AISI
High Performance Steel Corrosion Advisory Group
NYS DOT Moore Drive Bridge:
Coupon Exposure Project

<u>Interim Report #1</u>
Specimen Rack Construction and Installation

Sponsored by:

American Iron and Steel Institute

American Institute of Steel Construction

National Steel Bridge Alliance

Report # T:202 **March 29, 2002**

AISI High Performance Steel Corrosion Advisory Group

NYS DOT Moore Drive Bridge: Coupon Exposure Project

Interim Report #1
Specimen Rack Construction and Installation.

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Report Summary

The High Performance Steel Corrosion Advisory Group of the American Iron and Steel Institute has initiated an 8-year Coupon Exposure Project to investigate the corrosion performance of weathering steel coupons placed on the underside of Moore Drive Bridge, (NYSDOT #4443820), located in Rochester, New York. The unpainted weathering steel bridge, built in 1981, is 396' in length and crosses Interstate I-390 and the Erie Canal that runs parallel to the heavily used interstate. Large amounts of de-icing salts are applied to the interstate, contributing to significant corrosion of the four girders in the regions above the roadway, and resulting in the lack of formation of an adherent, protective rust layer. However in the regions away from the roadway, across the Erie Canal, the corrosion appears to be much less and an adherent rust layer has formed on the weathering steel.

In order to determine the effects of the road de-icing salts on the corrosion rates of the steel in typical under-bridge conditions, weathering steel coupons, (ASTM Type A588 B), were placed in three different locations on one girder on the underside of the bridge. Two Specimen Racks were placed at the west end of the bridge in regions close to and above the I-390 roadway. The third rack was placed at the east end about 250' from the roadway. The stainless steel Specimen Racks were designed and constructed at the Homer Research Laboratories, Bethlehem Steel Corporation in Bethlehem, PA. Each Specimen Rack consists of a Support Frame, four detachable Coupon Holders, and a Datalogger Base Plate for attaching corrosion monitoring instruments. Each Coupon Holder supports three 3" x 4" exposure coupons, thereby allowing 12 coupons to be attached to each Specimen Rack. The coupons were exposed in triplicate, two for mass-loss determination and one for spectroscopic analysis of the rust. One Coupon Holder from each rack is scheduled for removal after 12, 24, 48, and 96 months of exposure. The corrosion monitoring instrument consists of a Corrosion Coulometer which logs corrosion current between weathering steel and copper coupled by an electrolyte established by the under-bridge conditions. The data is downloaded at 6 month intervals. The Specimen Racks, which are 81" long, were bolted to the north side of the web of girder 3 of the bridge on September 27, 2001. The coupons are mounted horizontal and about 9 ½ " above the upper surface of the lower flange of the girder, which is about 16' above the ground. During rack installation, rust samples were collected and thickness measurements of the lower flange were recorded at each of the rack locations. These will be repeated when each coupon holder is removed after 12, 24, 48, and 96 months.

Preface:

The Moore Drive Bridge Coupon Exposure Project is one of several investigations initiated by the Corrosion Advisory Group, a subcommittee of the High Performance Steel Steering Committee of the American Iron and Steel Institute. Further information concerning AISI and its activities can be found at http://www.steel.org/. The new high performance steels (HPS) are being developed through a cooperative agreement between the Federal Highway Administration, the American Iron and Steel Institute, and the Department of the Navy. A description of the program and technical information can be found at http://www.fhwa.dot.gov/bridge/hps.htm, and http://www.steel.org/infrastructure/bridges/high_performance/index.html. General information on the first High Performance Steel, ASTM A709 Grade HPS-70W, and Weathering Steel in general, can be obtained from http://www.bethsteel.com/customers/prod_brid.shtml.

Technical information on Weathering Steel reviews in bridge applications can be found in two reports, [1, 2] at http://www.steel.org/infrastructure/bridges/ws_perfphase1/index.html and http://www.steel.org/infrastructure/bridges/ws_performance/index.html. The Federal Highway Administration has also prepared a Technical Advisory containing guidelines for proper application of uncoated weathering grade steels in highway structures, in 1989 [3]. It can be viewed at http://www.fhwa.dot.gov/legsregs/directives/techadvs/t514022.htm. Some details of the latest and proposed activities of CAG are contained in a report of the HPS Steering Committee found at http://www.bethsteel.com/customers/pdfs/hpsupdate.pdf .

In collaboration with the New York State Department of Transportation, NYSDOT, the CAG has been investigating the corrosion of Weathering Steel structures in the vicinity of Rochester, NY, a region that relies heavily on road de-icing salts to maintain traffic flow in times of snow accumulation. Further information on this and prior investigations of the Moore Drive Bridge is presented in the Introduction.

This report is the first of a series that will cover the progress of this Coupon Exposure Project over the next 8 years. The CAG Principal Investigators for this project are Desmond C. Cook and Richard D. Granata.

AISI HPS Corrosion Advisory Group members

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Report Format

Cover Page:

Photograph of Moore Drive Bridge (396') looking from West abutment across I-390 towards the East abutment. The Pier separates I-390 and the Erie Canal. The Specimen Rack is shown installed on Girder 3.

Notice:

Project Schedule:

July - 14 September, 2001	**Specimen Rack Construction** **Coupon Preparation**	**Homer Research Laboratories**
18 September, 2001	**Racks shipped to Rochester NYSDOT**	
27 September, 2001	**Rack Installation** **Instrument Mounting** **Thickness Measurements** **Rust Collection**	**D. C. Cook and** **R. D. Granata**
27 September, 2002	**Remove Coupon Holders 1A, 2A, 3A from Specimen Racks 1, 2, 3** **Datalogger Download*** **Thickness Measurements** **Rust Collection**	
27 September, 2003	**Remove Coupon Holders 1B, 2B, 3B from Specimen Racks 1, 2, 3** **Datalogger Download** **Thickness Measurements** **Rust Collection**	
27 September, 2005	**Remove Coupon Holders 1C, 2C, 3C from Specimen Racks 1, 2, 3** **Datalogger Download** **Thickness Measurements** **Rust Collection**	
27 September, 2009	**Remove Coupon Holders 1D, 2D, 3D from Specimen Racks 1, 2, 3** **Datalogger Download** **Thickness Measurements** **Rust Collection**	

***Downloading of the Corrosion Monitor datalogger is scheduled for each 6 months.**

Table of Contents

List of Figures

List of Tables

List of Maps
(Appendix A)

List of Photographs
(Appendix B)

Page

Specimen Rack Construction

List of Photographs (continued)
(Appendix B)

Page

Specimen Rack Installation

1. Introduction

Rochester, New York is located in the snow belt of the United States, receiving a very high average annual snowfall of about 90" due in large part to its close proximity to Lake Ontario. It is designated as Region 4 by the New York State Department of Transportation, NYSDOT. Heavy use of road de-icing salts is common throughout the region, especially along the I-390 corridor bypassing Rochester to the south, Map 1, where NYSDOT has reported using 20 tons per lane mile per year [4]. There are about 140 Weathering Steel bridges in the Rochester vicinity. In 1997, the Region 4 Bridge Washing Program field personnel reported significant rust deposits and flaking on several bridges, including the Moore Drive Bridge that crosses I-390 and the Erie Canal and is located between the Rochester International Airport and the University of Rochester, Maps 2, 3, Photograph 1. Soon after, NYSDOT requested advice from AISI concerning the state of its Region 4 bridges. Following several investigations, AISI published “Report on the Condition of Weathering Steel Bridges in the I-390 Corridor Rochester, N.Y.” by Robert L. Nickerson, on August 16, 1999, [5]. In summary, the report stated that about 14 uncoated weathering steel bridges showed signs of serious corrosion. This included Moore Drive Bridge, built in 1981, which showed corrosion under the abutment joints at the west end over I-390. Chemical analysis of rust samples showed the presence of about 0.9 wt.% chlorides, which was attributed as the major cause of the corrosion. In September 1999, core samples confirmed that Moore Drive Bridge was constructed of ASTM Type A588 B Weathering Steel. Since that time, about 50 bridges along I-390 in the Rochester vicinity have been inspected and found to have areas on which protective, stable rust layers do not appear to have developed.

In May 2000, the recently formed AISI High Performance Steel Corrosion Advisory Group held its first meeting in Rochester to discuss the problems raised by NYSDOT, visit Moore Drive Bridge, record girder thickness and to collect rust samples. The CAG observed very large amounts of loose sheet rust (1/4" thick in places), on all webs and flanges of all 4 girders in the vicinity of the I-390 traffic lanes, Photograph 2. The losses on lower flanges at the west abutment were approximated to be 20 mils per surface, (average loss 1 mpy). This loss would correspond to weathering steel exposed at the severe marine corrosion test site, the 25 m lot at Kure Beach, NC. The basic rust composition showed large amounts of Akaganeite, an iron oxide that forms in chloride containing environments. The CAG decided to undertake more precise thickness measurements and rust collection across the entire bridge.

On September 9-10, 2000, CAG member Desmond Cook revisited the bridge to collaborate with Ryan-Biggs Associates who recorded a detailed set of thickness measurements at 100 locations on 3 of the 4 girders, including webs and bottom flanges, between the west abutment and the Pier located at mid-bridge, between I-390 and the Erie Canal. Six sets of drip bars were removed to record original flange thickness. Rust samples were collected at the same locations as the thickness measurements. Figure 1 shows the locations (B, D, E, F, G, I, K) on the girders 1, 2, and 4, at which measurements and samples were taken. The 16 sets of drip bars are shown as red “V’s” and those inside green boxes were removed for analysis. Spectroscopic and chemical analysis of the rust and drip bars was performed at Old Dominion University and compared with the thickness losses. A report of the thickness measurements was submitted to AISI by Ryan-Biggs Associates, in September 2000, [6]. A final report on the rust analysis, including analysis of the thickness-loss data, is being prepared.

The thickness losses of the Moore Drive Bridge girders showed that in under-bridge regions above the six road lanes of I-390, the corrosion losses of the lower flanges were about 1.5 mm over 20 years, averaging 1.5 mpy per surface. This is a five-fold higher loss than is recommended for weathering steel structures. Variations in corrosion loss were detected for sections facing towards and away from the traffic directions, showing that under-bridge micro-environments, likely controlled by traffic flow and bridge design, are important for determining corrosion characteristics. The corrosion losses decreased at larger distances from the road in the regions of the bridge abutments, and on exterior webs and flanges of the outside girders exposed to rain and wet-dry cycling.

The investigation also included analysis of rust samples collected adjacent to the thickness measurement locations, in order to determine if protective rust layers had formed and if there was correlation between rust composition, thickness loss and chloride deposition. The spectroscopic and chemical analysis showed that, for regions above the roadway, no protective oxides had formed and that Akaganeite, a chloride containing iron oxide, was very predominant. The chloride levels reached 1.5 wt% in these regions and diminished to zero at distances greater than 200' from the road. The rust composition at the East abutment and on the exposed girder faces was that of an adherent protective patina expected to form on weathering steel. It contained no Akaganeite and very little chloride. Overall, there was correlation between thickness loss, Akaganeite fraction and chloride concentration in the rust.

The first investigation provided no insight of the present corrosion rates, or those in the first few years following bridge construction, when the effects of road salts are potentially important in preventing protective layer formation. Consequently, the CAG decided to plan the Coupon Exposure Project to investigate the corrosion rates and rust product chemistry of the same Type A588 B Weathering Steel over an 8-year period. Goals were to determine the effects of road de-icing salts on the corrosion rate of the steel in typical under-bridge conditions, and to determine possible correlation between the measured bridge corrosion characteristics and the amount of salt applied to the roads. The investigation was predicted to provide important information to allow calculation of the serviceable lifetimes before maintenance is required, and to understand if local microclimates are significant in controlling the corrosion of bridges located in the same region.

The basic Coupon Exposure Project planned to expose the Weathering Steel coupons in three locations on the North side of girder 3 of Moore Drive Bridge, as shown in Figure 1. These are: (a) close to the west abutment and facing oncoming traffic, about 20' off the roadway, which appears to be a region of accumulation of significant road spray, (b) above the right lane of I-390 S and facing oncoming traffic where previous measurements showed to have the highest mass loss of any point on the bridge, (c) close to the east abutment 220' away from I-390, where very little chloride and corrosion were observed. At the location of the three Specimen Racks, coupons were planned for exposure in triplicate for 12, 24, 48, and 96 months. Instrumentation for continuous corrosion rate measurement was planned for each rack.

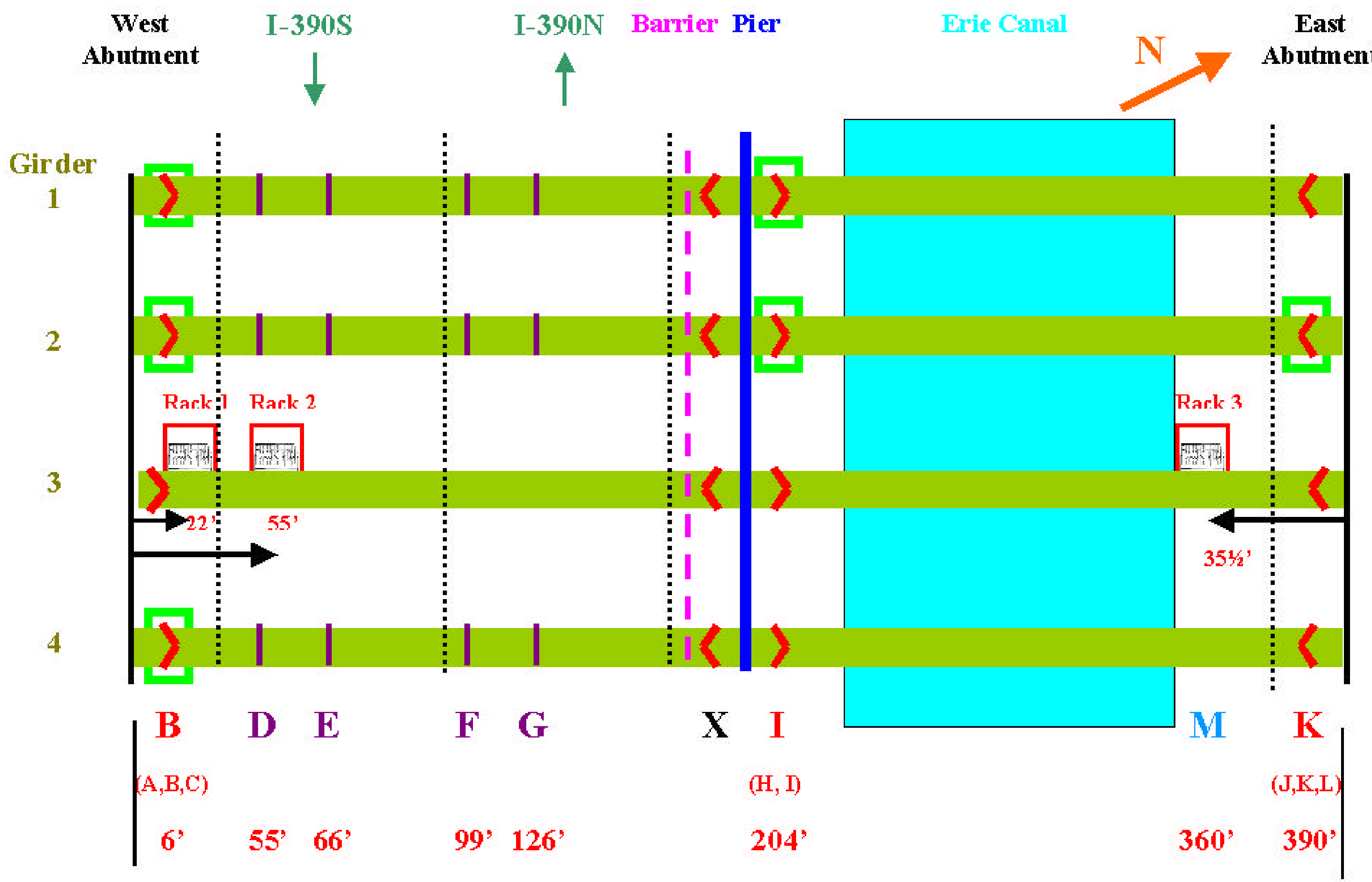


Figure 1: Moore Drive Bridge (#4443820), Rochester NY.
Coupon Exposure Project: Location of Specimen Rack 1 (3CN), Rack2 (3DN), Rack3 (3MN).

2. Specimen Racks

Three identical Specimen Racks were designed to support coupons and Corrosion Monitoring Instrumentation. Each Specimen Rack consists of a Support Frame, four Coupon Holders and Datalogger Base Plate. Figure 2 shows a drawing (#12954) of the Bridge Girder Specimen Rack complete with Coupon Holders, instrumentation and coupons. The Support Frame was constructed of 1¼" square tube (Type 316 stainless steel) welded to a rectangular shape 81¼" x 7", Photograph 3. Figure 3 shows a drawing (#12955) of the Support Frame including dimensions and 3 mounting flanges for attaching to the girder. The Specimen Rack was designed to be mounted to the vertical web of a girder using 6 bolts. To facilitate easy and accurate drilling of the mounting holes through the web, a Girder Drilling Template was constructed, the drawing of which is shown in Figure 4 (drawing #12956). The template rests on the upper surface of the lower flange, as shown in Figure 5 (drawing #12957), to permit the holes, and therefore the Specimen Racks to each, be located at the same height above the bottom of the girder. The template is now stored at Old Dominion University.

Coupons were attached to the Specimen Racks using detachable Coupon Holders, Photograph 4. Each rack holds 4 Coupon Holders which were constructed of ½" square Type 304 stainless steel tubing welded to a 13" x 8" rectangle as shown in Figure 4. Each Coupon Holder was designed to hold 3 coupons of size 4" x 3". Each of the three coupons is attached to the Coupon Holder by two bolts and each of the 4 Coupon Holders is attached to the Support Frame by two bolts, as shown in Figure 4 and Photographs 5 and 6. The Datalogger Base Plate, 8" x 7 3/8", was constructed from 1/8" thick Type 304 stainless steel plate, Figure 4, which was bolted on the left end of the Support Frame, Photographs 7, 8.

The Specimen Racks were separately identified as Rack #1, 2, or 3, using numbers punched in two locations on each end of the support frame, as shown in Figure 6. The four Coupon Holders on each rack were labeled with the rack number 1, 2, or 3, and A, B, C, or D to represent the location on each rack from the left (Datalogger) end. The labels 1A, 1B, 1C, 1D, 2A.......3D, were punched onto the upward facing horizontal steel surface on the front section of the Coupon Holders, as shown in Figure 6.

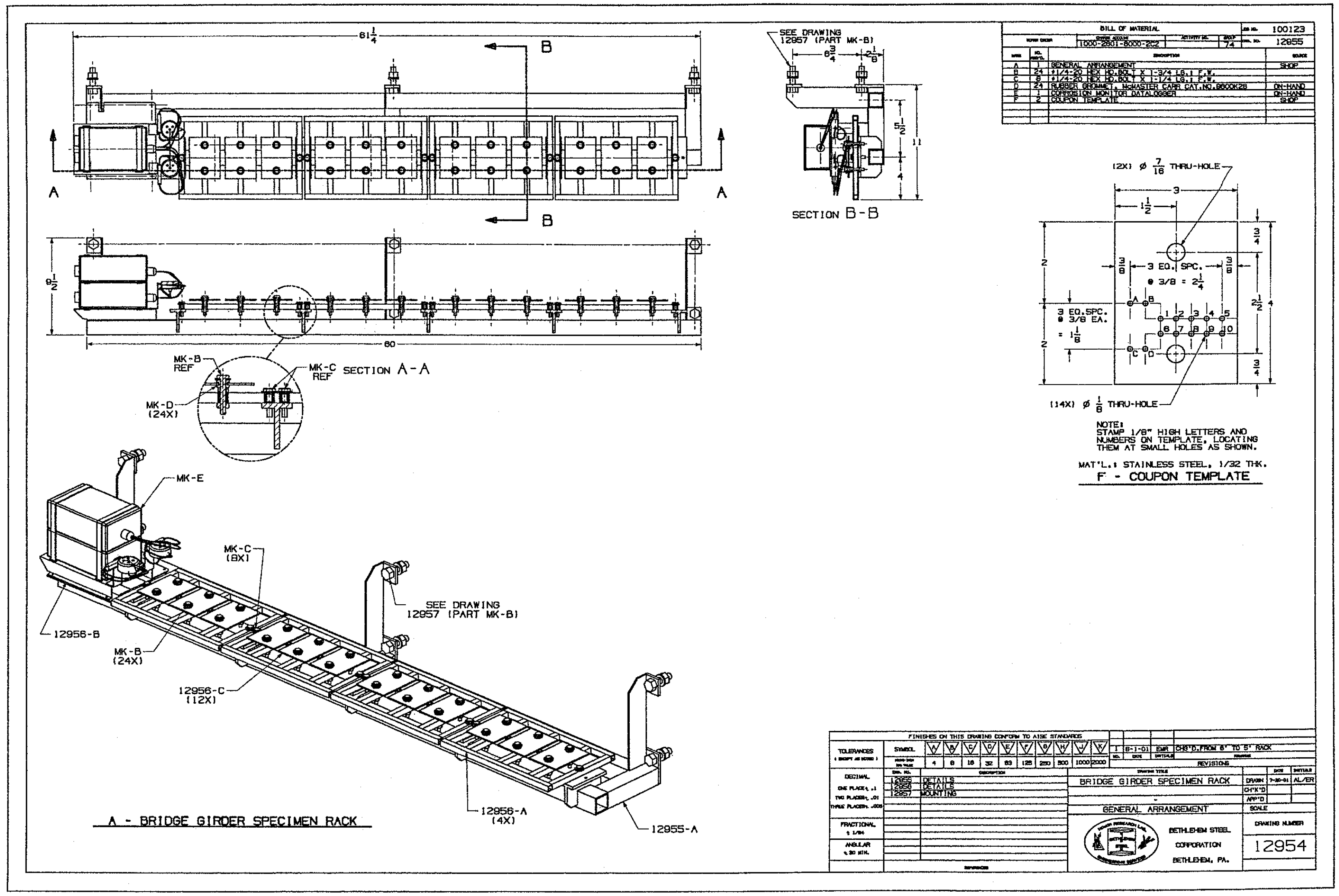


Figure 2
Design Drawings of Specimen Rack with Coupon Holders and Coupons

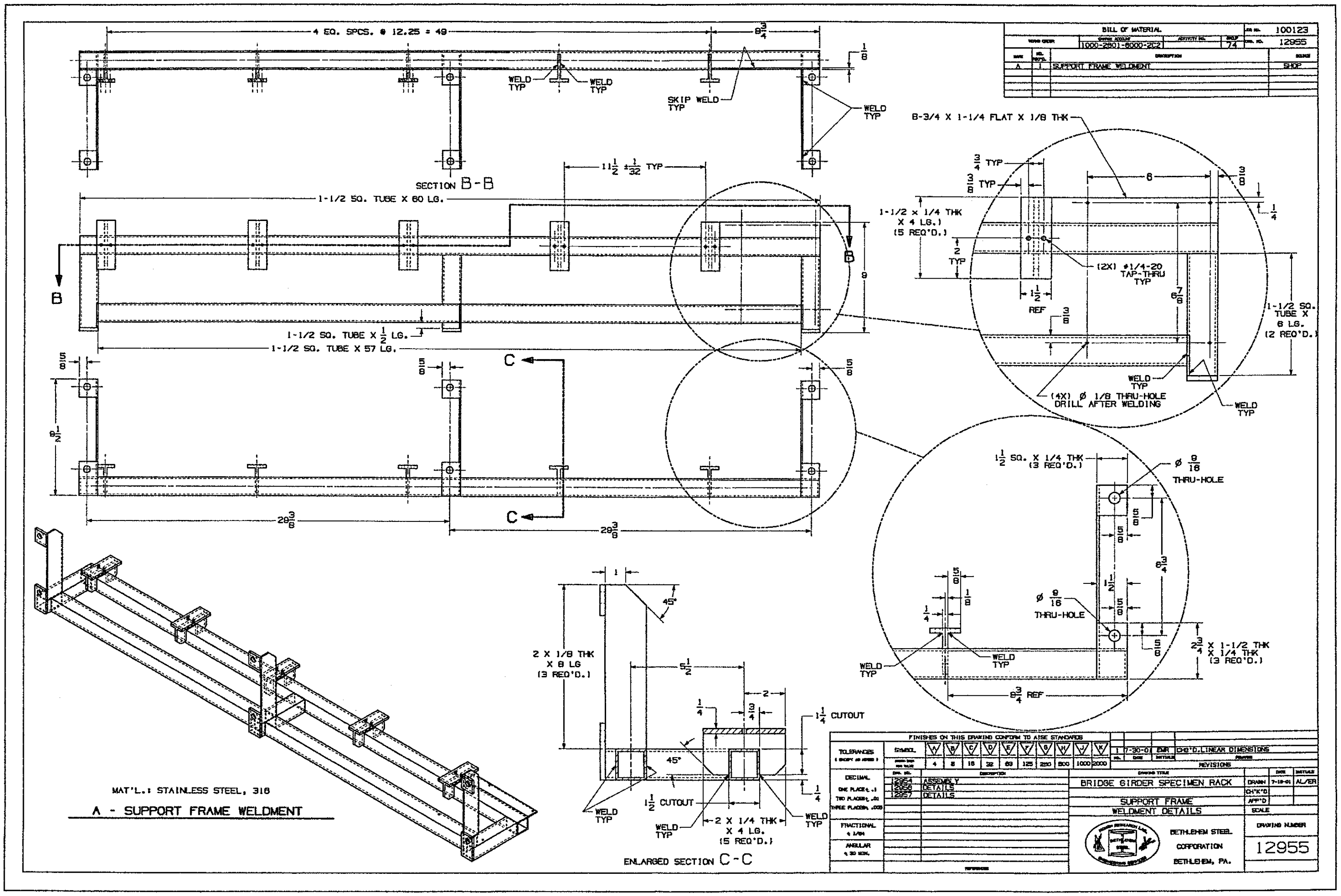
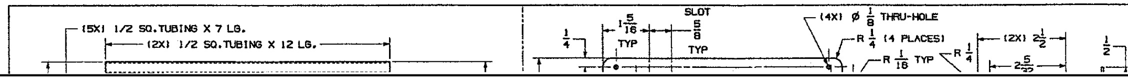


Figure 3
Drawing of Support Frame including Mounting Flanges



BILL OF MATERIAL			
	1000-2801-6000-2C2	74	JOB NO. 100123
			DWG. NO. 12956
A	4	COUPON HOLDER	SHOP
B	1	DATALOGGER BASE PLATE	SHOP
C	12	SAMPLE	SHOP

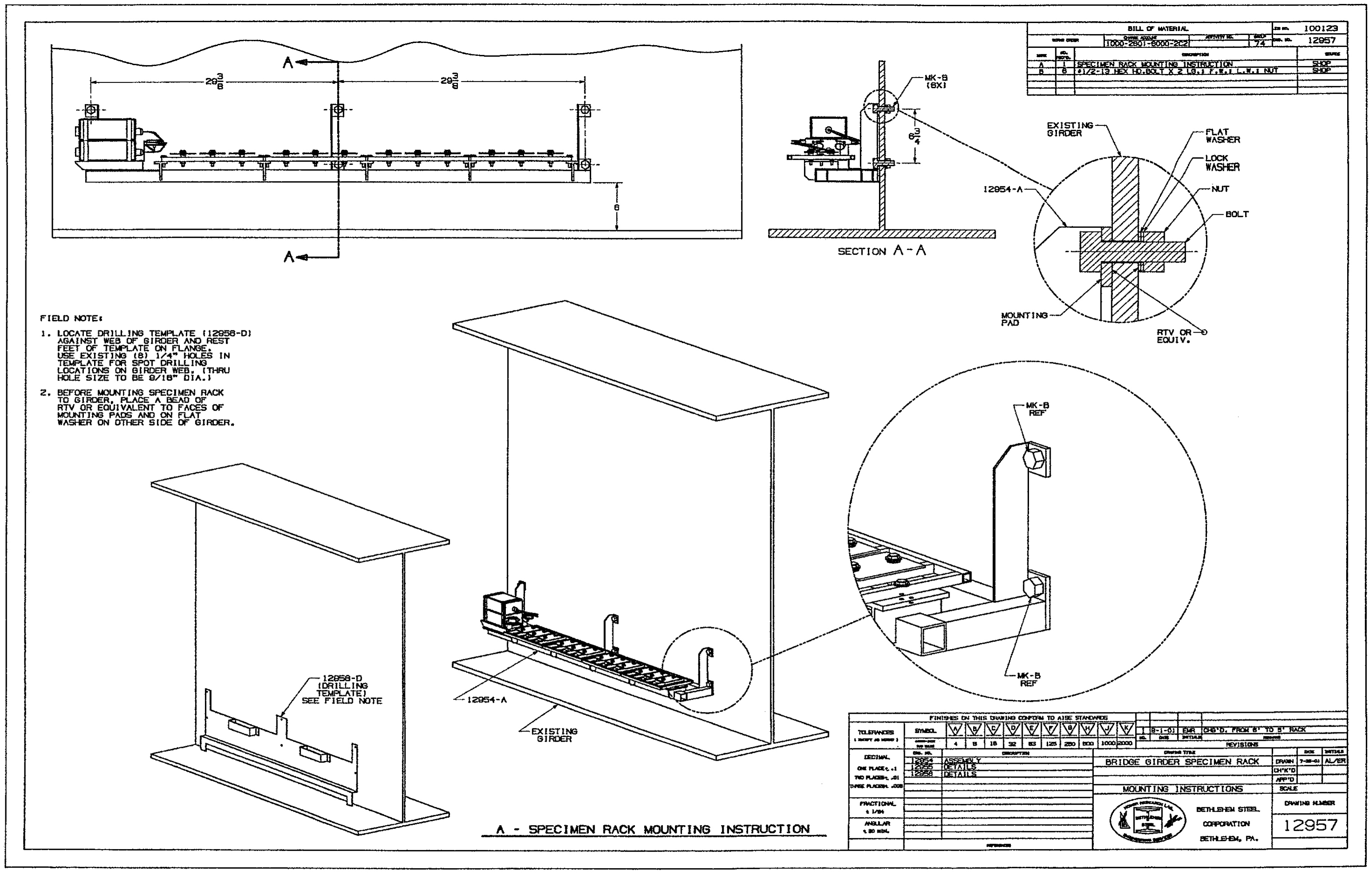


Figure 5
Drawing showing Girder Drilling Template and Specimen Rack in place on the girder

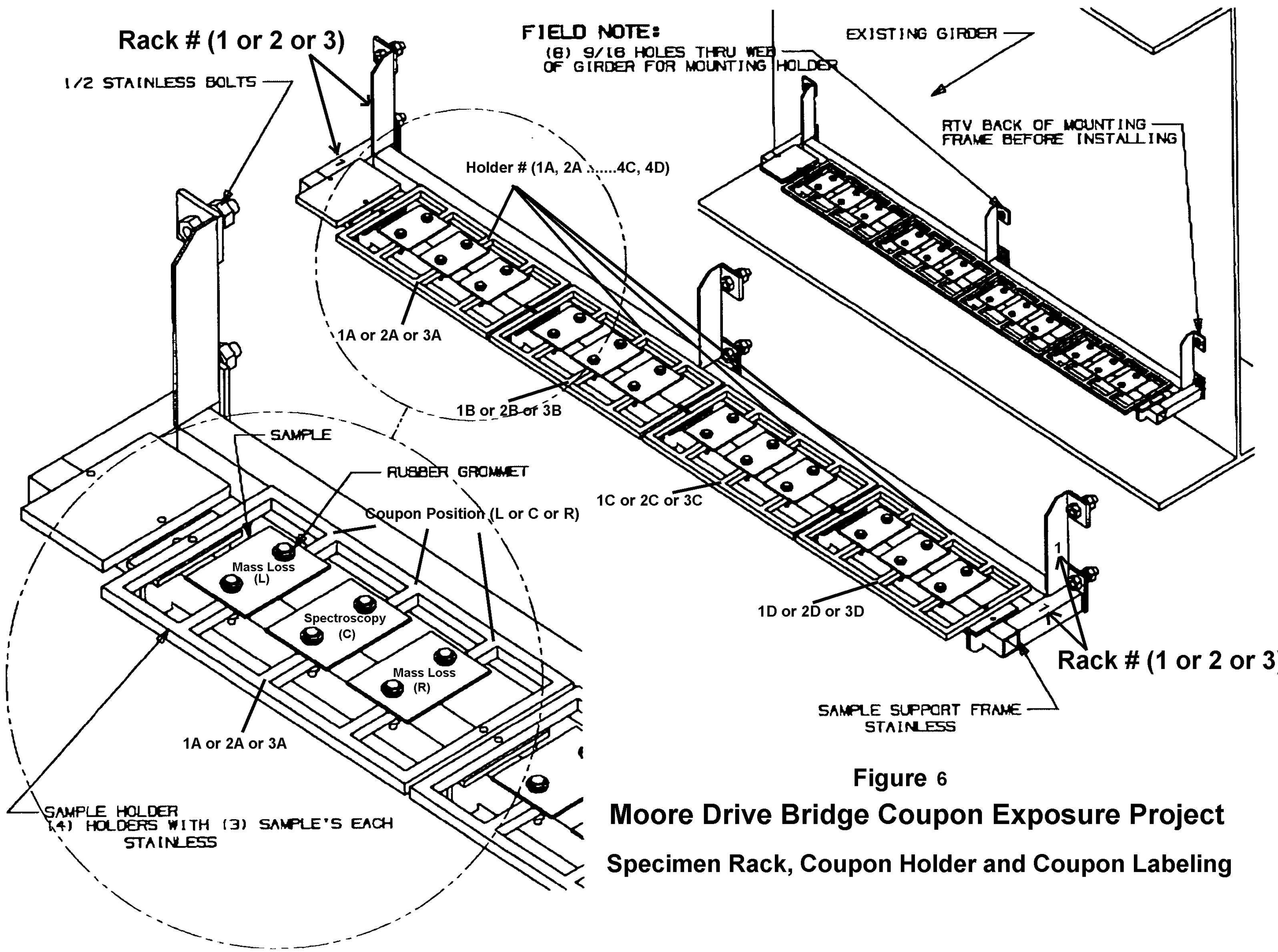


Figure 6

Moore Drive Bridge Coupon Exposure Project

Specimen Rack, Coupon Holder and Coupon Labeling

3. Coupon Preparation and Mounting

Coupons of ASTM Type A588 B Weathering Steel were prepared for exposure at three locations on girder 3 of the Moore Drive Bridge, Rochester, NY (NYSDOT # 4443820) for periods of 1, 2, 4, and 8 years. Each of the three Specimen Racks holds a total of 12 coupons, 3" x 4" in dimension, on the four Coupon Holders. A total of 38 coupons were prepared with 2 being stored as "unexposed reference standards" at Old Dominion University.

The original coupons were rolled, cut, bead blasted and labeled by Dr. Herbert E. Townsend at Bethlehem Steel in July 1999. They were part of a set of 795 coupons prepared from 5 different steels to be used for exposure by various groups. Of these, 180 coupons (numbered 601 - 780), of 4 different steels were for use by Dr. Desmond Cook at Old Dominion University in the México and ASTM atmospheric exposure programs. The original coupons were rolled and cut to 6" x 4" x 0.1" in size. The thickness dimension is nominal, that is close but not exact and varies from coupon to coupon due to the rolling. The coupons were bead blasted to remove millscale and stamped with a BSC Coupon ID Code. Following preparation and prior to any exposure, the Old Dominion University coupons were stored in a wooden box in a climate-controlled environment at the Homer Research Laboratories.

In August 2001, nineteen original coupons of ASTM Type A588 B Weathering Steel, numbered between 621 - 630 and 676 - 684, were prepared for the Moore Drive Bridge exposure project. The source and chemical composition of the steel are listed in Table I. The 6" x 4" coupons were stamped with a second Coupon Identification Code and sheared in half to 3" x 4" using a heavy duty pneumatic shearer. The resultant 38 "new" coupons each received a 2-hole Drill Identification Code, and two mounting holes, Photographs 9, 10. They were then measured, degreased and weighed prior to mounting on the 12 Coupon Holders. Data pertaining to the coupons is listed in Table II. Details of each stage of preparation are provided below.

Table I: Description and chemical composition (wt.%) of Exposure Material.

C-Number	Description			Origin			
1164	ASTM A588B, Weathering Steel			Sparrows Point, 2-in Plate, Heat No.422W056			
C	Mn	P	S	Si	Cu	Ni	Cr
0.10	1.18	0.012	0.011	0.36	0.30	0.31	0.53
V	Mo	Al	Sn	Ti	Nb	Co	N
0.039	0.006	0.048	0.003	0.002	<0.005	0.007	0.0065

Coupon Identification

Each 3" x 4" coupon contained two identification codes, a Coupon Identification Code consisting of a 5 or 6 character sequence punched into the surface, and a Drill Identification Code consisting of two holes drilled through the coupon.

(a) Coupon Identification Codes

The nineteen 6" x 4"coupons were previously punched with a BSC Coupon ID Code in the top-left and top-right corners, as shown in Figure 7, and as listed in Table II. It is noted that the BSC coupon numbers mentioned above, 621 - 630 and 676 - 684, are merely reference numbers for documentation purposes only and are not present on the coupons. For example coupon #623 with the BSC Coupon ID Code, L4N5-5, would display L4N5 in the top left corner and 5 in the top right corner, across the 3" top of the coupon, as shown in Figure 7.

Prior to shearing the coupon to 3" x 4", a new Coupon Identification Code was punched in the bottom-left and bottom-right corners as shown in Figure 7. The code was the same as the original, with “B” added to the sequence. For the above example, the new code would be L4N5-5B, with L4N5 being displayed in the bottom-left corner and 5B in the bottom-right corner, Photograph 9.

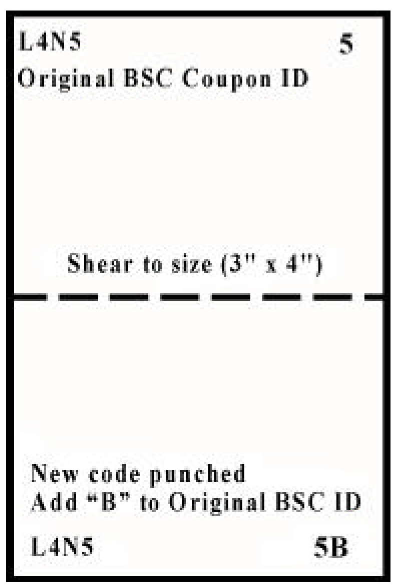


Figure 7. Original 6" x 4" coupon showing the location of the original and new Coupon Identification Codes prior to shearing.

The 6" x 4" coupon was then cut in half using a hydraulic shear, resulting in each 3" x 4" coupon having a unique Coupon Identification Code as summarized in Table II. The punched surface was designated to be mounted, and therefore exposed, upwards on the Specimen Racks. The coupon orientation on the rack is shown in Figure 8.

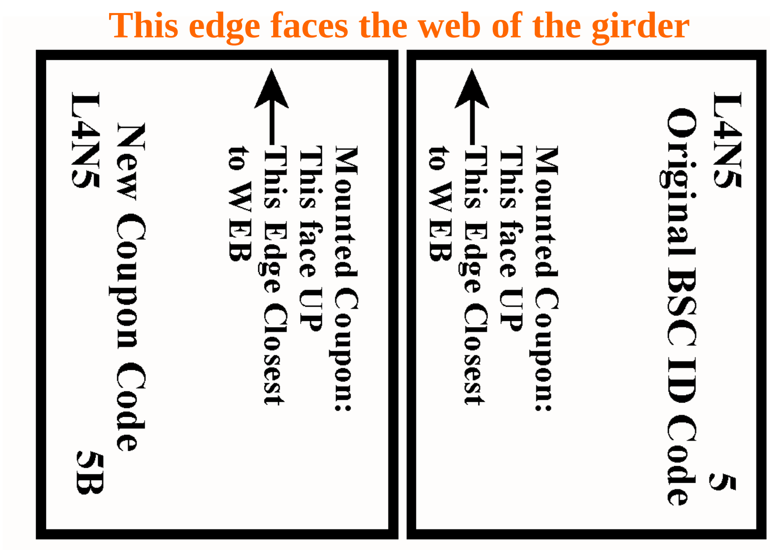


Figure 8. Mounting orientation of the 3" x 4" coupons on the Specimen Racks.

(b) Drill Identification Codes

Following shearing, each coupon received a 2-hole Drill Identification Code, and two mounting holes in the locations shown in Figure 9, and as can be seen in Photographs 9 and 10. A 3" x 4" stainless steel drill template was produced to accurately position the two mounting holes, and the two-hole Drill Identification Code. The Drill Identification Code followed the guidelines of ASTM G92, Standard Practice for Characterization of Atmospheric Test Sites, [7]. However the location of the holes was modified to suit the coupons being used. The template drawing, which is shown in Figure 10, contains four rows of holes, two labeled A, B and C, D and two labeled 1, 2, 3, 4, 5 and 6, 7, 8, 9, 10. The Coupon Drill Code for each coupon spans the ranges A1...A10, B1...B10, C1....C10, D1...D8, thereby covering the 38 coupons prepared, and as specified in Table II. The hole-size was 0.125". The two mounting holes were $^{7}/_{16}$" in diameter, which is larger than the $^{5}/_{16}$" holes in the Coupon Holders. The oversized mounting holes were to facilitate rubber grommets prior to mounting. The Drill Identification Code Template is stored at Old Dominion University.

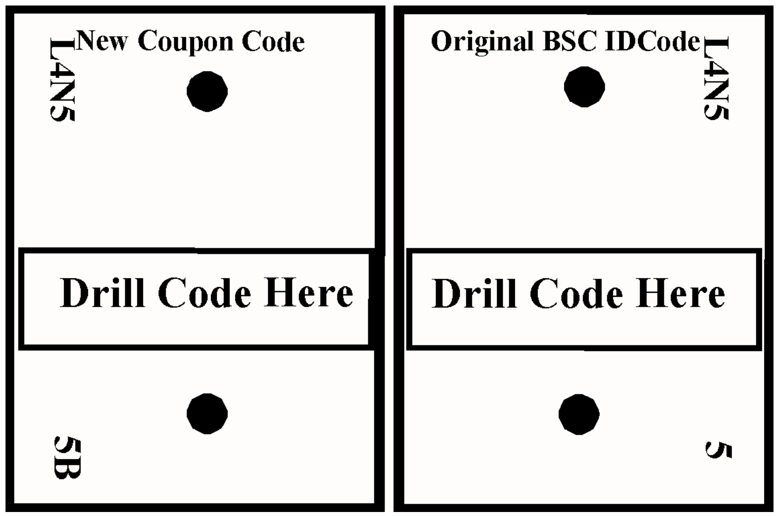


Figure 9. Location of the Coupon Drill Identification Code and two mounting holes.

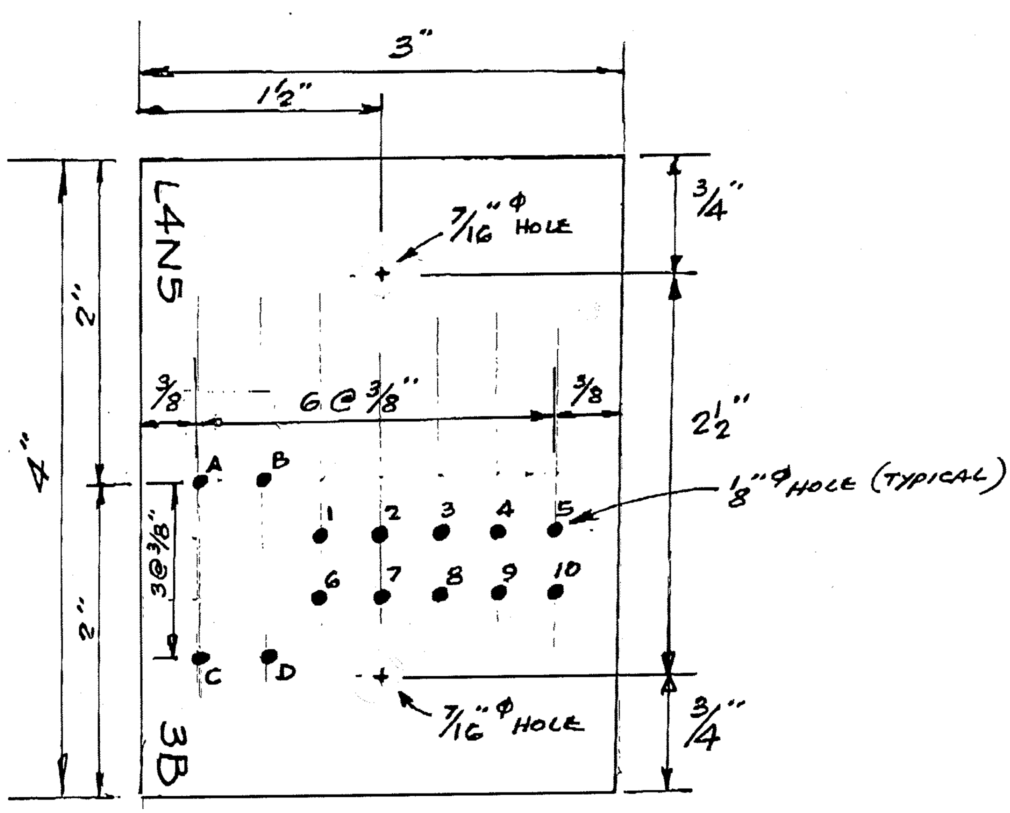


Figure 10. Drill Identification Code Template showing the location of the 4 rows of holes for Coupon Identification and the two mounting holes.

Coupon Measurement

Each coupon was measured prior to degreasing. The length, width (vernier) and thickness (micrometer) were measured to an accuracy of ±0.001". Two measurements were recorded for each length (L1 and L2), width (W1 and W2) and thickness (T1 and T2) at extreme positions on each coupon as shown Figure 11. The data is recorded in Table II.

The 38 coupons were ultrasonically degreased in acetone for 5 minutes and then weighed once (M1) to the nearest 0.001 g, using a calibrated electronic balance. The masses are recorded in Table II.

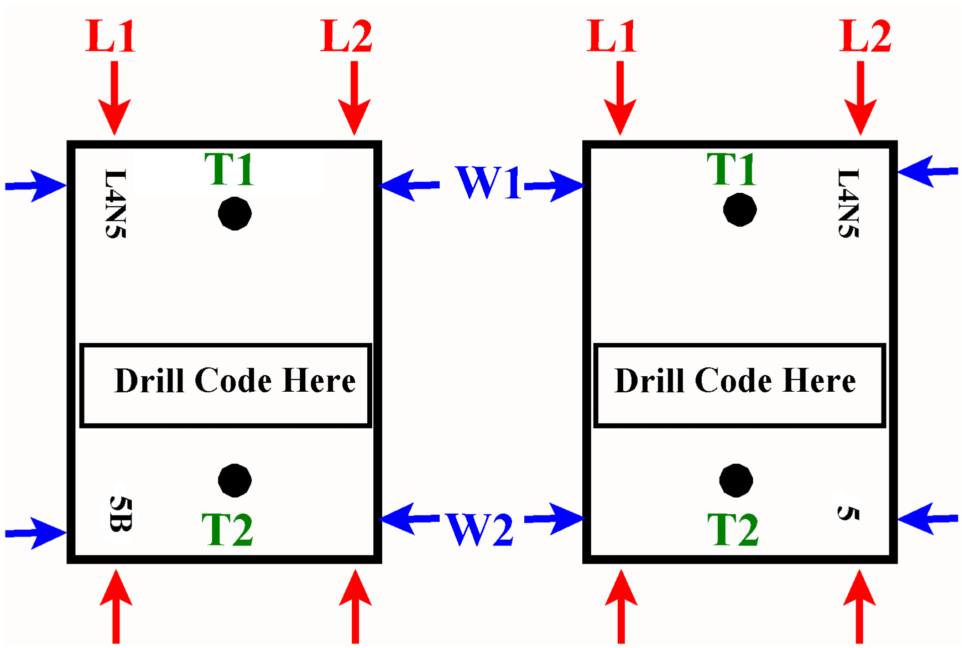


Figure 11: Coupon Measurement Locations: Lengths L1, L2, Widths W1, W2, Thickness, T1, T2.

Coupon Mounting

The total number of coupons mounted for exposure on Moore Drive Bridge was 36, those having Drill Identification Codes A1 - D6. They were mounted in triplicate on the 12 Coupon Holders, which were in turn bolted in their designated position to their appropriate Support Frame as described in Section 3. Rubber grommets were placed in the two mounting holes on each coupon to provide electrical isolation from the stainless steel mounting bolts and Coupon Holders. The positions of the three coupons on each Coupon Holder are designated left (L), center (C) and right (R) as shown in Figure 6. The three coupons on each Coupon Holder will be exposed for the same period, after which the Coupon Holder and the attached coupons will be removed for analysis. The two coupons at the L and R positions will be used for mass loss determination while that at the C position will be used for spectroscopic analysis. The two remaining coupons (D7, D8) were sent to Old Dominion University for storage and will be used as Mass References. Table II cross-references coupon numbers with their locations on the Specimen Racks. Also included in this table is the designated exposure time for each coupon, that being either 12, 24, 48, or 96 months. Table III also summarizes the locations of each coupon on each Specimen Rack.

Storage and Shipment

The above rack construction work was performed at the Homer Research Laboratories in the period July - September 2001. On 18 September 2001, the three completed Specimen Racks, with coupons mounted, were wrapped in waterproof paper, secured inside specially constructed wooden boxes. The Data-logging instrumentation was not mounted to the racks at this time. The boxes were shipped to Mr. Brian J. McMahon, NYSDOT Regional Structures Engineer, Rochester, NY. Instructions were to store the boxes inside in a building, to be protected from moisture, until 27 September 2001, when they would be mounted on the bridge.

Table II: Moore Drive Bridge: Coupon Identification and Location Codes, Dimensions, Masses and Exposure Schedule.

BSC Item #	BSC Coupon ID	New Coupon ID	MD Drill Code	Sample Dimensions (0.001") {23 August, 2001}						Sample Mass in g M1	Rack/Holder/Position			Exp. Time (mth)	Scheduled Date IN	Date In (Actual)
				L1 Length	L2	W1 Width	W2	T1 Thickness	T2		Rack #	Holder #	Position			
621	L4N5-3	L4N5-3	A1	3.989	3.996	3.006	2.983	0.115	0.114	163.974	1	1A	L	12	27 Sept. 2002	
		L4N5-3B	A2	3.999	3.990	2.989	3.024	0.114	0.113	163.901	1	1A	C	12	27 Sept. 2002	
622	L4N5-4	L4N5-4	A3	3.982	3.992	2.991	2.985	0.109	0.114	158.532	1	1A	R	12	27 Sept. 2002	
		L4N5-4B	A4	3.978	3.974	3.023	3.036	0.110	0.114	162.315	2	2A	L	12	27 Sept. 2002	
623	L4N5-5	L4N5-5	A5	3.986	3.995	2.998	2.989	0.114	0.115	162.044	2	2A	C	12	27 Sept. 2002	
		L4N5-5B	A6	3.988	3.981	3.012	3.034	0.114	0.115	164.275	2	2A	R	12	27 Sept. 2002	
624	L4N5-6	L4N5-6	A7	4.002	4.009	2.992	2.988	0.115	0.113	163.440	3	3A	L	12	27 Sept. 2002	
		L4N5-6B	A8	4.017	4.002	3.019	3.042	0.115	0.114	166.536	3	3A	C	12	27 Sept. 2002	
625	L4P5-1	L4P5-1	A9	3.989	4.001	2.996	2.990	0.105	0.108	152.357	3	3A	R	12	27 Sept. 2002	
		L4P5-1B	A10	3.993	3.991	3.001	3.017	0.103	0.107	150.520	1	1B	L	24	27 Sept. 2003	
626	L4P5-2	L4P5-2	B1	3.994	3.997	3.002	2.976	0.109	0.108	154.065	1	1B	C	24	27 Sept. 2003	
		L4P5-2B	B2	4.001	3.991	2.995	3.031	0.107	0.107	153.248	1	1B	R	24	27 Sept. 2003	
627	L4P5-3	L4P5-3	B3	3.997	4.007	3.003	2.985	0.109	0.106	153.613	2	2B	L	24	27 Sept. 2003	
		L4P5-3B	B4	4.007	3.992	2.994	3.028	0.107	0.109	153.362	2	2B	C	24	27 Sept. 2003	
628	L4P5-4	L4P5-4	B5	3.983	3.989	2.998	2.970	0.103	0.105	148.175	2	2B	R	24	27 Sept. 2003	
		L4P5-4B	B6	3.992	3.982	2.991	3.028	0.104	0.107	150.620	3	3B	L	24	27 Sept. 2003	
629	L4P5-5	L4P5-5	B7	3.981	3.982	3.000	2.975	0.106	0.106	149.767	3	3B	C	24	27 Sept. 2003	
		L4P5-5B	B8	3.988	3.975	2.989	3.030	0.106	0.107	152.768	3	3B	R	24	27 Sept. 2003	
630	L4P5-6	L4P5-6	B9	3.989	4.006	2.991	2.991	0.106	0.105	150.279	1	1C	L	48	27 Sept. 2005	
		L4P5-6B	B10	4.000	3.994	2.999	3.011	0.107	0.105	152.012	1	1C	C	48	27 Sept. 2005	
676	M4Q5-1	M4Q5-1	C1	3.979	3.990	2.982	2.979	0.117	0.116	164.111	1	1C	R	48	27 Sept. 2005	
		M4Q5-1B	C2	3.984	3.983	3.015	3.022	0.113	0.116	165.328	2	2C	L	48	27 Sept. 2005	
677	M4Q5-2	M4Q5-2	C3	3.985	3.993	2.999	2.985	0.116	0.116	165.380	2	2C	C	48	27 Sept. 2005	
		M4Q5-2B	C4	3.984	3.983	2.997	3.018	0.116	0.116	166.451	2	2C	R	48	27 Sept. 2005	
678	M4Q5-3	M4Q5-3	C5	3.972	3.984	3.002	2.989	0.117	0.113	163.013	3	3C	L	48	27 Sept. 2005	
		M4Q5-3B	C6	3.981	3.972	2.996	3.017	0.116	0.112	162.778	3	3C	C	48	27 Sept. 2005	
679	M4Q5-4	M4Q5-4	C7	3.988	3.997	2.997	2.981	0.114	0.117	165.001	3	3C	R	48	27 Sept. 2005	
		M4Q5-4B	C8	3.984	3.979	3.004	3.023	0.117	0.119	168.293	1	1D	L	96	27 Sept. 2009	
680	M4Q5-5	M4Q5-5	C9	3.984	3.999	2.99*	2.990	0.117	0.116	165.956	1	1D	C	96	27 Sept. 2009	
		M4Q5-5B	C10	4.000	3.984	3.006	3.016	0.118	0.117	168.557	1	1D	R	96	27 Sept. 2009	
681	M4Q5-6	M4Q5-6	D1	4.003	4.013	3.000	2.997	0.117	0.113	164.437	2	2D	L	96	27 Sept. 2009	
		M4Q5-6B	D2	4.013	4.003	2.996	3.014	0.117	0.113	166.837	2	2D	C	96	27 Sept. 2009	
682	M4L2-1	M4L2-1	D3	3.988	3.991	2.995	3.002	0.113	0.116	136.664	2	2D	R	96	27 Sept. 2009	
		M4L2-1B	D4	3.994	3.982	3.016	3.015	0.110	0.114	162.383	3	3D	L	96	27 Sept. 2009	
683	M4L2-2	M4L2-2	D5	3.985	3.996	2.992	2.975	0.116	0.118	165.903	3	3D	C	96	27 Sept. 2009	
		M4L2-2B	D6	3.990	3.985	3.015	3.039	0.115	0.116	166.710	3	3D	R	96	27 Sept. 2009	
684	M4L2-3	M4L2-3	D7	4.030	4.047	2.998	2.979	0.117	0.114	166.616				0	At ODU	
		M4L2-3B	D8	4.034	4.029	3.000	3.032	0.116	0.112	166.925				0	At ODU	

Table III: Moore Drive Bridge Coupon Exposure Project: Coupon Position on Sample Racks.

Exposure Coupons, Coupon Holder and Specimen Rack Location.
Refer Figures 2-6 for more details

Specimen Rack 1: Location MD_3CN (22' from West Abutment) (Refer Figure 12)

Sample Holder 1A (12 months)			Sample Holder 1B (24 months)			Sample Holder 1C (48 months)			Sample Holder 1D (96 months)		
L	C	R	L	C	R	L	C	R	L	C	R
L4N5-3 A1	L4N5-3B A2	L4N5-4 A3	L4P5-1B A10	L4P5-2 B1	L4P5-2B B2	L4P5-6 B9	L4P5-6B B10	M4Q5-1 C1	M4Q5-4B C8	M4Q5-5 C9	M4Q5-5B C10

Specimen Rack 2: Location MD_3DN (55' from West Abutment) (Refer Figure 12)

Sample Holder 2A (12 months)			Sample Holder 2B (24 months)			Sample Holder 2C (48 months)			Sample Holder 2D (96 months)		
L	C	R	L	C	R	L	C	R	L	C	R
L4N5-4B A4	L4N5-5 A5	L4N5-5B A6	L4P5-3 B3	L4P5-3B B4	L4P5-4 B5	M4Q5-1B C2	M4Q5-2 C3	M4Q5-2B C4	M4Q5-6 D1	M4Q5-6B D2	M4L2-1 D3

Specimen Rack 3: Location MD_3MN (35½' from East Abutment)(Refer Figure 13)

Sample Holder 3A (12 months)			Sample Holder 3B (24 months)			Sample Holder 3C (48 months)			Sample Holder 3D (96 months)		
L	C	R	L	C	R	L	C	R	L	C	R
L4N5-6 A7	L4N5-6B A8	L4P5-1 A9	L4P5-4B B6	L4P5-5 B7	L4P5-5B B8	M4Q5-3 C5	M4Q5-3B C6	M4Q5-4 C7	M4L2-1B D4	M4L2-2 D5	M4L2-2B D6

Reference Samples: (Stored at Old Dominion University)

Samples sent to ODU for Reference	
M4L2-3 D7	M4L2-3B D8

4. Corrosion Monitors

Corrosion coulometers were installed (2 instruments) on each of the three Specimen Racks as shown in Figure 2. They were attached to the Datalogger Base Plate, Photographs 7, 8 with two by large hose clamps, Photographs 12, 19, 23 and 24. The technology of their operation has been described in References 8-10. The devices were designed to obtain atmospheric corrosion data every six minutes, to average 10 consecutive measurements and to store the data each hour. The result is 24 data points per day for up to 18 months before resetting the instrument for additional datalogging. Detailed corrosion information is obtained which can be correlated to specific events affecting atmospheric or other environmental influences on corrosion, such as deicer application or wet conditions.

The instruments installed at Moore Drive were modified with an additional circuit board to accommodate extra batteries for the long-term, harsh (winter) application. Lithium batteries were selected based upon their package energy density and superior performance at low temperatures relative to typical alkaline batteries. The estimated battery life of the six 9-volt parallel battery package is over 1 year in the outdoor Rochester, NY, environment. Isolating diodes were used to prevent cross-discharging of the parallel batteries. This battery package fit within the original instrument case.

The steel sensor elements of the corrosion coulometers were fabricated from a steel material similar to Type A588 steel. Elemental analysis of the material showed the material to be similar, but not identical to A588 material. Calculations by H. Townsend, based upon elemental composition, indicated that the material would exhibit corrosion behavior similar to A588 material. The unavailability of thin-gauge weathering steel material dictated the use of this sensor material. The material has been used previously, [9]

Prior to placement of the sensors, the steel and copper surfaces were lightly abraded with individual ScotchBrite pads and alcohol-wiped to ensure clean surfaces at the beginning of the exposure tests.

5. Specimen Rack Installation

The three Specimen Racks were installed on the Moore Drive Bridge on Thursday 27 September 2001, under the supervision of HPS Corrosion Advisory Group members Desmond Cook and Richard Granata. The specimen racks were removed from their boxes, coupon locations on each rack verified and the dual Corrosion Monitor Dataloggers mounted and tested. The Girder Drilling Template was used for drilling holes (6 per rack) in the web and the three Specimen Racks were mounted, Photograph 12. Workers from Rochester NYSDOT performed all mounting, in about 4 hours. Traffic control was required with the right lane of I-390S being closed for drilling and mounting of Racks 1 and 2 at the West abutment. Details are provided below.

The three Specimen Racks were mounted on the north side of the web of Girder 3, at the general locations 3CN, 3DN and 3MN shown in Figure 1 and more specifically at the locations shown in Figures 12-13. Mounting holes were drilled for racks 1 and 2 (locations 3C and 3D respectively) at the West abutment, while the racks were kept in the support vehicle on the roadway, to protect the coupons from excessive airborne dust and corrosion material dislodged during drilling. Loose rust was removed from the web around the mounting holes and the racks hoisted to their location, Photographs 13, 14. Waterproof caulking was applied in and around the 6 holes in the web to prevent water from seeping between the Weathering Steel web and the stainless steel mounting flanges. The racks were bolted securely to the web and additional caulking was applied to the upper surfaces of the mounting flanges joining to the web, Photograph 15. The same procedure was used for mounting rack 3 to girder 3 at the East abutment. The upper surface of the coupons was 9 ½" above the upper surface of the lower flange for each rack.

Specimen Rack 1: Location Code 3CN; exactly 22' 0" from the end of girder 3 at the **West Abutment** to the center of the rack. The rack was positioned between the second Intermediate Stiffener on the north web and the first Intermediate Diaphragm, from the west end, which spans girders 2 and 3 and as shown in Figure 12, Photographs 15, 16. This rack was located above the lower section of the sloped stone block paving at the West Abutment.

Specimen Rack 2: Location Code 3DN; exactly 55' 0" from the end of girder 3 at the **West Abutment** to the center of the rack. This is 5 ½ east of the second Intermediate Diaphragm, which spans girders 2 and 3 as shown in Figure 12, Photograph 17. The rack is positioned above the center of the right lane of I-390 South, Photograph 18. The vertical distance from the paved road surface to the upper surface of the lower flange was measured to be 16' 4" at the center of the rack.

Specimen Rack 3: Location Code 3MN; exactly 35' 6 ½" from the end of girder 3 at the **East Abutment** to the center of the rack. The rack was positioned between the first and second Intermediate Diaphragms on the north web, from the east end, which spans girders 2 and 3, as shown in Figure 13, Photographs 19 - 21. This position is over the jogging path along the edge of the Erie Canal, Photograph 22. It is mentioned that the originally planned location for this Rack 3 was 22' from the East Abutment to mirror the location of Rack 1 at the West Abutment. However, due to the vandalism at this end of the bridge, mainly graffiti, and the ease at which people can step up to and walk along the bottom flanges, it was decided to move the rack as far as practicable from the abutment, that being at the edge of the canal. Placing the rack to the west side of the first Intermediate Diaphragm increases the difficulty of vandalism to the rack. NYSDOT cut the “grab bars” off the side of the girder to reduce vandalism. The vertical distance from the paved jogging path to the upper surface of the lower flange was measured to be 15' 8" at the center of the rack

6. Additional Measurements

At the time the Specimen Racks were mounted to the Moore Drive Bridge, flange thickness measurements were recorded and rust samples collected. These procedures should be repeated following each exposure period.

Thickness Measurements

During the eight-year coupon exposure project, thickness measurements will be taken on girder 3 in the vicinity of the Specimen Racks and Drip Bars. Thickness measurements have previously been recorded for girders 1, 2, and 4 on 9-10 September 2000, the data from which is found in a separate report, [6].

Thickness measurements were recorded, at the following locations on Thursday 27 September 2001 during the Specimen Rack installation. The data and analysis will be presented in the future report that will cover the first 12 months of coupon exposure. The thickness of the lower flange on the north side of girder 3 was measured at the specified locations using an Electromatic Equipment Co., Model TI-14 Ultrasonic Wall Thickness Gauge. This instrument is owned by AISI and is the same one used for the May 14, 1997 and May 10, 1999 inspections of the Doullut Canal Bridge, Louisiana, [11, 12]. Typically, measurements were made in triplicate with gauge calibration being repeated for each new location. The thickness measurements were made on the lower flange, at positions 30" to the left and right of the centerline of each Specimen Rack, Photographs 15, 16, 20, 22. These positions are on the flanges directly below each end of the Specimen Racks. To facilitate consistent thickness measurements of the steel only, the rust on the flange was removed using a 9" grinding disk on a power drill. Typically a 3" - 4" diameter region of rust was removed from the upper surface only of the flange about 9" in from the outer flange edge towards the web. Only light grinding was required for consistent measurements. It is estimated that only about 10% bright steel was showing at the center of the grind region. Often a series of (3 - 5) measurements were taken at the center of the grind region as well as 1" - 2" towards the edge of that region which contained a 100% coverage of very thin rust. The grinding, and thickness measurements were performed after the mounting holes were drilled through the web but before the Specimen Racks were mounted. This prevented contamination of the coupons from rust dispersed due to the grinding.

Additional flange thickness measurements were made on girder 3 at the locations of the drip bars at the West and East abutments. These measurements also replicate those taken at drip bar locations on girders 1, 2, and 4 on September 9, 2000. The upper and lower drip bars were removed from the north side of girder 3 at locations 3BN (west abutment) and 3KN (east abutment). The flange steel was still bright under each drip bar, showing no signs of corrosion. Two sets of thickness measurements were taken at each drip bar location, the outer region, 1" in, and the inner region, 15" in, from the flange edge. The drip bars were then bolted back onto girder 3.

Additional thickness measurements will be taken at each Specimen Rack location at the time of removal of each Coupon Rack following 12, 24, 48, and 96 months exposure. Thickness measurements will be repeated at the same flange positions at the end of each rack, as well as at a new position on the flange directly beneath the removed Coupon Rack. Thickness measurements will also be repeated at the Drip Bar locations at each abutment.

Rust Collection

Rust samples were collected from the flange and web on the north side of girder 3, at the locations of the three Specimen Racks and the drip bars at the two abutments. Spectroscopic and chemical analysis of these samples will be undertaken to compare with the data from samples collected from the other three girders in September 2000, and to be compared with the analysis of the coupons that will be removed after each exposure period.

At the times of removal of the Coupon Racks following 12, 24, 48, and 96 months exposure, rust scrapings will be collected from the thickness measurement locations at each Specimen Rack. This will provide information on the actual flange corrosion since the time of initial grinding on September 27, 2001.

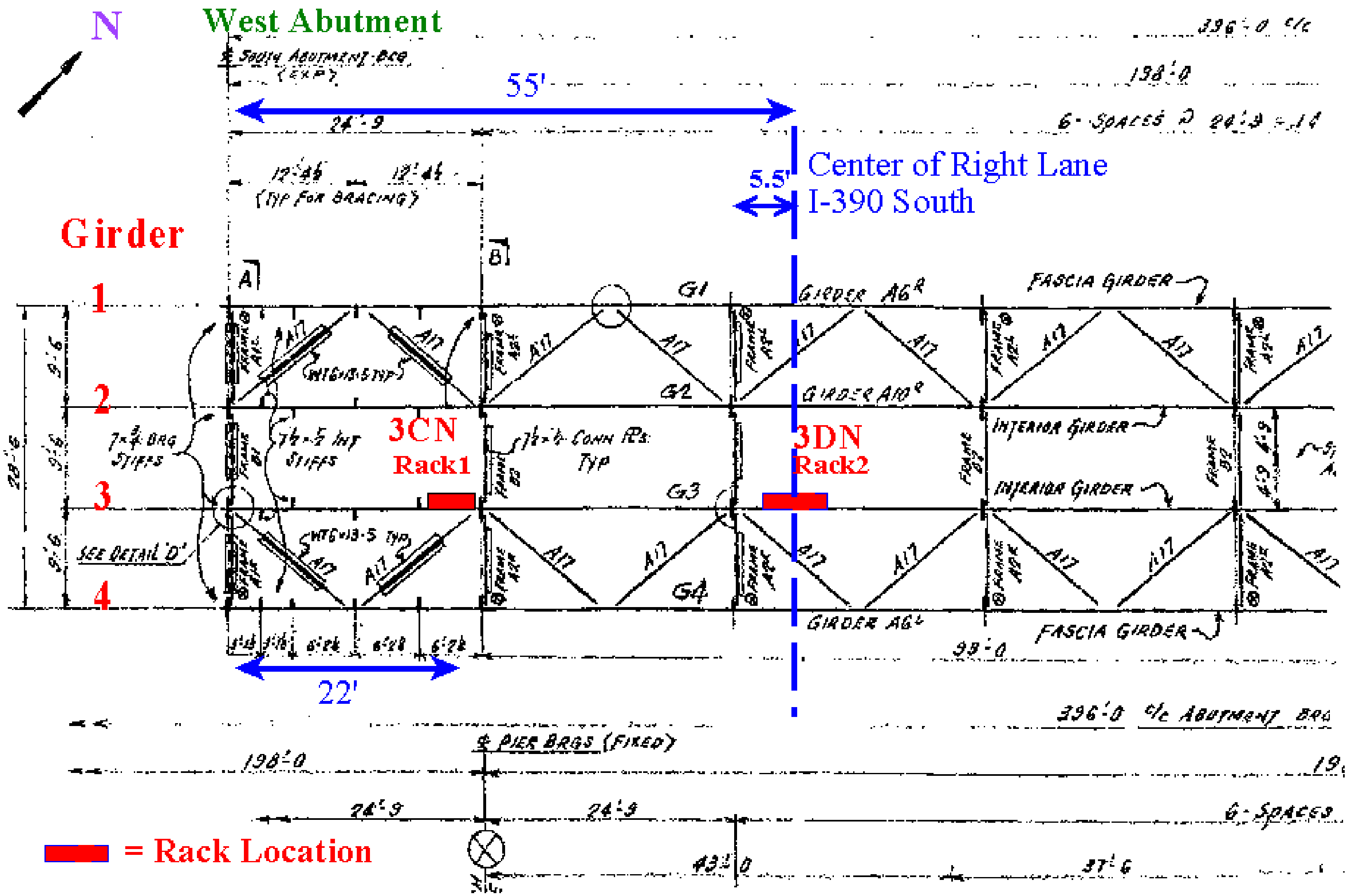


Figure 12: Moore Drive Bridge, west abutment Specimen Rack locations on girder 3, north side.

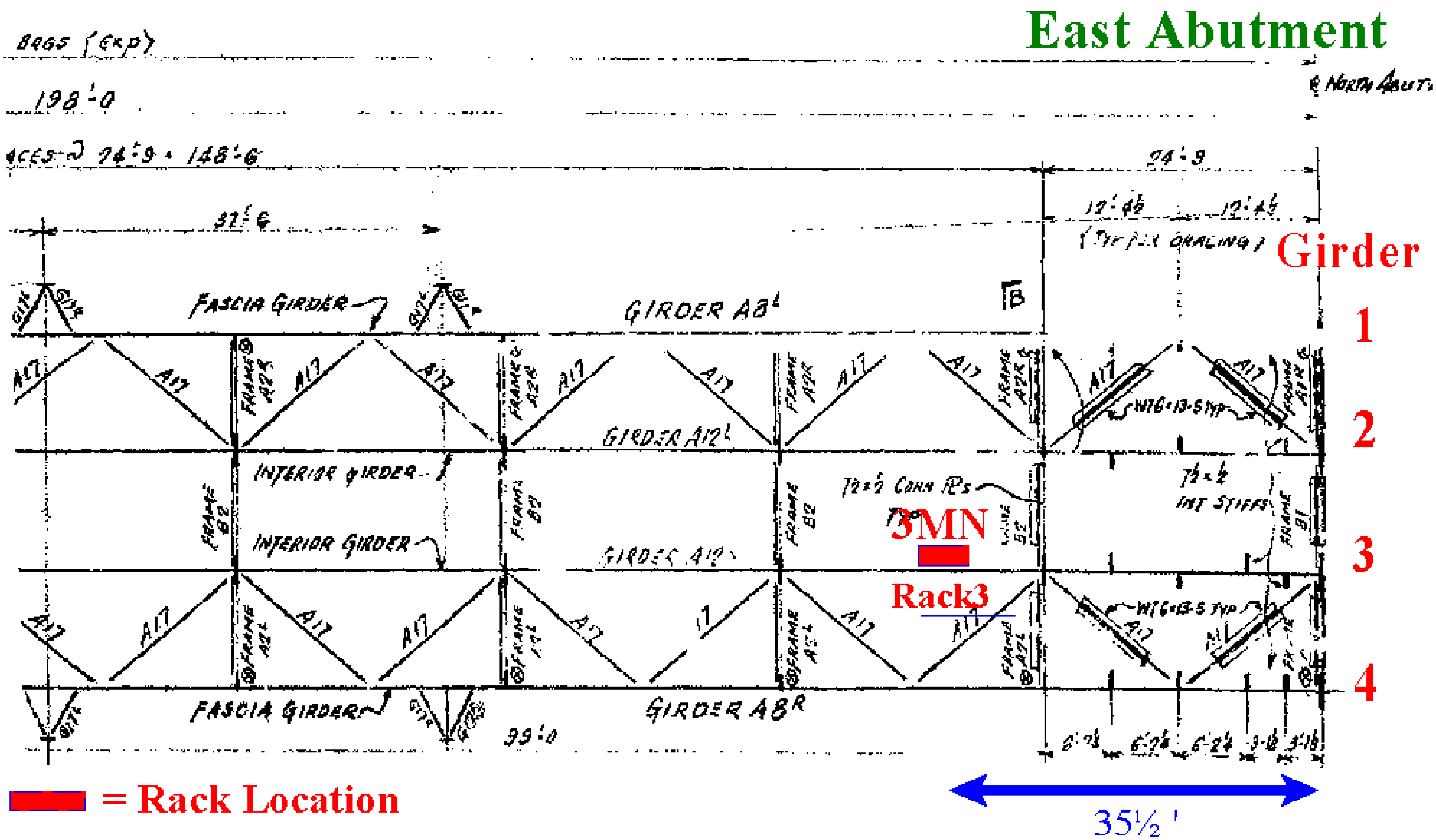


Figure 13: Moore Drive Bridge, east abutment Specimen Rack locations on girder 3, north side.

7. Bibliography

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10. Update on Applications of Corrosion Coulometers, R. D. Granata, J. W. Fisher and J. C. Wilson, NACE International Paper Number 307, Corrosion 97 Annual Conference and Exhibition.

11. Corrosion Monitoring Program, Route #23 over Doullut Canal Bridge at Empire, Louisiana. Second Interim Report, Robert L. Nickerson. September 19, 1997. AISI.

12. Corrosion Monitoring Program, Route #23 over Doullut Canal Bridge at Empire, Louisiana. Third Interim Report, Robert L. Nickerson. May 10, 1999. AISI.

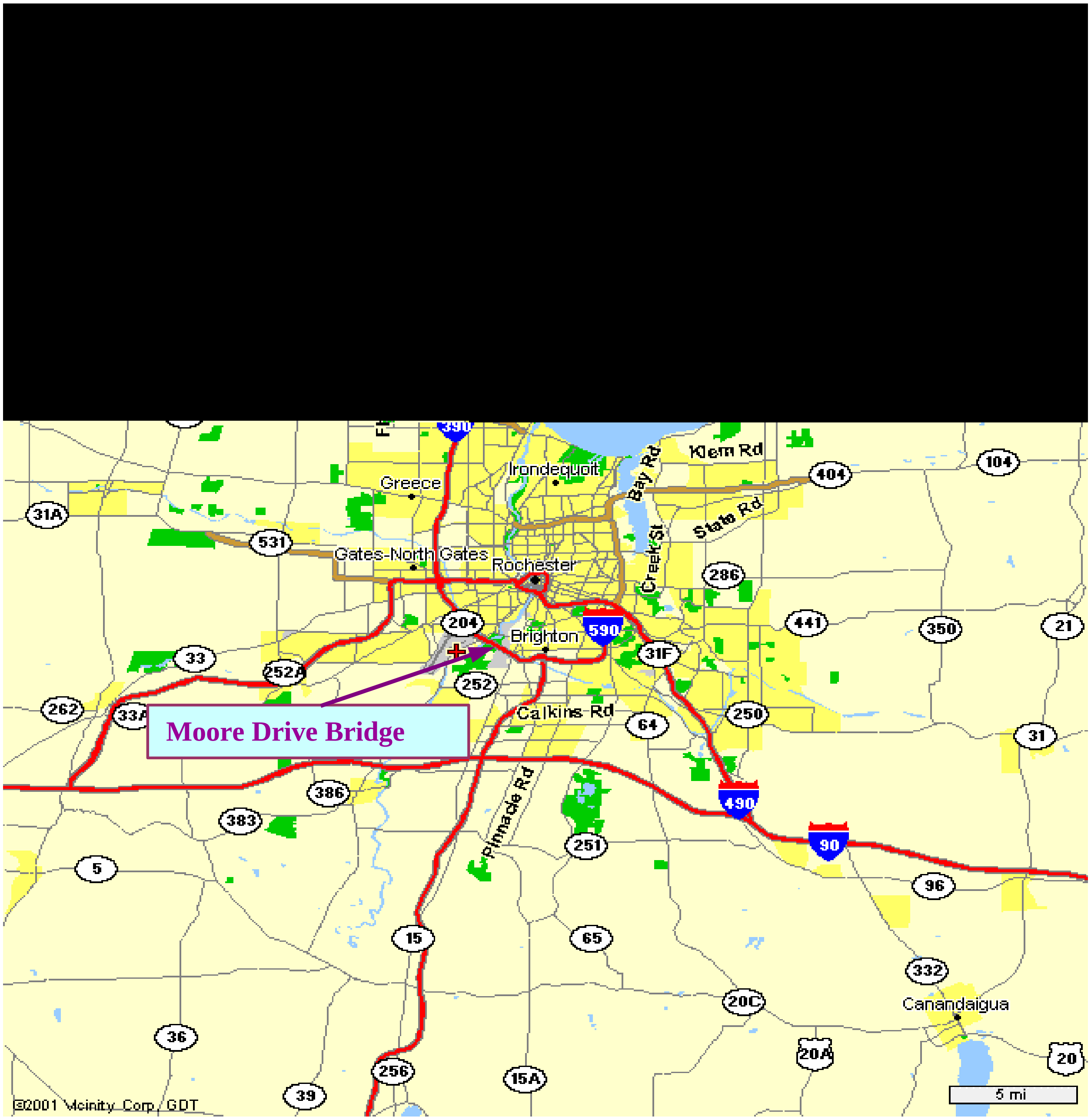
Appendix A: Moore Drive Bridge Location Maps

This section contains maps for locating the Moore Drive Bridge over Interstate I-390, Rochester NY.

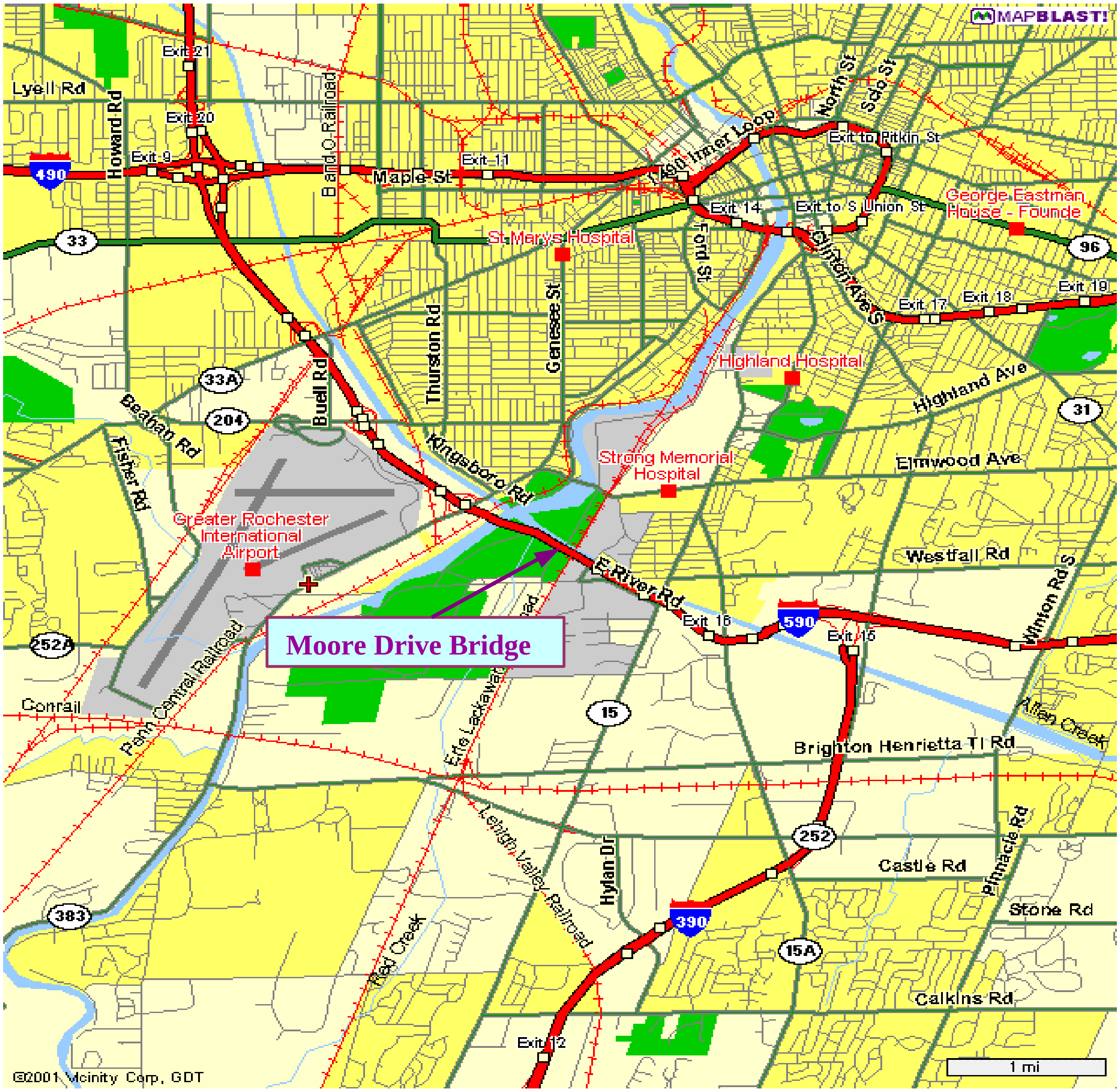
For readers accessing this report on-line, the maps are interactive. Click on the location of Moore Drive Bridge, close to the Rochester International Airport (ROC), to zoom in.

Table IV: List of Maps.

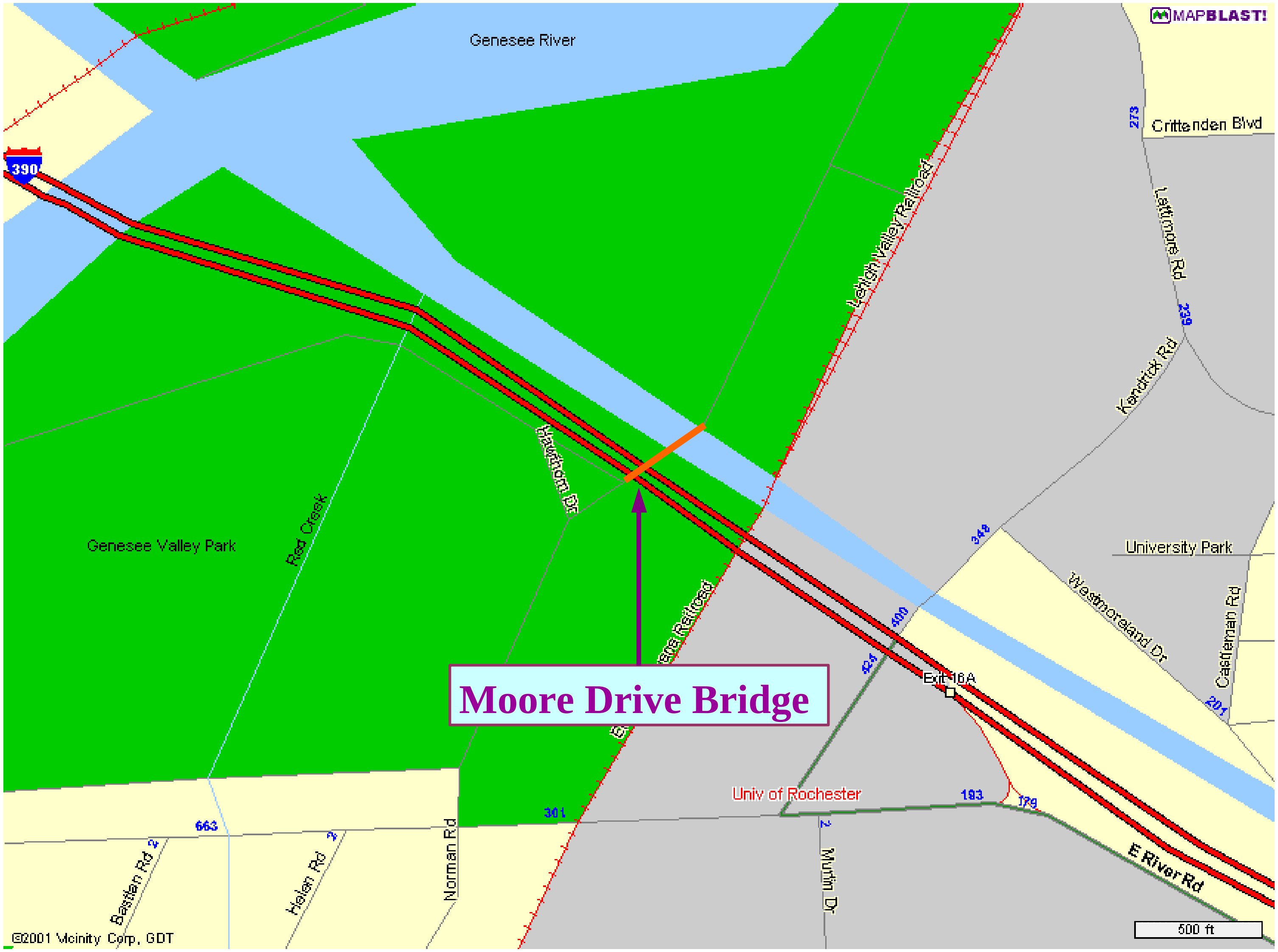
Bridge Maps	
Map #	**Topic**
1	Rochester, NY showing I-390 ring-road
2	Moore Drive Bridge over I-390 near airport
3	Moore Drive Bridge across I-390 and Erie Canal



Map 1. Rochester, NY. Moore Drive Bridge located by arrow.



Map 2. Moore Drive Bridge located over I-390 between Rochester Airport and the University of Rochester.



Map 3. Moore Drive Bridge located over I-390 and the Erie Canal.

Appendix B: Rack and Installation Photographs

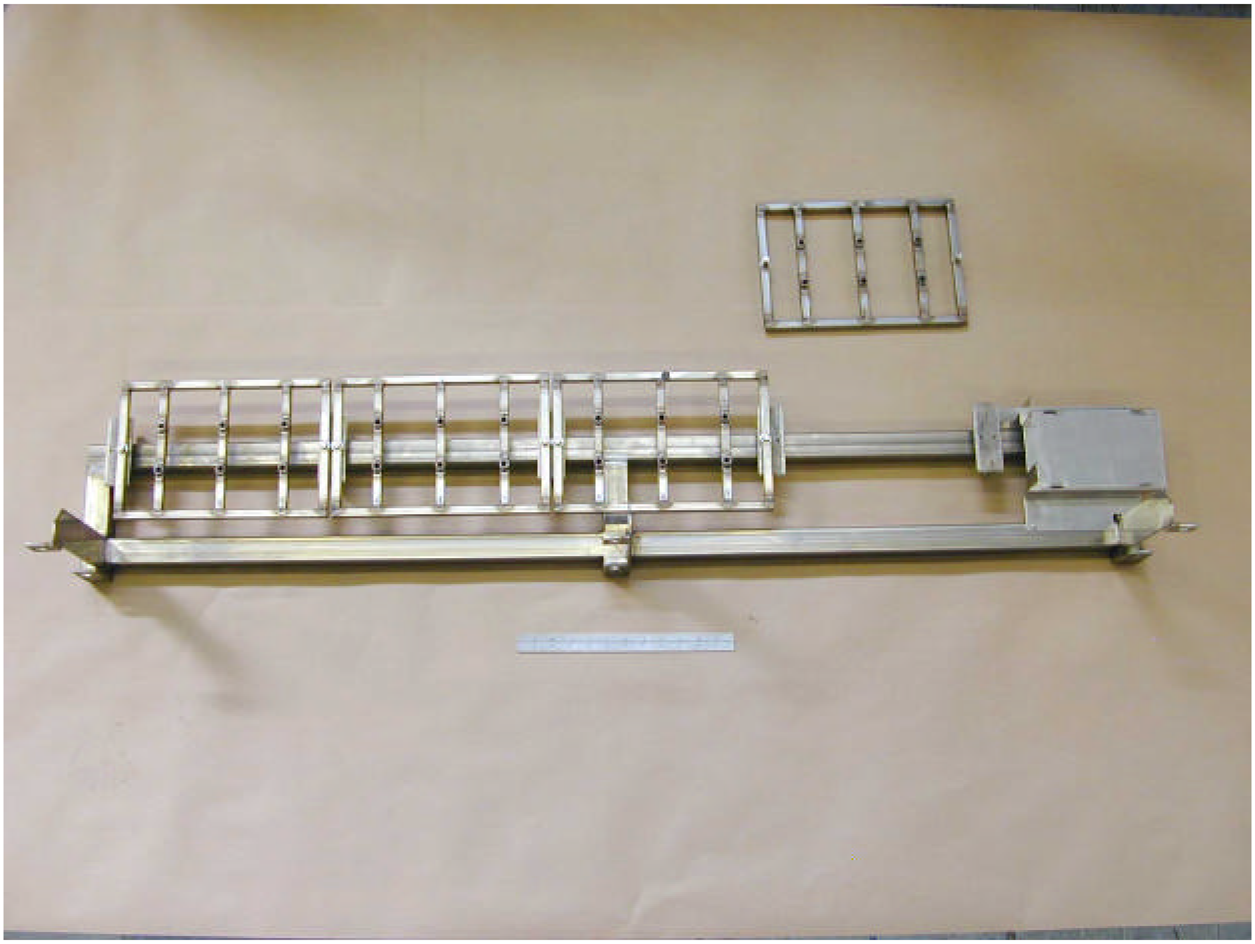
Photographs taken during Specimen Rack construction (at Homer Research Laboratories) and during bridge installation are included in this section. They are referenced throughout this report.

Table V: List of Photographs.

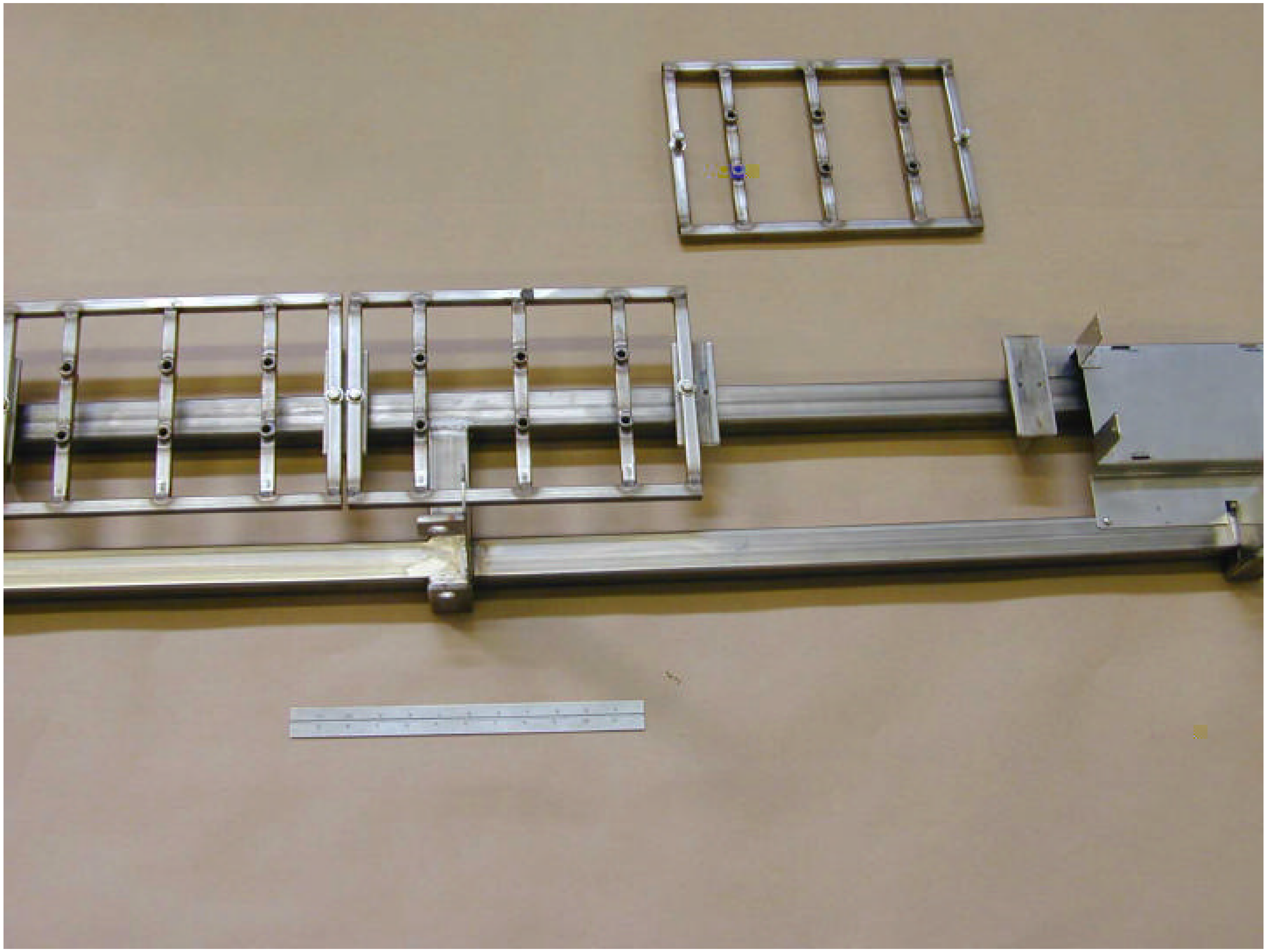
Bridge Photographs		**Specimen Rack Installation**	
Photograph #	**Topic**	**Photograph #**	**Topic**
1	Bridge from I-390 S	12	Rack 2 ready for mounting
2	Corrosion of Girder 4 at 4GN	13	Rack 2 being hoisted
Specimen Rack Construction		14	NYSDOT “Skeletons” snatch the rack
Photograph #	**Topic**	15	Rack 1 mounted
3	Rack with Coupon Holders	16	Rack 1 mounted (end view)
4	Rack with Coupon Holders (zoom)	17	Rack 2 mounted (end view)
5	Rack 2 with Coupons	18	Rack 2 location above lane 1 (I-390S)
6	Rack 2 with Coupons (zoom)	19	Rack 3 mounted
7	Rack 2 with Datalogger plate	20	Rack 3 mounted (end view 1)
8	Rack 2 with Datalogger plate (end view)	21	Rack 3 mounted (end view 2)
9	Rack 2, Coupon Holder 2A, Coupon mounting and Drill Codes	22	Rack 3 mounted (with Erie Canal)
10	Rack 2, Coupon Holder 2B, Coupon mounting and Drill Codes	23	Corrosion Monitor Datalogger (Rack 3)
11	Rack design and construction team	24	Corrosion Monitor Datalogger (top view, Rack3)

Photograph 1:
Moore Drive Bridge, Rochester NY, viewed along I-390 S. Visible is one half of the 396' bridge. The West abutment is to the right and Pier (mid-bridge) is to the left. The Erie Canal (not visible) is to the left of the Pier. The East abutment is on the far side of the canal.

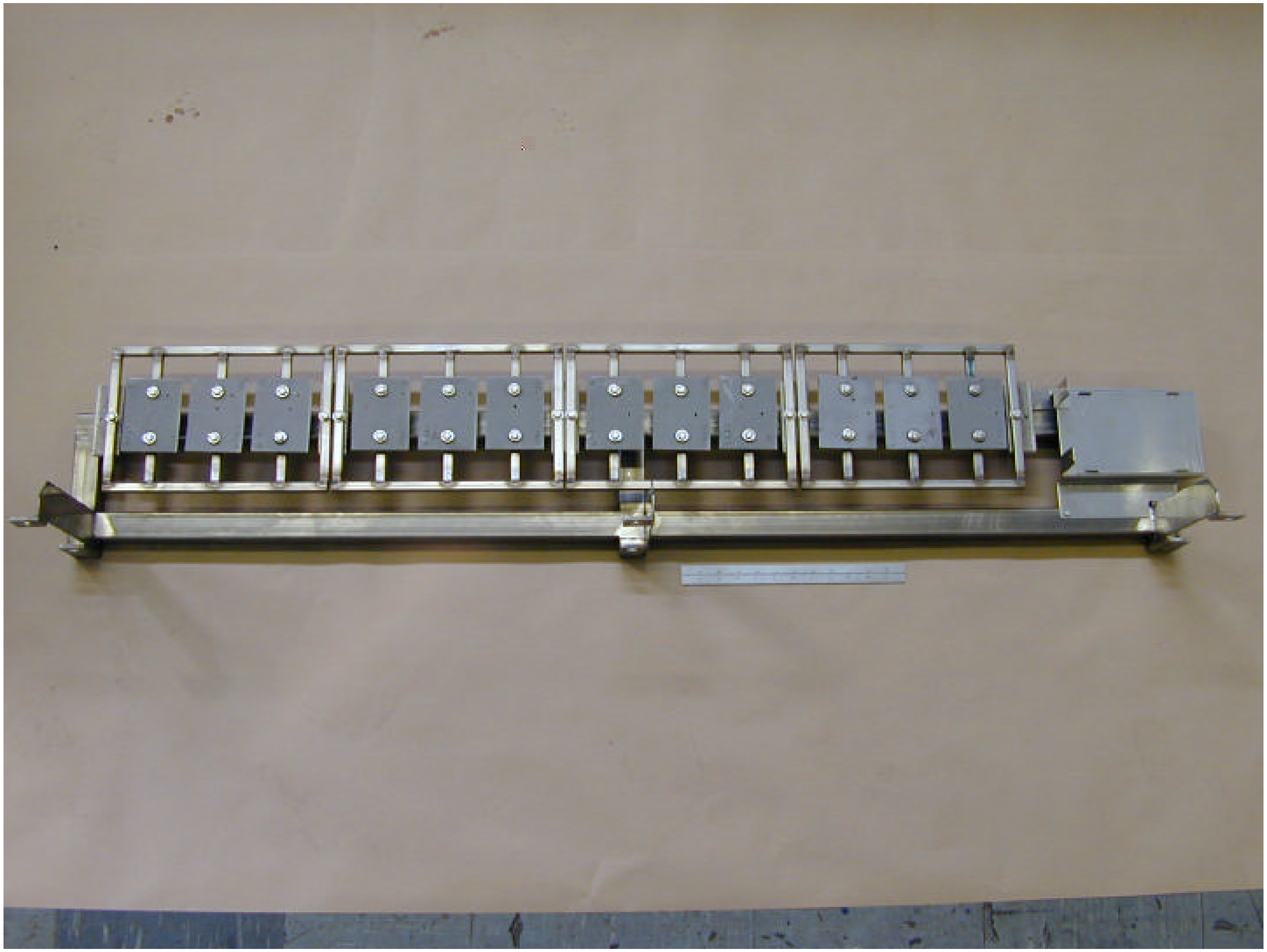
Photograph 2:
Moore Drive Bridge, Rochester NY. Corrosion of Girder 4 north web and bottom flange at location 4G (above center lane of I-390 N).



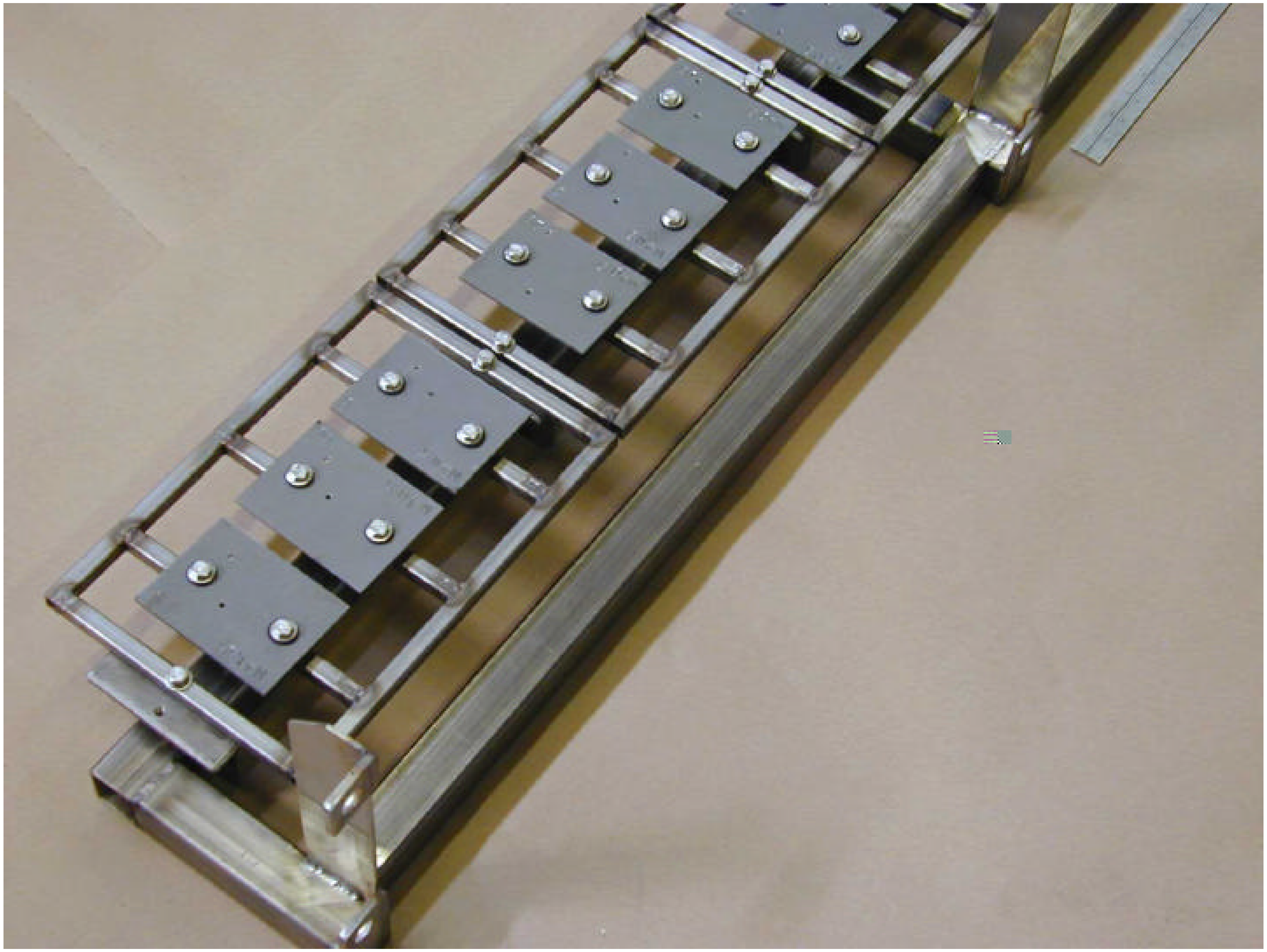
Photograph 3:
Specimen Rack comprising of Support Frame, 4 Coupon Holders and Datalogger Base Plate.



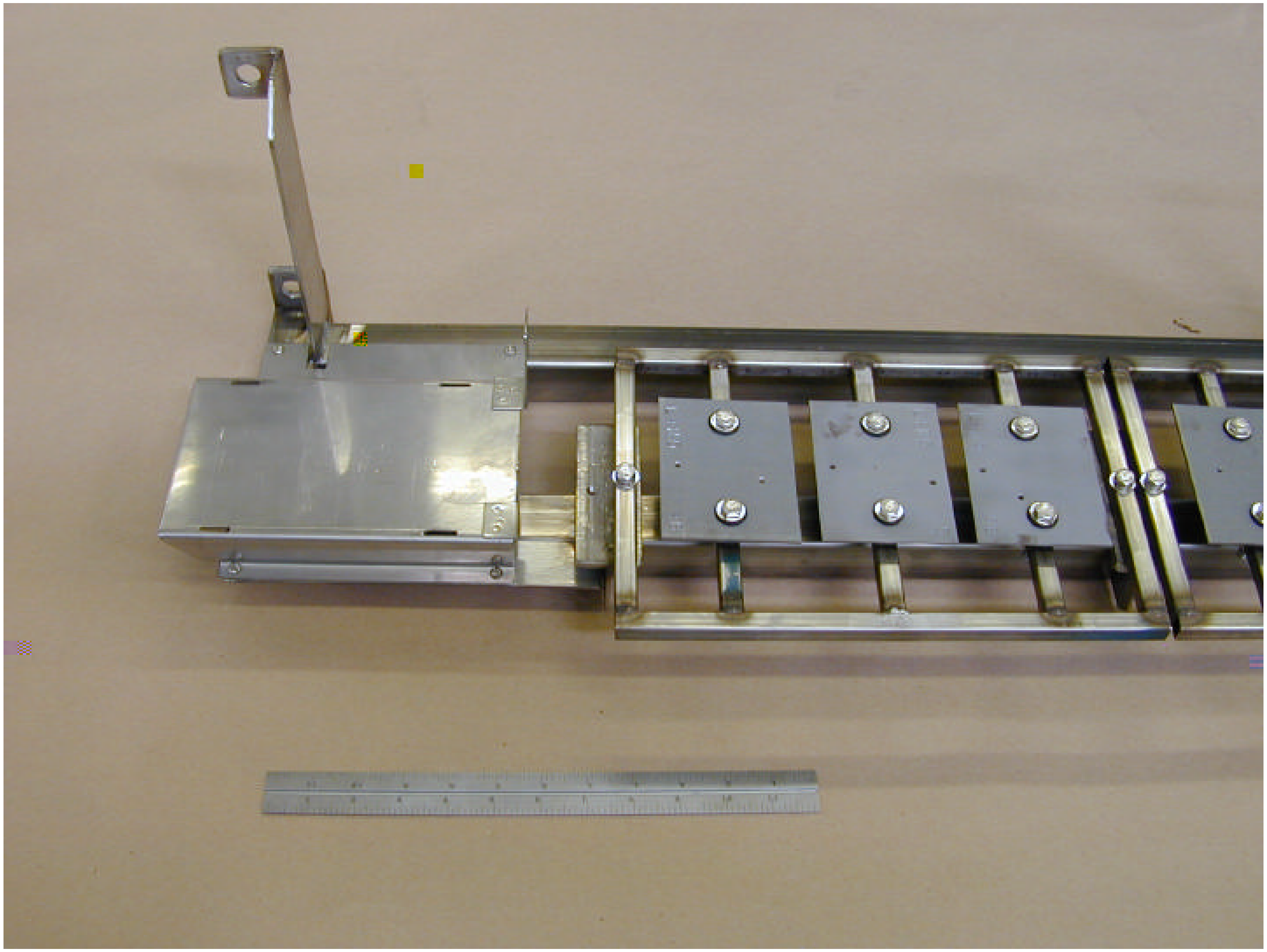
Photograph 4:
Specimen Rack showing detachable Coupon Holder.



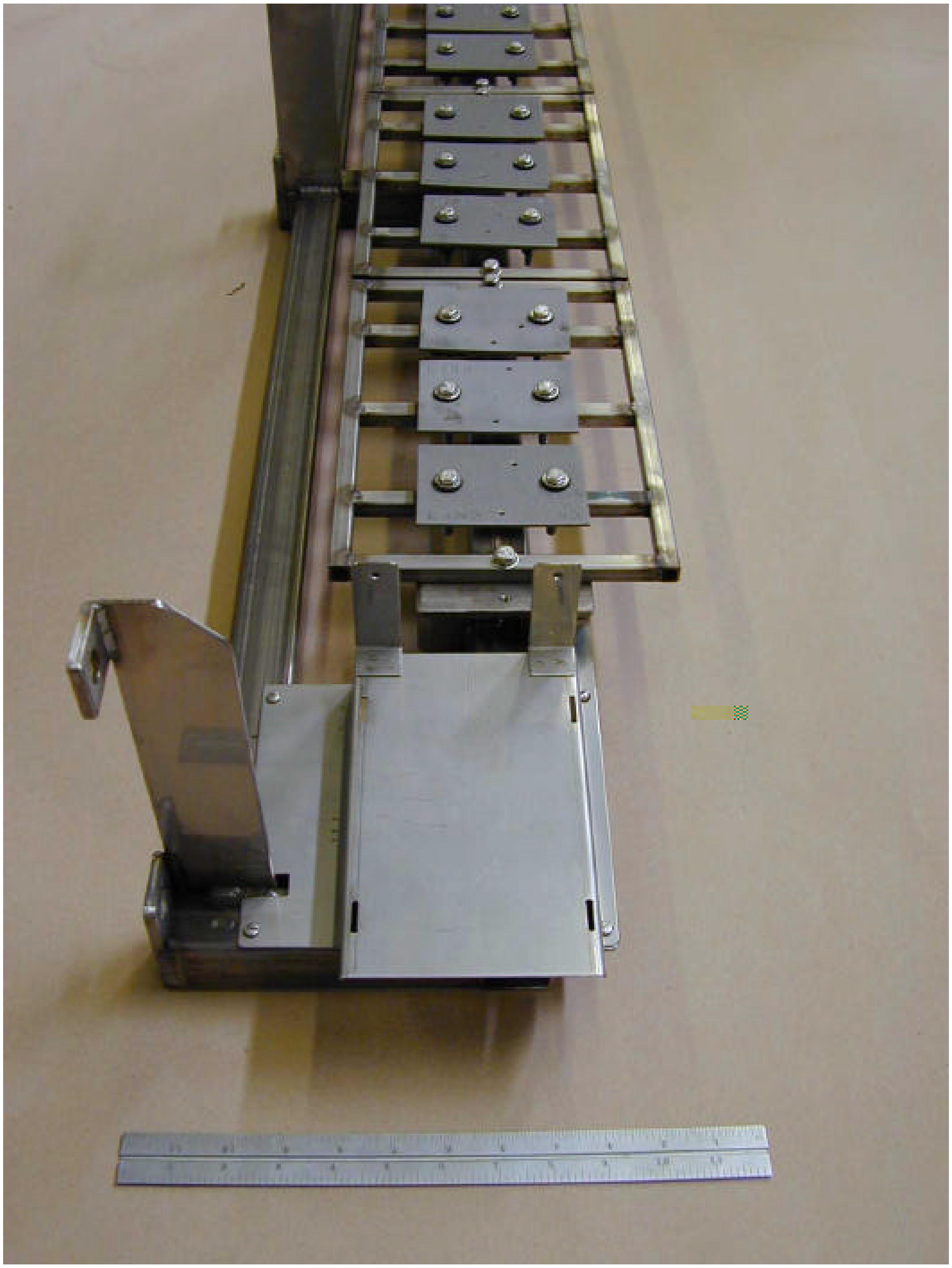
Photograph 5
Specimen Rack 2 with 12 coupons mounted on 4 detachable Coupon Holders.



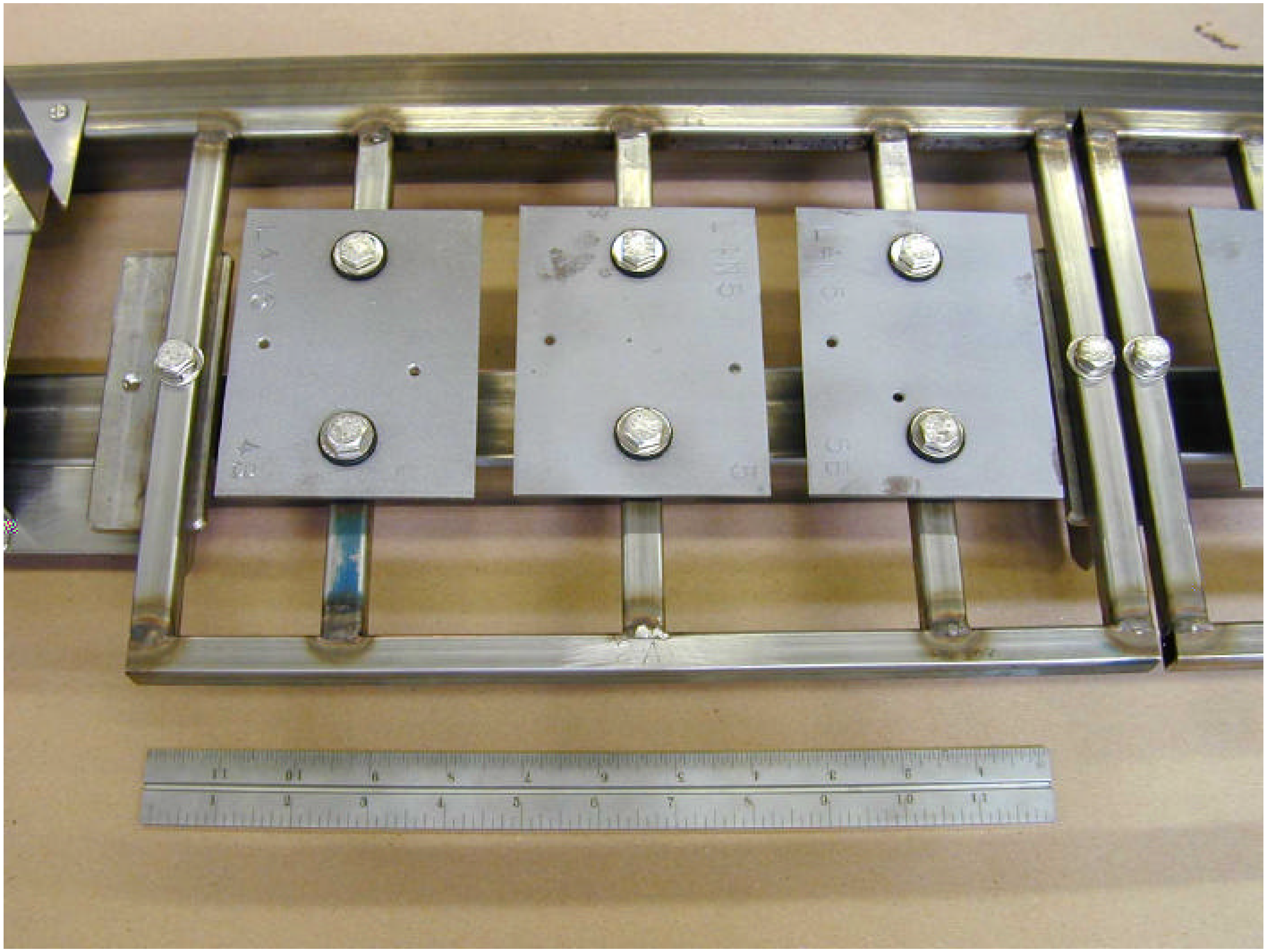
Photograph 6
Specimen Rack 2 with Coupon Holders 2C and 2D.



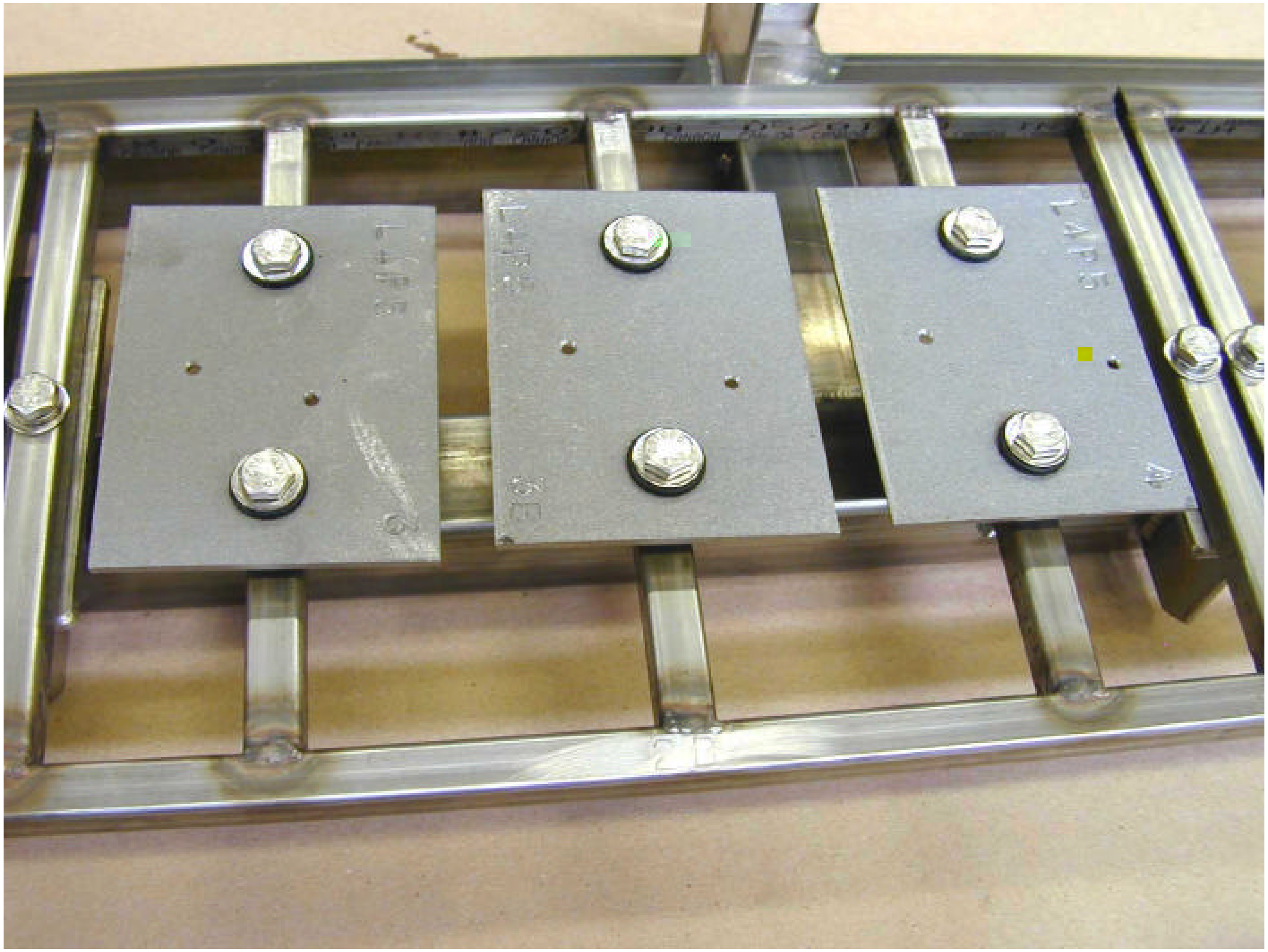
Photograph 7
Specimen Rack 2 showing Datalogger Base Plate and Coupon Holder 2A.



Photograph 8
Specimen Rack 2 showing Datalogger Base Plate.



Photograph 9
Specimen Rack 2 with Coupon Holder 2A, showing Drill Identification Codes.



Photograph 10:
Specimen Rack 2 with Coupon Holder 2B, showing Drill Identification Codes.

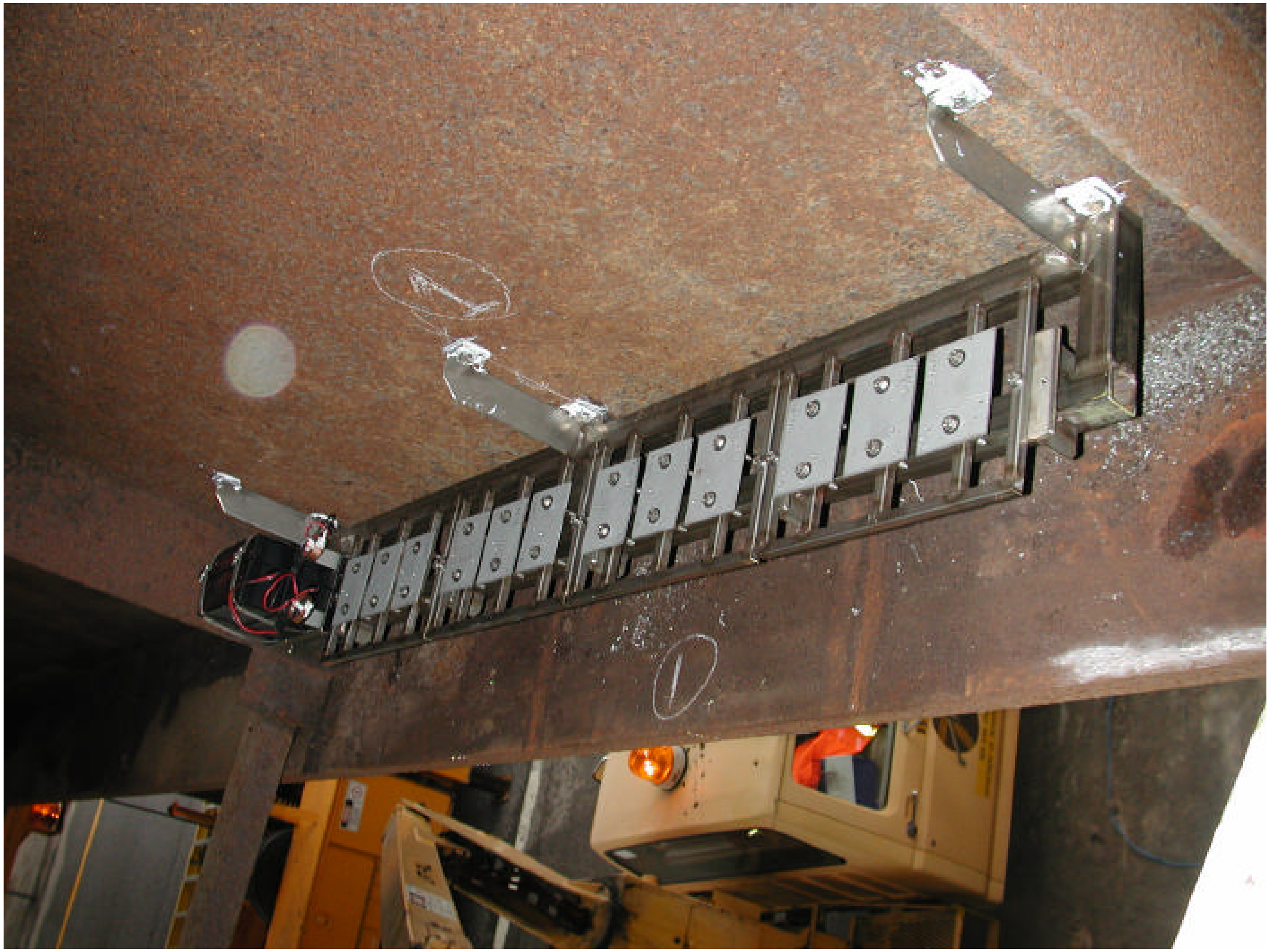
Photograph 11:
Specimen Rack construction team (Homer Research Laboratories).
L to R: Mike Erle (machine shop), Charlie Gorman (CAG Chair), Rich Doll (welding), Al Nestler (rack drawings and coordinator). Absent: Jay Hoffman (coupon measurement).

Photograph 12:
Specimen Rack 2 ready for installation with Corrosion Monitors attached. Taken at Moore Drive Bridge, West Abutment.

Photograph 13:
Specimen Rack 2 being hoisted up to Girder 3.

Photograph 14:
Specimen Rack 2 being snatched by NYSDOT "skeletons".

Photograph 15:
Specimen Rack 1 installed. White caulking is seen at the mounting holes. Thickness measurement positions are on the flange below each end of the rack.



Photograph 16:
Specimen Rack 1 installed (end view), at location 3CN above west abutment.

Photograph 17:
Specimen Rack 2 (end view), installed at location 3DN above right lane of I-390 S.

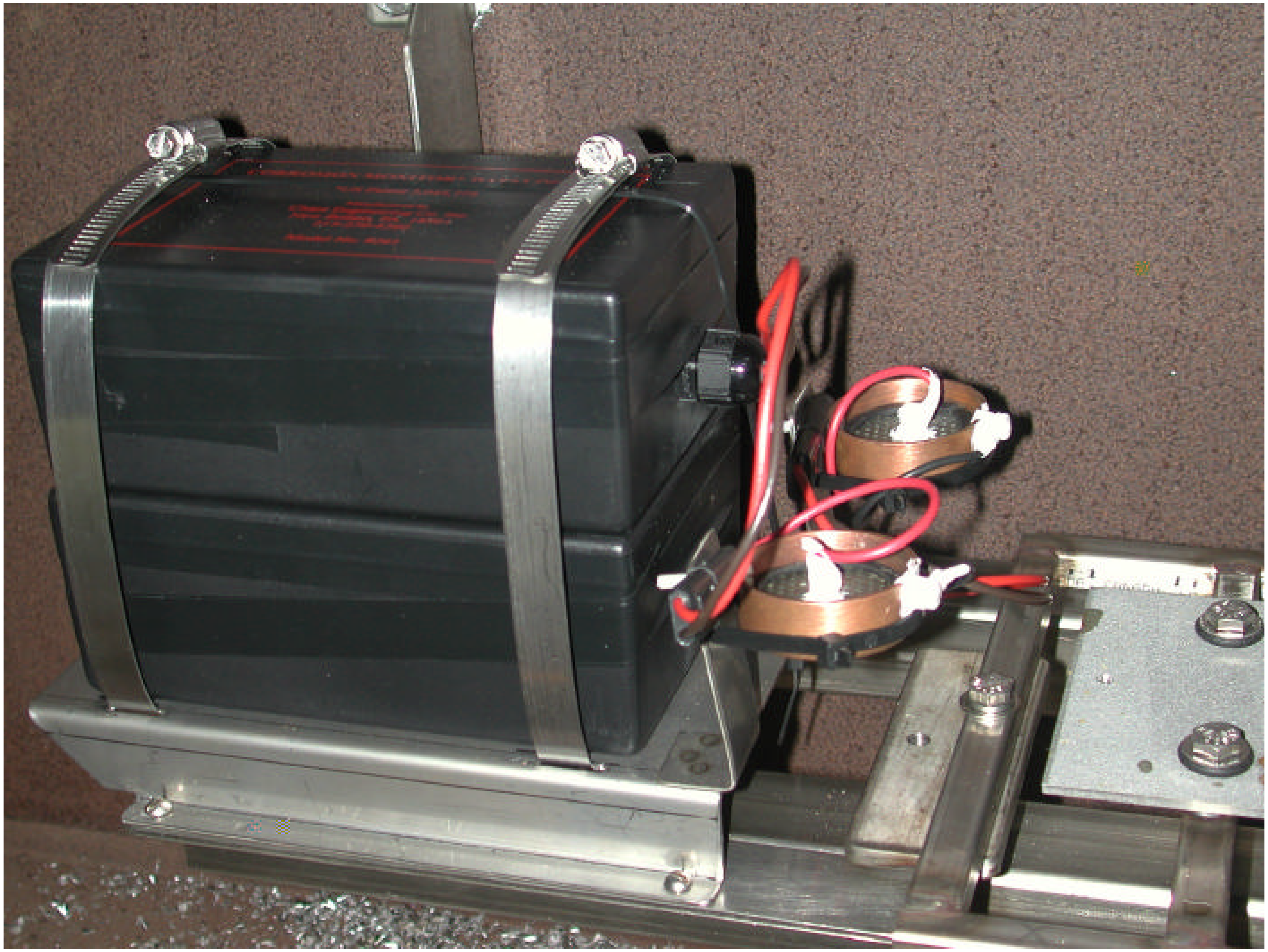
Photograph 18:
View of right lane of I-390 S (looking north) from the centerline of Specimen Rack 2.

Photograph 19:
Specimen Rack 3 installed at location 3MN at East abutment.

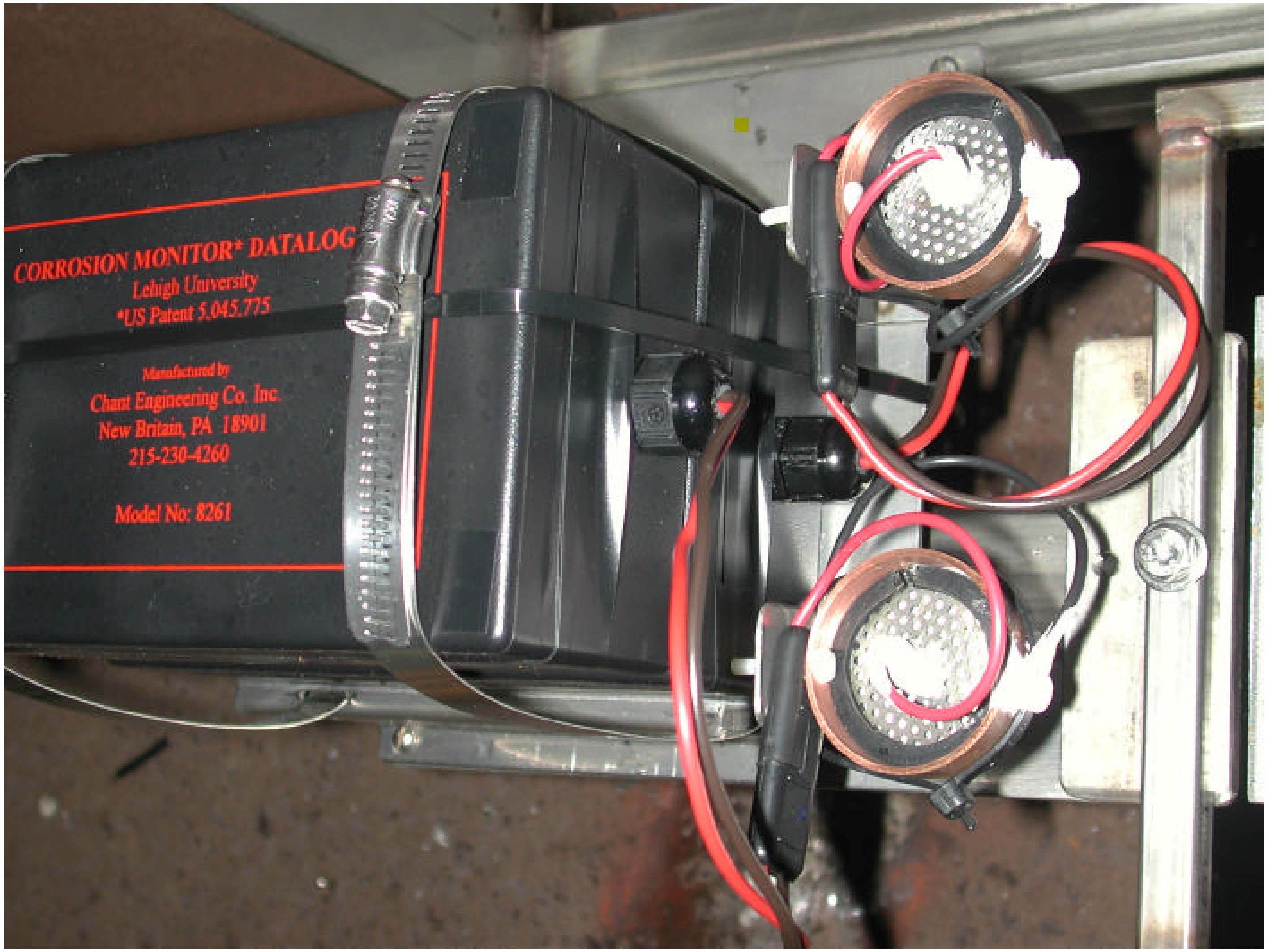
Photograph 20: Specimen Rack 3 installed at location 3MN at the East abutment. Thickness measurement positions are visible on the flange below each end of the rack.

Photograph 21:
Specimen Rack 3 (end view) installed at location 3MN above the jogging path at the east abutment.

Photograph 22:
Specimen Rack 3 installed above the jogging path at the edge of the Erie Canal.



Photograph 23: Corrosion Monitor Datalogger (in duplicate).



Photograph 24:
Corrosion Monitor Datalogger (top view), showing the corrosion sensors and datalogger boxes.