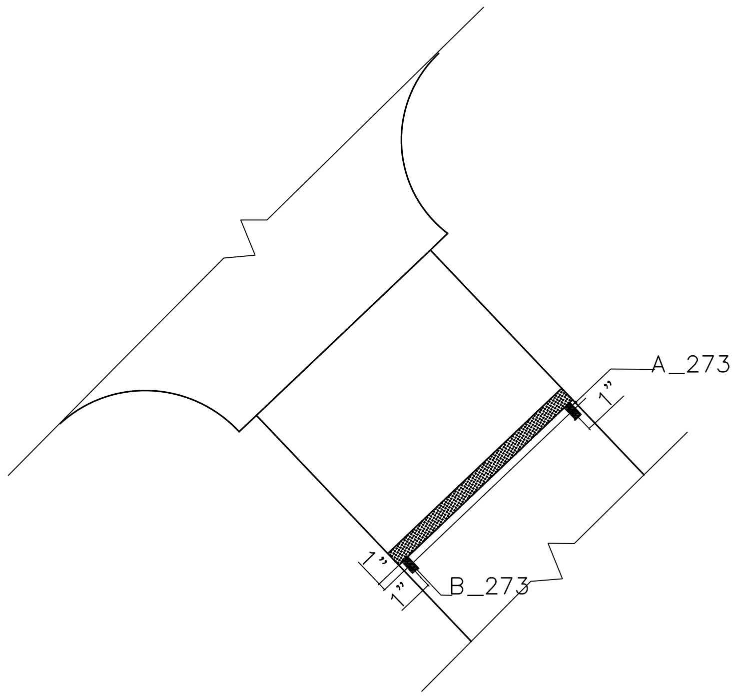
SHEET NOTES:

NO.	DESCRIPTION	DATE	BY
2	REPORT	1/10/08	ICH
1	INITIAL SUBMITTAL	10/19/07	ICH

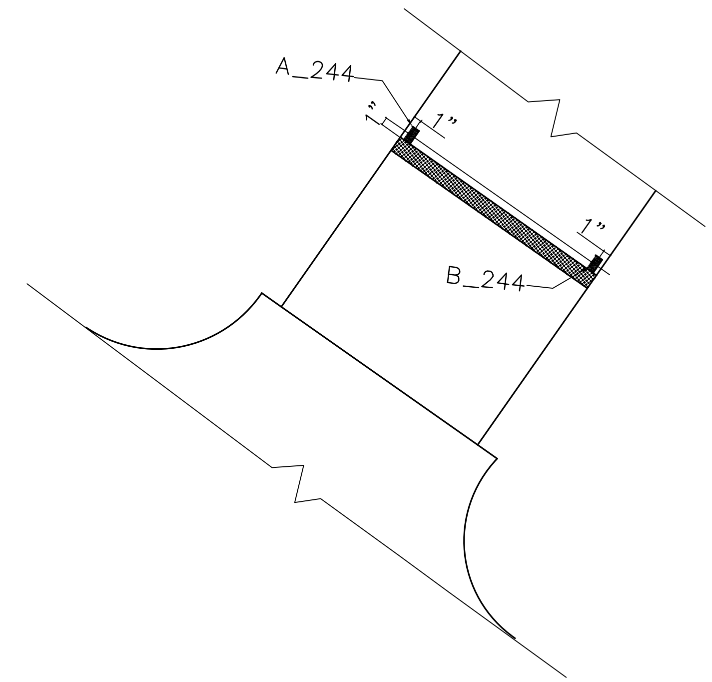
DESIGNED BY:	ICH/BTY
DRAWN BY:	CB
CHECKED BY:	ICH
SCALE:	NTS
DATE:	10/19/07
PROJECT NO.:	
SHEET TITLE:	

WELD DETAILS

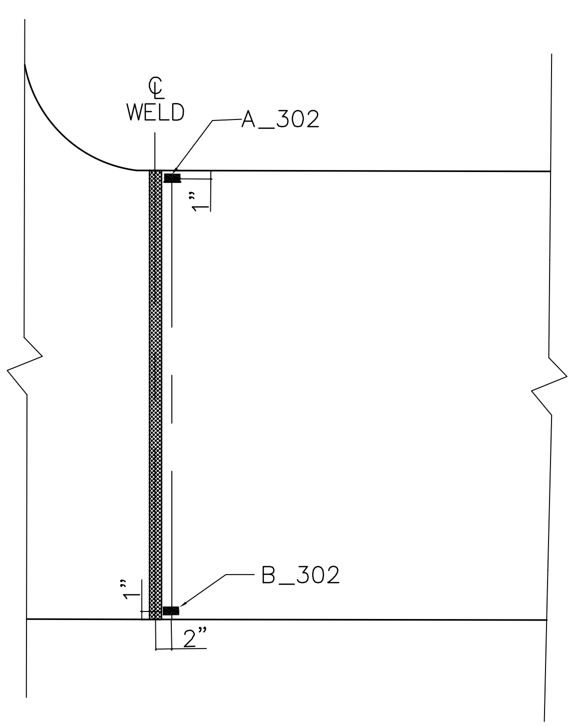
SHEET NO.:



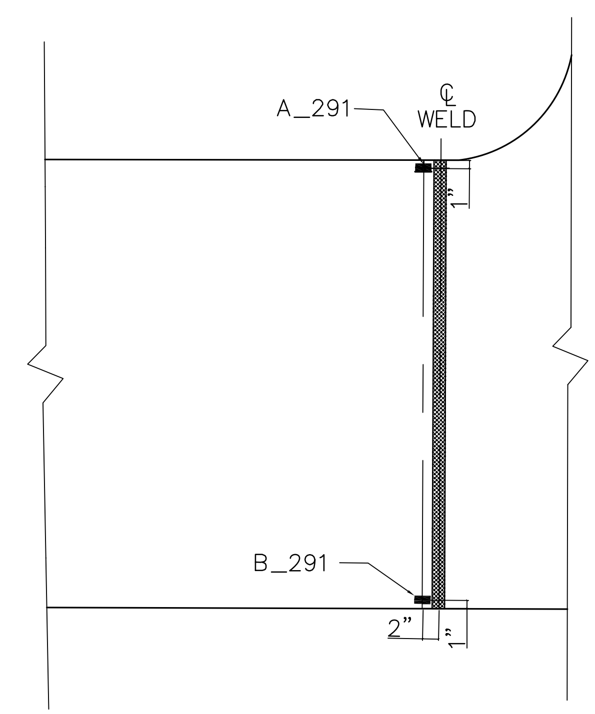
E
1
WELD 273
(OUTBOARD)



G
1
WELD 244
(INBOARD)



F
1
WELD 302
(INBOARD)



H
1
WELD 291
(OUTBOARD)

ATLSS
ADVANCED TECHNOLOGY FOR
LARGE STRUCTURAL SYSTEMS
117 ATLSS Drive
Lehigh University
Bethlehem, PA 18015
610-758-3535 FAX 610-758-6842

PROJECT:

COMMODORE BARRY BRIDGE

SHEET NOTES:

NO.	DESCRIPTION	DATE	BY
2	REPORT	1/10/08	ICH
1	INITIAL SUBMITTAL	10/19/07	ICH

DESIGNED BY:	ICH/BTY
DRAWN BY:	CB
CHECKED BY:	ICH
SCALE:	NTS
DATE:	10/19/07
PROJECT NO.:	
SHEET TITLE:	

WELD DETAILS

SHEET NO.:

3 OF 3

APPENDIX B

Development of Stress-range Histograms used to Calculate Fatigue Life

B.1 Stress-Range Histograms

Stress-range histogram data were developed from the continuous time-history data collected during Phase 2 of the long-term monitoring. This histograms represent the random variable-amplitude stress-range spectrum for the selected strain gages. It has been shown that a variable-amplitude stress-range spectrum can be represented by an equivalent constant-amplitude stress range equal to the cube root of the mean cube (rmc) of all stress ranges (i.e., Miner's rule) [1] (i.e., $S_{reff} = [\Sigma\alpha_i S_{ri}{}^3]^{1/3}$).

During the long-term monitoring program, stress-range histograms were developed using the rainflow cycle counting method [2]. Although several other methods have been developed to convert a random-amplitude stress-range response into a stress-range histogram, the rainflow cycle counting method is widely used and accepted for use in most structures.

The rainflow cycle counting method considers a fixed period (10 minutes was used for this project) of time-history data (i.e., stress versus time). First, the tensile and compressive peaks are determined. Then the peaks are paired up to determine the number and magnitude of stress range cycles which are totaled to form a stress-range histogram for that particular period of time. This process is repeated for the next segment of time. The histograms are summed in order to develop a cumulative stress-range histogram. It should be noted that since the peaks are paired up within a block of time (e.g., 10 min.), one stress cycle may not necessarily be the result of one vehicle. For instance if one truck causes tensile stress in a detail while crossing in the eastbound lanes, and a similar truck causes compressive stress at the same detail while crossing in the westbound lanes (both crossings occur within the same 10 minute block of time), the stress range would be the peak-to-peak stress caused by the two trucks (assuming no other vehicles cross the bridge in this time period).

References:

1. Miner, M.A., “Cumulative Damage in Fatigue,” Journal of Applied Mechanics, Vol. 1, No.1, Sept., 1945.
2. Downing S.D., Socie D.F., “Simple Rainflow Counting Algorithms,” International Journal of Fatigue, January 1982.

APPENDIX C

UT Inspection Reports

Bureau Veritas, 2007 (8 pages)
Pennoni Associates, 2006 (8 pages)
WTTI, 1999 (8 pages)

INSPECTION SUPPORT SERVICES Inc.

PO Box 237
Gibbsboro, NJ 08026
Phone (856) 816-5270
Fax (856) 784-7473

Ultrasonic Inspection Report of Structural Steel (AWS Form)

USEL @ Commodore Barry Bridge for the DRPA (Survey of existing flaws in electroslag welds.)

Date:	10/4/2007
Project No.:	82624
Weld Identification:	44
Material Thickness:	1-1/8"
Weld Joint AWS:	Square Butt
Welding Process:	ESW (Electroslag)
Quality Requirements-Section No.:	AWS D1.5 – Sect.6 table 6.3
Remarks:	

Line Number	Indication Number	Transducer Angle	From Face	Leg	Decibels: Indication Level a	Decibels: Reference Level b	Decibels: Attenuation Factor c	Decibels: Indicating Rating d	Discontinuity: Length	Discontinuity: Angular distance (sound Path)	Discontinuity: Depth From "A" Surface	Discontinuity: Distance From X	Discontinuity: Distance From Y	Discontinuity Evaluation	Remarks
1	1	70	A	I	84	70	4	+10	1.0"	3.2"	1.0"	-.875"	8.00"	Acc	
2	2	70	A	I	84	70	4	+10	.75"	3.2"	1.0"	.00"	8.5"	Acc	
3	3	70	A	I	84	70	4	+10	.25"	3.2"	1.0"	-.75"	27.25"	Acc	
4															
5															
6															
7															
8															
9															
10															
11															
12															
13															
14															
15															

We the undersigned, certify that the statements in this report are correct and the welds are prepared and tested in conformance with the requirements of Section 6, Part F of AWS D1.5/D1.5M (2006) Bridge Welding Code-Steel.
(year)

INSPECTION SERVICES SUPPORT Inc.
PO Box 237
Gibbsboro, NJ 08026
Phone (856) 816-5270
Fax (856) 784-7473

Ultrasonic Inspection Report of Structural Steel (AWS Form)

USEL @ Commodore Barry Bridge for the DRPA (Survey of existing flaws in electroslag welds.)

Date:	10/4/2007
Project No.:	82624
Weld Identification:	244
Material Thickness:	1-1/8"
Weld Joint AWS:	Square Butt
Welding Process:	ESW (Electroslag)
Quality Requirements-Section No.:	AWS D1.5 – Sect.6 table 6.3
Remarks:	

					Decibels				Discontinuity						
Line Number	Indication Number	Transducer Angle	From Face	Leg	Indication Level	Reference Level	Attenuation Factor	Indicating Rating	Length	Angular distance (sound Path)	Depth From "A" Surface	Distance		Discontinuity Evaluation	Remarks
					a	b	c	d				From X	From Y		
1	1	70	A	I	77	70	2	+5	1.25"	2"	.71"	-.5"	6.25"	Rej	
2	2	70	A	I	76	70	1	+5	.5"	1.3"	.45"	+.5"	7.25"	Rej	
3															
4															
5															
6															
7															
8															
9															
10															
11															
12															
13															
14															
15															

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(year)

INSPECTION SUPPORT SERVICES Inc.
PO Box 237
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Phone (856) 816-5270
Fax (856) 784-7473

ISS, Inc. QCP# 301 Revision No. 1
Dated: 11/19/2002

Ultrasonic Inspection Report of Structural Steel (AWS Form)

USEL @ Commodore Barry Bridge for the DRPA (Survey of existing flaws in electroslag welds.)

Date:	10/17/2007
Project No.:	82624
Weld Identification:	273
Material Thickness:	1.5"
Weld Joint AWS:	Square Butt
Welding Process:	ESW (Electroslag)
Quality Requirements-Section No.:	AWS D1.5 – Sect.6 table 6.3
Remarks:	

					Decibels				Discontinuity						
Line Number	Indication Number	Transducer Angle	From Face	Leg	Indication Level a	Reference Level b	Attenuation Factor c	Indicating Rating d	Length	Angular distance (sound Path)	Depth From "A" Surface	Distance From X	Distance From Y	Discontinuity Evaluation	Remarks
1	1	70	A	I	82	70	2	+10	1.12"	1.95"	.67"	0"	4"	Acc	
2															
3															
4															
5															
6															
7															
8															
9															
10															
11															
12															
13															
14															
15															

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(year)

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Ultrasonic Inspection Report of Structural Steel (AWS Form)

USEL @ Commodore Barry Bridge for the DRPA (Survey of existing flaws in electroslag welds.)

Date:	10/17/2007
Project No.:	82624
Weld Identification:	291
Material Thickness:	1.25"
Weld Joint AWS:	Square Butt
Welding Process:	ESW (Electroslag)
Quality Requirements-Section No.:	AWS D1.5 – Sect.6 table 6.3
Remarks:	

Line Number	Indication Number	Transducer Angle	From Face	Leg	Decibels: Indication Level a	Decibels: Reference Level b	Decibels: Attenuation Factor c	Decibels: Indicating Rating d	Discontinuity: Length	Discontinuity: Angular distance (sound Path)	Discontinuity: Depth From "A" Surface	Discontinuity: Distance From X	Discontinuity: Distance From Y	Discontinuity Evaluation	Remarks
1		70	A	I/II		70								Acc	
2															
3															
4															
5															
6															
7															
8															
9															
10															
11															
12															
13															
14															
15															

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(year)

INSPECTION SUPPORT SERVICES Inc.

PO Box 237
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Fax (856) 784-7473

Ultrasonic Inspection Report of Structural Steel (AWS Form)

USEL @ Commodore Barry Bridge for the DRPA (Survey of existing flaws in electroslag welds.)

Date:	10/17/2007
Project No.:	82624
Weld Identification:	302
Material Thickness:	2"
Weld Joint AWS:	Square Butt
Welding Process:	ESW (Electroslag)
Quality Requirements-Section No.:	AWS D1.5 – Sect.6 table 6.3
Remarks:	

Line Number	Indication Number	Transducer Angle	From Face	Leg	Decibels				Discontinuity					Discontinuity Evaluation	Remarks
					Indication Level	Reference Level	Attenuation Factor	Indicating Rating	Length	Angular distance (sound Path)	Depth From "A" Surface	Distance			
					a	b	c	d				From X	From Y		
1	1	70	A	I	86	70	3	+13	3"	2.35"	.8"	0"	21"	Acc	
2	2	70	A	I	84	70	3	+11	8"	2.35"	.8"	0"	25"	Acc	
3															
4															
5															
6															
7															
8															
9															
10															
11															
12															
13															
14															
15															

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(year)

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Phone (856) 816-5270
Fax (856) 784-7473

Ultrasonic Inspection Report of Structural Steel (AWS Form)

USEL @ Commodore Barry Bridge for the DRPA (Survey of existing flaws in electroslag welds.)

Date:	10/9/2007
Project No.:	82624
Weld Identification:	418
Material Thickness:	2"
Weld Joint AWS:	Square Butt
Welding Process:	ESW (Electroslag)
Quality Requirements-Section No.:	AWS D1.5 – Sect.6 table 6.3
Remarks:	

Line Number	Indication Number	Transducer Angle	From Face	Leg	Decibels				Discontinuity					Discontinuity Evaluation	Remarks
					Indication Level	Reference Level	Attenuation Factor	Indicating Rating	Length	Angular distance (sound Path)	Depth From "A" Surface	Distance			
					a	b	c	d				From X	From Y		
1	1	70	A	I	83	70	2	+11	5"	2.4"	.83"	0"	45"	Acc	
2	2	70	A	I	80	70	3	+7	5"	2.6"	.90"	0"	52.25"	Acc	
3															
4															
5															
6															
7															
8															
9															
10															
11															
12															
13															
14															
15															

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(year)

INSPECTION SUPPORT SERVICES Inc.

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Phone (856) 816-5270
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ISS, Inc. QCP# 301 Revision No. 1
Dated: 11/19/2002

Ultrasonic Inspection Report of Structural Steel (AWS Form)

USEL @ Commodore Barry Bridge for the DRPA (Survey of existing flaws in electroslag welds.)

Date:	10/4/2007
Project No.:	82624
Weld Identification:	444
Material Thickness:	1-1/8"
Weld Joint AWS:	Square Butt
Welding Process:	ESW (Electroslag)
Quality Requirements-Section No.:	AWS D1.5 – Sect.6 table 6.3
Remarks:	

Line Number	Indication Number	Transducer Angle	From Face	Leg	Decibels				Discontinuity					Discontinuity Evaluation	Remarks
					Indication Level	Reference Level	Attenuation Factor	Indicating Rating	Length	Angular distance (sound Path)	Depth From "A" Surface	Distance			
					a	b	c	d				From X	From Y		
1	1	70	A	I	88	70	3	+15	.125"	2.6"	.90	.5"	23.75"	Acc	
2															
3															
4															
5															
6															
7															
8															
9															
10															
11															
12															
13															
14															
15															

We the undersigned, certify that the statements in this report are correct and the welds are prepared and tested in conformance with the requirements of Section 6, Part F of AWS D1.5/D1.5M (2006) Bridge Welding Code-Steel.
(year)

ISS, Inc. QCP# 301	Revision No.1	11/19/2002	By: J. Herman	John Herman

INSPECTION SUPPORT SERVICES Inc.

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Gibbsboro, NJ 08026
Phone (856) 816-5270
Fax (856) 784-7473

ISS, Inc. QCP# 301 Revision No. 1
Dated: 11/19/2002

Ultrasonic Inspection Report of Structural Steel (AWS Form)

USEL @ Commodore Barry Bridge for the DRPA (Survey of existing flaws in electroslag welds.)

Date:	10/4/2007
Project No.:	82624
Weld Identification:	448
Material Thickness:	1-1/2"
Weld Joint AWS:	Square Butt
Welding Process:	ESW (Electroslag)
Quality Requirements-Section No.:	AWS D1.5 – Sect.6 table 6.3
Remarks:	

Line Number	Indication Number	Transducer Angle	From Face	Leg	Decibels				Discontinuity					Discontinuity Evaluation	Remarks
					Indication Level a	Reference Level b	Attenuation Factor c	Indicating Rating d	Length	Angular distance (sound Path)	Depth From "A" Surface	Distance From X	Distance From Y		
1	1	70	A	I	84	70	0	+14	.125"	1.1"	.34	.75"	24.00"	Acc	
2															
3															
4															
5															
6															
7															
8															
9															
10															
11															
12															
13															
14															
15															

We the undersigned, certify that the statements in this report are correct and the welds are prepared and tested in conformance with the requirements of Section 6, Part F of AWS D1.5/D1.5M (2006) Bridge Welding Code-Steel.
(year)

Pennoni
PENNONI ASSOCIATES INC.
ONSULTING ENGINEERS

ULTRASONIC EXAMINATION REPORT

Project: Commodore Barry Bridge- Electroslag Welds **Date:** 9/15/2006

Location: Bridgeport, NJ **Pennoni Project No.:** AMMA 0601

Owner: Delaware River Port Authority **Contractor:** Amman and Whitney

Weld joint designation (AWS): Square Groove/1.125" Thick

Welding Process: ESW

Quality requirements – AWS Section No.: D1.5 Sec. 6, Table 6.3

Remarks: Weld No. 44. X-Axis measured 1" from numbered Die-Stamps at edge of weld.

Piece Mark	Weld Identification Area	Indication Number	Transducer Angle	Form Face	Leg	Decibels: Indication Level (a)	Decibels: Reference Level (b)	Decibels: Attenuation Factor (c)	Decibels: Indication Rating (d)	Discontinuity: Length	Discontinuity: Angular Distance (sound path)	Discontinuity: Depth from "A" surface	Discontinuity: Distance From X	Discontinuity: Distance From Y	Remarks
	44	1	70	A	1	63	50	4	+9	.25"	3.2"	1"	0	27.25"	Acceptable
	44	2	70	A	1	56	50	4	+2	.5"	3.2	1"	0	8.5"	Rejectable

The above welds were prepared and tested in accordance with the requirements of ANSI/AWS D1.5 (2004).
(year)

Reported to: ______

Technician: James Bowen

PENNONI ASSOCIATES INC.

3602 Horizon Drive, Suite 160, King of Prussia, Pa 19406-2669 Tel: 610-277-2402 Fax: 610-277-7449
2041 Avenue C, Suite 100, Bethlehem, PA 18017-2179 Tel: 610-231-0600 Fax: 610-231-2033

Pennoni

PENNONI ASSOCIATES INC.
CONSULTING ENGINEERS

ULTRASONIC EXAMINATION REPORT

Project: Commodore Barry Bridge- Electroslag Welds **Date:** 9/15/2006

Location: Bridgeport, NJ **Pennoni Project No.:** AMMA 0601

Owner: Delaware River Port Authority **Contractor:** Amman and Whitney

Weld joint designation (AWS): Square Groove/1.125" Thick

Welding Process: ESW

Quality requirements – AWS Section No.: D1.5 Sec. 6, Table 6.3

Remarks: Weld No.244. X-Axis measured 1" from numbered Die-Stamps at edge of weld.

Piece Mark	Weld Identification Area	Indication Number	Transducer Angle	Form Face	Leg	Decibels: Indication Level (a)	Decibels: Reference Level (b)	Decibels: Attenuation Factor (c)	Decibels: Indication Rating (d)	Discontinuity: Length	Discontinuity: Angular Distance (sound path)	Discontinuity: Depth from "A" surface	Discontinuity: Distance From X	Discontinuity: Distance From Y	Remarks
	244	1	70	A	1	56	50	2	+4	1.25"	2"	.71"	-.5"	6.75"	Rejectable
	244	2	70	A	1	55	50	1	+4	.5"	1.3"	.45"	+.5"	7.25"	Rejectable(Parallel)

The above welds were prepared and tested in accordance with the requirements of ANSI/AWS D1.5 (2004).
(year)

Reported to: ____________________

Technician: James Bowen

PENNONI ASSOCIATES INC.

Pennoni

PENNONI ASSOCIATES INC.
CONSULTING ENGINEERS

ULTRASONIC EXAMINATION REPORT

Project: Commodore Barry Bridge- Electroslag Welds **Date:** 9/15/2006

Location: Bridgeport, NJ **Pennoni Project No.:** AMMA 0601

Owner: Delaware River Port Authority **Contractor:** Amman and Whitney

Weld joint designation (AWS): Square Groove/ 1.5" Thick

Welding Process: ESW

Quality requirements – AWS Section No.: D1.5 Sec. 6, Table 6.3

Remarks: Weld No.273. X-Axis measured 1" from numbered Die-Stamps at edge of weld.

Piece Mark	Weld Identification Area	Indication Number	Transducer Angle	Form Face	Leg	Decibels: Indication Level (a)	Decibels: Reference Level (b)	Decibels: Attenuation Factor (c)	Decibels: Indication Rating (d)	Discontinuity: Length	Discontinuity: Angular Distance (sound path)	Discontinuity: Depth from "A" surface	Discontinuity: Distance From X	Discontinuity: Distance From Y	Remarks
	273	1	70	A	1	62	50	2	+10	1.25"	1.95"	.675	0	4"	Acceptable

The above welds were prepared and tested in accordance with the requirements of ANSI/AWS D1.5 (2004).
(year)

Reported to: ____________________

Technician: James Bowen

PENNONI ASSOCIATES INC.

Pennoni

PENNONI ASSOCIATES INC.
CONSULTING ENGINEERS

ULTRASONIC EXAMINATION REPORT

Project: Commodore Barry Bridge- Electroslag Welds **Date:** 9/15/2006

Location: Bridgeport, NJ **Pennoni Project No.:** AMMA 0601

Owner: Delaware River Port Authority **Contractor:** Amman and Whitney

Weld joint designation (AWS): Square Groove/ 1.25" Thick

Welding Process: ESW

Quality requirements – AWS Section No.: D1.5 Sec. 6, Table 6.3

Remarks: Weld No.291. X-Axis measured 1" from numbered Die-Stamps at edge of weld. 0-8" from Y inaccessible.

Piece Mark	Weld Identification Area	Indication Number	Transducer Angle	Form Face	Leg	Decibels: Indication Level a	Reference Level b	Attenuation Factor c	Indication Rating d	Discontinuity: Length	Angular Distance (sound path)	Depth from "A" surface	Distance From X	Distance From Y	Remarks
	291		70	A	1/2		50								Acceptable

The above welds were prepared and tested in accordance with the requirements of ANSI/AWS D1.5 (2004).
(year)

Reported to:

Technician: James Bowen

PENNONI ASSOCIATES INC.

3602 Horizon Drive, Suite 160, King of Prussia, Pa 19406-2669 Tel: 610-277-2402 Fax: 610-277-7449
2041 Avenue C, Suite 100, Bethlehem, PA 18017-2179 Tel: 610-231-0600 Fax: 610-231-2033

Pennoni

PENNONI ASSOCIATES INC.
CONSULTING ENGINEERS

ULTRASONIC EXAMINATION REPORT

Project: Commodore Barry Bridge- Electroslag Welds **Date:** 9/15/2006

Location: Bridgeport, NJ **Pennoni Project No.:** AMMA 0601

Owner: Delaware River Port Authority **Contractor:** Amman and Whitney

Weld joint designation (AWS): Square Groove/ 1.375" Thick

Welding Process: ESW

Quality requirements – AWS Section No.: D1.5 Sec. 6, Table 6.3

Remarks: Weld No.302. X-Axis measured 1" from numbered Die-Stamps at edge of weld.

Piece Mark	Weld Identification Area	Indication Number	Transducer Angle	Form Face	Leg	Decibels				Discontinuity					Remarks
						Indication Level	Reference Level	Attenuation Factor	Indication Rating	Length	Angular Distance (sound path)	Depth from "A" surface	Distance		
						a	b	c	d				From X	From Y	
	302	1	70	A	1	64	48	3	+13	3"	2.35"	.8"	0	21"	Acceptable
	302	2	70	A	1	62	48	3	+11	8"	2.35	.8	0	25"	Acceptable

The above welds were prepared and tested in accordance with the requirements of ANSI/AWS D1.5 (2004).
(year)

Reported to: ______________________

Technician: James Bowen

PENNONI ASSOCIATES INC.

Pennoni

PENNONI ASSOCIATES INC.
CONSULTING ENGINEERS

ULTRASONIC EXAMINATION REPORT

Project: Commodore Barry Bridge- Electroslag Welds

Date: 9/15/2006

Location: Bridgeport, NJ

Pennoni Project No.: AMMA 0601

Owner: Delaware River Port Authority

Contractor: Amman and Whitney

Weld joint designation (AWS): Square Groove/ 2" Thick

Welding Process: ESW

Quality requirements – AWS Section No.: D1.5 Sec. 6, Table 6.3

Remarks: Weld No.418. X-Axis measured 1" from numbered Die-Stamps at edge of weld.

Piece Mark	Weld Identification Area	Indication Number	Transducer Angle	Form Face	Leg	Decibels: Indication Level (a)	Decibels: Reference Level (b)	Decibels: Attenuation Factor (c)	Decibels: Indication Rating (d)	Discontinuity: Length	Discontinuity: Angular Distance (sound path)	Discontinuity: Depth from "A" surface	Distance: From X	Distance: From Y	Remarks
	418	1	70	A	1	67	54	2	+11	.5"	2.4"	.83"	0	45"	Acceptable
	418	2	70	A	1	64	54	3	+7	.5"	2.6"	.9	0	52.25"	Acceptable

The above welds were prepared and tested in accordance with the requirements of ANSI/AWS D1.5 (2004).
(year)

Reported to: ______________________

Technician: James Bowen

PENNONI ASSOCIATES INC.

3602 Horizon Drive, Suite 160, King of Prussia, Pa 19406-2669 Tel: 610-277-2402 Fax: 610-277-7449
2041 Avenue C, Suite 100, Bethlehem, PA 18017-2179 Tel: 610-231-0600 Fax: 610-231-2033

Pennoni

PENNONI ASSOCIATES INC.
CONSULTING ENGINEERS

ULTRASONIC EXAMINATION REPORT

Project: Commodore Barry Bridge- Electroslag Welds
Date: 9/15/2006
Location: Bridgeport, NJ
Pennoni Project No.: AMMA 0601
Owner: Delaware River Port Authority
Contractor: Amman and Whitney
Weld joint designation (AWS): Square Groove/ 1.125" Thick
Welding Process: ESW
Quality requirements – AWS Section No.: D1.5 Sec. 6, Table 6.3
Remarks: Weld No.444. X-Axis measured 1" from numbered Die-Stamps at edge of weld.

Piece Mark	Weld Identification Area	Indication Number	Transducer Angle	Form Face	Leg	Decibels: Indication Level (a)	Decibels: Reference Level (b)	Decibels: Attenuation Factor (c)	Decibels: Indication Rating (d)	Discontinuity: Length	Discontinuity: Angular Distance (sound path)	Discontinuity: Depth from "A" surface	Discontinuity: Distance From X	Discontinuity: Distance From Y	Remarks
	444	1	70	A	1	72	54	3	+15	.125"	2.6"	.9"	.5"	23.75	Acceptable

The above welds were prepared and tested in accordance with the requirements of ANSI/AWS D1.5 (2004).
(year)

Reported to:

Technician: James Bowen

PENNONI ASSOCIATES INC.

Pennoni

PENNONI ASSOCIATES INC.
CONSULTING ENGINEERS

ULTRASONIC EXAMINATION REPORT

Project: Commodore Barry Bridge- Electroslag Welds
Date: 9/15/2006
Location: Bridgeport, NJ
Pennoni Project No.: AMMA 0601
Owner: Delaware River Port Authority
Contractor: Amman and Whitney
Weld joint designation (AWS): Square Groove/ 1.5" Thick
Welding Process: ESW
Quality requirements – AWS Section No.: D1.5 Sec. 6, Table 6.3
Remarks: Weld No.448. X-Axis measured 1" from numbered Die-Stamps at edge of weld.

Piece Mark	Weld Identification Area	Indication Number	Transducer Angle	Form Face	Leg	Decibels: Indication Level (a)	Decibels: Reference Level (b)	Decibels: Attenuation Factor (c)	Decibels: Indication Rating (d)	Discontinuity: Length	Discontinuity: Angular Distance (sound path)	Discontinuity: Depth from "A" surface	Discontinuity: Distance From X	Discontinuity: Distance From Y	Remarks
	448	1	70	A	1	68	54	0	+14	.125"	1.1"	.34"	.75"	24"	Acceptable

The above welds were prepared and tested in accordance with the requirements of ANSI/AWS D1.5 (2004).
(year)

Reported to: ______

Technician: James Bowen

PENNONI ASSOCIATES INC.

3602 Horizon Drive, Suite 160, King of Prussia, Pa 19406-2669 Tel: 610-277-2402 Fax: 610-277-7449
2041 Avenue C, Suite 100, Bethlehem, PA 18017-2179 Tel: 610-231-0600 Fax: 610-231-2033

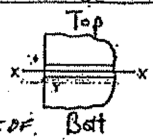
WTTI

WELDER TRAINING & TESTING INSTITUTE, INC.
1144 N. Graham Street, Allentown, PA 18103-1263
Phone: (610) 820-9551 FAX: (610) 820-0271

REPORT OF ULTRASONIC TESTING OF WELDS

Project: Drexel Univ. - Commodore Barry Bridge Report no. 2

Left



X Axis Ref Located @ Base of Weld

Weld Identification: 44
Material thickness: 1.125"
Weld joint AWS: Square Groove
Welding process: Electro Slag (ESW)
Quality requirements — section no.: AWS D1.1 Tab. 6.3
Remarks:

Line number	Indication number	Transducer angle	From Face	Leg*	Decibels: Indication level a	Reference level b	Attenuation factor c	Indication rating d	Discontinuity: Length	Angular distance (sound path)	Depth from "A" surface	Distance: From X	From Y	Discontinuity evaluation	Remarks
1	1	70°	A	1	59	45	3	6	.25"	.90"	.30"	+1.25"	13.25"	Reject	
2															
3	2	70°	A	1	54	45	3	8	.25"	.90"	.30"	+1.25"	14.25"	Reject	
4															
5	3	70°	A	1	56	45	3	8	.25"	.90"	.30"	+1.25"	14.25"	Reject	
6															
7	4	70°	A	1	58	45	3	10	.25"	.90"	.30"	+1.25"	17.37"		
8															
9															
10															
11															
12															
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16															
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18															
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20															
21															
22															
23															
24															
25															
26															

We, the undersigned, certify that the statements in this record are correct and that the welds were prepared and tested in accordance with the requirements of section 6, Part C of ANSI/AWS D1.1, (94 year) Structural Welding Code-Steel.

Test date: 8-26-99
Inspected by: Rob K. ... Lev II

Manufacturer or contractor:
Authorized by:
Date:

Note: This form is applicable to sections 8 and 9 (Statically and Dynamically Loaded Structures). Do NOT use this form for Tubular Structures (section 10).

Form D-11

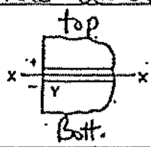
WTTI

WELDER TRAINING & TESTING INSTITUTE, INC.
1144 N. Graham Street, Allentown, PA 18103-1263
Phone: (610) 820-9551 FAX: (610) 820-0271

REPORT OF ULTRASONIC TESTING OF WELDS

Project Drexel Univ. - Commodore Barry Bridge Report no. 1

Right



Weld identification 244
Material thickness 1.125"
Weld joint AWS Square Groove
Welding process Electro Slag (ESW)
Quality requirements — section no. AWS D1.1 tab. 6.3
Remarks

Line number	Indication number	Transducer angle	From Face	Leg*	Decibels: Indication level (a)	Decibels: Reference level (b)	Decibels: Attenuation factor (c)	Decibels: Indication rating (d)	Discontinuity: Length	Discontinuity: Angular distance (sound path)	Discontinuity: Depth from "A" surface	Discontinuity: Distance From X	Discontinuity: Distance From Y	Discontinuity evaluation	Remarks
1	1	70°	A	1	56	46	1	9	2.00"	1.30"	.45"	+.50"	17.25"	Reject	⊥ Stress
2															
3	2	70°	A	1	56	46	1	9	5.00"	1.30"	.45"	+.50"	7.25"	Reject	⊥ Stress
4															
5	3	70°	A	1	56	46	1	3	3.50"	1.30"	.45"	+.50"	3.50"	Reject	⊥ Stress
6															
7															
8															
9															
10															
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25															
26															

We, the undersigned, certify that the statements in this record are correct and that the welds were prepared and tested in accordance with the requirements of section 6, Part C of ANSI/AWS D1.1, (99 year) Structural Welding Code-Steel.

Test date 8-25-99
Inspected by Rob K. Wiesner Lev II

Manufacturer or contractor
Authorized by
Date

Note: This form is applicable to sections 8 and 9 (Statically and Dynamically Loaded Structures). Do NOT use this form for Tubular Structures (Section 10).

Form D-11

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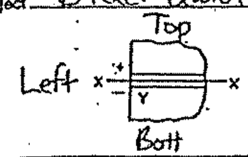
REPORT OF ULTRASONIC TESTING OF WELDS

Project: Drexel Univ. - Commodore Barry Bridge Report no. 8



Weld identification: Y-273
Material thickness: 1.125"
Weld joint AWS: Square Groove
Welding process: Electro Slag (ESW)
Quality requirements — section no.: AWS D1.1 tab. 6.3
Remarks:

Line number	Indication number	Transducer angle	From Face	Leg*	Decibels: Indication level a	Reference level b	Attenuation factor c	Indication rating d	Discontinuity: Length	Angular distance (sound path)	Depth from "A" surface	Distance: From X	From Y	Discontinuity evaluation	Remarks
1	1	70°	A	1	24	18	0	6	6.50"	.75"	.25"	.625"	4.00"	Reject	
2															
3	2	70°	A	1	28	18	0	10	.75"	.75"	.25"	.625"	13.25"		
4															
5	3	70°	A	1	28	18	0	10	.75"	.75"	.25"	.625"	15.75"		
6															
7	4	70°	A	1	26	18	0	8	4.25"	.75"	.25"	.625"	19.60"	Reject	
8															
9															
10															
11															
12															
13															
14															
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17															
18															
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22															
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26															

We, the undersigned, certify that the statements in this record are correct and that the welds were prepared and tested in accordance with the requirements of section 6, Part C of ANSI/AWS D1.1, (94 year) Structural Welding Code-Steel.

Test date: 9-20-99
Inspected by: Rob K. Wisner Lev II

Manufacturer or contractor:
Authorized by:
Date:

Note: This form is applicable to sections 8 and 9 (Statically and Dynamically Loaded Structures). Do NOT use this form for Tubular Structures (section 10).

Form D-11

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1144 N. Graham Street, Allentown, PA 18103-1263
Phone: (610) 820-9551 FAX: (610) 820-0271

REPORT OF ULTRASONIC TESTING OF WELDS

Project: Drexel Univ. - Commodore Barry Bridge Report no. 6

Weld identification: Y-241
Material thickness: 1.250"
Weld joint AWS: Square Groove
Welding process: Electro Slag (ESW)
Quality requirements — section no.: AWS D1.1 tab. 6.3
Remarks:

Top — Right / Left — X, Y

Line number	Indication number	Transducer angle	From Face	Leg*	Decibels: Indication level (a)	Decibels: Reference level (b)	Decibels: Attenuation factor (c)	Decibels: Indication rating (d)	Discontinuity: Length	Discontinuity: Angular distance (sound path)	Discontinuity: Depth from "A" surface	Discontinuity: Distance From X	Discontinuity: Distance From Y	Discontinuity evaluation	Remarks
1	1	70°	A	1	52	42	0	10	.125"	1.30"	.375"	0	2.00"		
2															
3	2	70°	A	1	52	42	0	10	.125"	1.30"	.375"	0	4.50"		
4															
5	3	70°	A	1	52	42	0	10	.125"	1.30"	.375"	0	5.50"		
6															
7	4	70°	A	1	52	42	0	10	.125"	1.30"	.375"	0	8.00"		
8															
8	5	70°	A	1	48	42	2	4	.125"	2.00"	.70"	±.50"	17.00"	Reject	
10															
11	6	70°	A	1	54	42	2	10	.125"	2.00"	.70"	+.50"	19.00"		
12															
13	7	70°	A	1	50	42	2	6	.125"	2.00"	.70"	+.50"	27.00"	Reject	
14															
15	8	70°	A	1	48	42	2	4	1.00"	2.00"	.70"	+.50"	37.00"	Reject	
16															
17	9	70°	A	1	48	42	2	4	.125"	2.00"	.70"	+.50"	48.00"	Reject	
18															
19	10	70°	A	1	54	42	2	10	.250"	2.00"	.70"	+.50"	54.00"		
20															
21															
22															
23															
24															
25															
26															

We, the undersigned, certify that the statements in this record are correct and that the welds were prepared and tested in accordance with the requirements of section 6, Part C of ANSI/AWS D1.1, (94 Year) Structural Welding Code-Steel.

Test date: 9-9-99
Inspected by: Rob K. Wi[illegible] Lev II

Manufacturer or contractor:
Authorized by:
Date:

Note: This form is applicable to sections 8 and 9 (Statically and Dynamically Loaded Structures). Do NOT use this form for Tubular Structures (Section 10).

Form D-11

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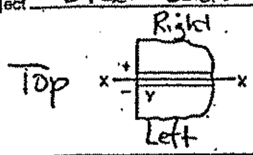
1144 N. Graham Street, Allentown, PA 18103-1263

Phone: (610) 820-9551 FAX: (610) 820-0271

REPORT OF ULTRASONIC TESTING OF WELDS

Project: Drexel Univ - Commodore Barry Bridge Report no. 7



Weld identification: Y-302

Material thickness: 1.375"

Weld joint AWS: Single Bevel

Welding process: ESW

Quality requirements — section no.: AWS D1.1 tab. 6.3

Remarks:

Line number	Indication number	Transducer angle	From Face	Leg*	Decibels: Indication level (a)	Reference level (b)	Attenuation factor (c)	Indication rating (d)	Discontinuity: Length	Angular distance (sound path)	Depth from "A" surface	Distance: From X	From Y	Discontinuity evaluation	Remarks
1	1	70°	A	1	28	18	4	6	2.50"	2.98"	1.00"	0	21.00"	Reject	
2															
3	2	70°	A	1	28	18	4	6	10.00"	2.98"	1.00"	+.75"	25.00"	Reject	
4															
5															
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26															

We, the undersigned, certify that the statements in this record are correct and that the welds were prepared and tested in accordance with the requirements of section 6, Part C of ANSI/AWS D1.1, (94 year) Structural Welding Code-Steel.

Test date: 9-13-99

Inspected by: Rollo K. Wisswesser Lev II

Manufacturer or contractor:

Authorized by:

Date:

Note: This form is applicable to sections 8 and 9 (Statically and Dynamically Loaded Structures). Do NOT use this form for Tubular Structures (section 10).

Form D-11

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Phone: (610) 820-9551 FAX: (610) 820-0271

REPORT OF ULTRASONIC TESTING OF WELDS

Project: Drexel Univ. - Commodore Barry Bridge Report no.: 9

Weld identification: Y = 4.8
Material thickness: 1.50"
Weld joint AWS: Square Groove
Welding process: Electro Slag (ESW)
Quality requirements — section no.: AWS D1.1 Tab. 6.3
Remarks:

Line number	Indication number	Transducer angle	From Face	Leg*	Decibels: Indication level (a)	Reference level (b)	Attenuation factor (c)	Indication rating (d)	Discontinuity: Length	Angular distance (sound path)	Depth from "A" surface	Distance: From X	From Y	Discontinuity evaluation	Remarks
1	1	70°	A	1	26	20	3	3	.25"	2.50"	.68"		46.00"	Reject	
2															
3	2	70°	A	1	24	20	4	0	.25"	3.00"	.84"		52.25"	Reject	
4															
5															
6															
7															
8															
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25															
26															

We, the undersigned, certify that the statements in this record are correct and that the welds were prepared and tested in accordance with the requirements of section 6, Part C of ANSI/AWS D1.1, (94 Year) Structural Welding Code-Steel.

Test date: 9-30-99
Inspected by: [signature] Lev. II

Manufacturer or contractor:
Authorized by:
Date:

Note: This form is applicable to sections 8 and 9 (Statically and Dynamically Loaded Structures). Do NOT use this form for Tubular Structures (Section 10).

Form D-11

WTTI

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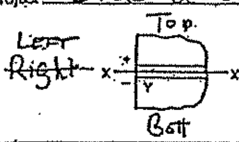
Phone: (610) 820-9551 FAX: (610) 820-0271

REPORT OF ULTRASONIC TESTING OF WELDS

Project: Drexel Univ. - Commodore Barry Bridgi Report no. 4



Weld identification: Y-444
Material thickness: 1.125"
Weld joint AWS: Square Groove
Welding process: Electro Slag (ESW)
Quality requirements — section no.: AWS D1.1 tab. 6.3
Remarks:

Line number	Indication number	Transducer angle	From Face	Leg*	Decibels: Indication level a	Reference level b	Attenuation factor c	Indication rating d	Discontinuity: Length	Angular distance (sound path)	Depth from "A" surface	Distance: From X	From Y	Discontinuity evaluation	Remarks
1	1	70°	A	1	44	40	1	3	.125"	1.70"	.60"	+.75"	12.00"	Reject	
2															
3	2	70°	A	1	46	40	0	6	.125"	1.30"	.44"	0	15.60"	Reject	
4															
5	3	70°	A	1	50	40	0	10	.125"	1.20"	.40"	+.125"	23.75"		⊥ to Stress
6															
7															
8															
9															
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22															
23															
24															
25															
26															

We, the undersigned, certify that the statements in this record are correct and that the welds were prepared and tested in accordance with the requirements of section 6, Part C of ANSI/AWS D1.1, (94 year) Structural Welding Code-Steel.

Test date: 8-27-99
Inspected by: Ron K. Wissler Lev II

Manufacturer or contractor:
Authorized by:
Date:

Note: This form is applicable to sections 8 and 9 (Statically and Dynamically Loaded Structures). Do NOT use this form for Tubular Structures (section 10).

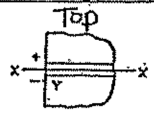
Form D-11

WTTI

WELDER TRAINING & TESTING INSTITUTE, INC.
1144 N. Graham Street, Allentown, PA 18103-1263
Phone: (610) 820-9551 FAX: (610) 820-0271.

REPORT OF ULTRASONIC TESTING OF WELDS

Project: Drexel Univ. - Commodore Barry Bridge Report no. 5



Weld identification: Y-448
Material thickness: 1.50"
Weld joint AWS: Square Groove
Welding process: Electro Slag (ESW)
Quality requirements — section no.: AWS D1.1 Tab. 6.3
Remarks:

Line number	Indication number	Transducer angle	From Face	Leg*	Decibels: Indication level (a)	Reference level (b)	Attenuation factor (c)	Indication rating (d)	Discontinuity: Length	Angular distance (sound path)	Depth from "A" surface	Distance: From X	From Y	Discontinuity evaluation	Remarks
1	1	70°	A	1	46	40	0	6	.250"	1.20"	.47"	0	8.75"	Reject	
2										1.68"					
3	2	70°	A	1	46	40	0	6	.250"	1.60"	.55"	+.125"	19.67"	Reject	
4															
5	3	70°	A	1	46	40	0	6	.250"	1.60"	.55"	+.125"	21.00"	Reject	
6															
7	4	70°	A	1	50	40	0	10	.125"	.90"	.30"	+.175"	24.00"		⊥ to Stress
8															
9															
10															
11															
12															
13															
14															
15															
16															
17															
18															
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25															
26															

We, the undersigned, certify that the statements in this record are correct and that the welds were prepared and tested in accordance with the requirements of section 6, Part C of ANSI/AWS D1.1, (98 year) Structural Welding Code-Steel.

Test date: 8-27-99
Inspected by: Rob K. Wiesner Lev II

Manufacturer or contractor:
Authorized by:
Date:

Note: This form is applicable to sections 8 and 9 (Statically and Dynamically Loaded Structures). Do NOT use this form for Tubular Structures (section 10).

Form D-11