



Organizational Results Research Report

February 2011
OR11.013

Experimental Galvanic Anode for Cathodic Protection of Bridge A12112

Prepared by
Missouri Department of
Transportation

Final Report

RI04 - 030

**Experimental Galvanic Anode for Cathodic Protection of
Bridge A12112**

Prepared for
Missouri Department of Transportation
Organizational Results

by

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Missouri DOT

Acknowledgement to
Clem Firlotte, P.E.
Corrpro Companies Incorporated

November 2010

The opinions, findings, and conclusions expressed in this publication are those of the principal investigators. They are not necessarily those of the Missouri Department of Transportation, the U.S. Department of Transportation or the Federal Highway Administration. This report does not constitute a standard or regulation.

Technical Report Documentation Page:

1. Report No.: OR 11-013	2. Government Accession No.:	3. Recipient's Catalog No.:	
4. Title and Subtitle: Experimental Galvanic Anode for Cathodic Protection of Bridge A12112		5. Report Date: November 2010	
		6. Performing Organization Code: RI 04 - 030	
7. Author(s): John D. Wenzlick, P.E.		8. Performing Organization Report No.:	
9. Performing Organization Name and Address:		10. Work Unit No.:	
		11. Contract or Grant No.:	
12. Sponsoring Agency Name and Address: Missouri Department of Transportation Organizational Results PO BOX 270 JEFFERSON CITY MO 65102		13. Type of Report and Period Covered: Final	
		14. Sponsoring Agency Code:	
15. Supplementary Notes The investigation was conducted in cooperation with the U. S. Department of Transportation, Federal Highway Administration.			
16. Abstract: Cathodic Protection (CP) has been used by MoDOT for more than 30 years to stop corrosion of reinforced concrete bridge decks. These systems require power from local electrical connections. A galvanic system uses the difference in electrical potential between the anode and the reinforcing steel in the deck to generate enough current itself to cathodically protect the steel. Corpro Cos. Inc. approached MoDOT with a new galvanic CP anode, at no cost, for installation on a portion of bridge deck. The anode was installed along with a concrete overlay in 2005 and monitored for five years. The anode's power output was adequate to protect the reinforcing steel but so reactive when installed in the wet concrete that it caused disbonding of the overlay. It is not recommended for future use in its current configuration. This was the best galvanic anode for bridge decks developed so far; a good galvanic anode for bridges is still needed.			
17. Key Words: Cathodic Protection, Galvanic, Reinforcing Steel, Corrosion, Concrete Overlay		18. Distribution Statement No restrictions. This document is available to the public through National Technical Information Center, Springfield, Virginia 22161	
19. Security Classification (of this report): Unclassified	20. Security Classification (of this page): Unclassified	21. No. of Pages: 26	22. Price:

Form DOT F 1700.7 (06/98)

Executive Summary:

Cathodic Protection (CP) has been used by MoDOT on bridges in Kansas City and St. Louis to stop corrosion of reinforced concrete bridge decks for more than 30 years. These systems require power from local electrical connections. The power must be kept on at all times and causes considerable expense and limits putting the systems in rural areas where power is harder to access. A galvanic system uses the difference in electrical potential between the anode and the reinforcing steel in the deck to generate enough electrical current itself to cathodically protect the steel, no power source is needed. If refined this galvanic anode would eliminate the need for power while still providing dependable corrosion control of reinforced concrete decks using black steel rebar.

Corrpro Companies Inc. approached MoDOT Bridge and Research divisions with a new galvanic CP anode for a portion of bridge deck at no cost to MoDOT. The anode was developed as part of an NCHRP-IDEA investigation, "Evaluation of Al-Zn-In Alloy for Galvanic Cathodic Protection of Bridge Decks" Corrpro was involved in. The anode design changed several times finally ending up as an expanded aluminum mesh with an Aluminum – Zinc – Indium alloy thermally sprayed on it. In July of 2005, this anode was finally placed on a bridge located on the eastbound lanes of I-44 in Crawford County near Leasburg. The experimental anode was placed on top of the old concrete and encapsulated in a new dense concrete overlay riding surface. It was installed on the outside shoulder which is 10 ft. wide and out of traffic.

The largest area of concern was that during construction the anode was very active in the wet concrete and produced gas bubbles from self corrosion. Not only did this affect the life expectancy of the anode but more significantly it caused early delamination of the new concrete overlay verified by coring the deck. Delamination at the level of the anode showed up in the first year and continued to grow every year. After five years 45.6 percent of the concrete overlay above experimental anode was debonded. There has been no spalling of the concrete in this area which luckily is on the shoulder and gets no significant traffic load.

The anode has produced enough galvanic current to protect the rebar over the last five years and has met national codes as shown by the electrical readings over this time. It is questionable whether the anode will last at this rate of corrosion for the 25 years as hoped. It burned a lot of its life up at the beginning when it reacted with the wet concrete but the worst problem was it started delaminating the concrete overlay and now half of the surface area is delaminated in just five years. The inspections made over those five years indicate that there may be some problems in the future of the deck spalling in this area but since it is in the shoulder it should need nothing more than normal maintenance and an occasional patch over the next fifteen years.

It is recommended that the anode, at least in this configuration, not be tried on any more bridges.

Hopefully Corrpro Cos. Inc. will try and develop a better galvanic anode that will produce as much current as this one did for bridge deck cathodic protection and not have any harmful side effects. There is still a very large market for this type of system to help maintain our many aging bridges decks.

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Problem, Background, and Significance:

Cathodic Protection (CP) has been used by MoDOT on bridges in Kansas City and St. Louis to stop corrosion of reinforced concrete bridge decks for more than 30 years. These systems are induced current systems, which require power from local electrical connections. The power must be kept on at all times and causes considerable expense and limits putting the systems in rural areas where power is harder to access. A galvanic system uses the difference in electrical potential between the anode and the reinforcing steel in the deck to provide enough power to cathodically protect the steel, no power source is needed. If refined this galvanic anode would eliminate the need for power while still providing dependable corrosion control of reinforced concrete decks using black steel rebar.

Corrpro Companies Inc. provided a new galvanic CP anode for a portion of the bridge deck at no cost and MoDOT provided a bridge to apply the system on, Bridge A12112 on a bridge rehabilitation project, Job No. J9I0509.

Corrpro had approached MoDOT with an experimental galvanic CP anode which could be used under a concrete bridge deck overlay. The anode was developed as part of an NCHRP-IDEA investigation, "Evaluation of Al-Zn-In Alloy for Galvanic Cathodic Protection of Bridge Decks"¹ Corrpro was involved in. It would be placed on a bridge that had a reinforced concrete superstructure that was not actively corroding but was contaminated with enough chlorides from deicing salt that it soon could start corroding more actively and causing potholes in the deck. Since the first meetings with MoDOT Bridge and Research personnel the anode design had changed from a grating or grid configuration to an expanded metal mesh. Bridge A12112 is located on the eastbound lanes of I-44 in Crawford County just west of Exit 210 in Leasburg. The project called for the bridge deck to be patched and for new barrier walls attached, and then a new dense concrete overlay to be placed on it. It was decided to apply as much of the galvanic anode as Corrpro could supply on top of the old concrete on the outside shoulder which is 10 ft. wide.

Construction

The galvanic anode ended up being a 0.060 inch thick aluminum expanded mesh with an aluminum/zinc/indium (Al/Zn/In) alloy arc sprayed on its surface. Corrpro had tried using a solid Al/Zn/In alloy sheet and cutting and expanding it but the alloy was too brittle and the sheet fractured when they cut and then pulled to expand it.

After the bridge contractor had removed the old curb and barrier wall and was forming the new one, on July 6, 2005, Corrpro attached a ground wire to the reinforcing steel mat and also installed four silver/silver chloride Half Cells to monitor the CP system. They also installed conduit to carry the wires out to a control box which would be located on the outside edge of the

¹ Highway IDEA Project 100 – see Bibliography

deck near the west abutment. On July 21, 2005 after the contractor had placed concrete for the new deck edge and barrier wall. Corpro returned and laid out and installed the anode mesh. The mesh came in 4 ft. x 8 ft. panels. Seventeen panels were place for a total area of 544 sq. ft. of deck covered. The 8 ft. length was laid transversely and slid up against the barrier so it would not extend past the shoulder which was designed to be striped 10 ft. wide. On the inside edge it had to be cut 2" away from the steel deck drains so that it would not be possible for it to short out to the rebar in the deck.



Figure 1: Silver/Silver Chloride Half Cells, one at level of top rebar and one at bottom rebar.



Figure 2 &3: Anode electrically connected to each other with metal clamps at each corner of 4' x 8' sheet. (Black patch is insulation around clamps to keep out concrete during placement.). White anode lead wire is connected to sheet in two locations. Anode was cut to fit around steel deck drains so it won't short out to the rebar.



Figure 4: Anode laid out ready for concrete. Note: White spots are plastic anchors to hold sheet in place during concrete placement foreground.

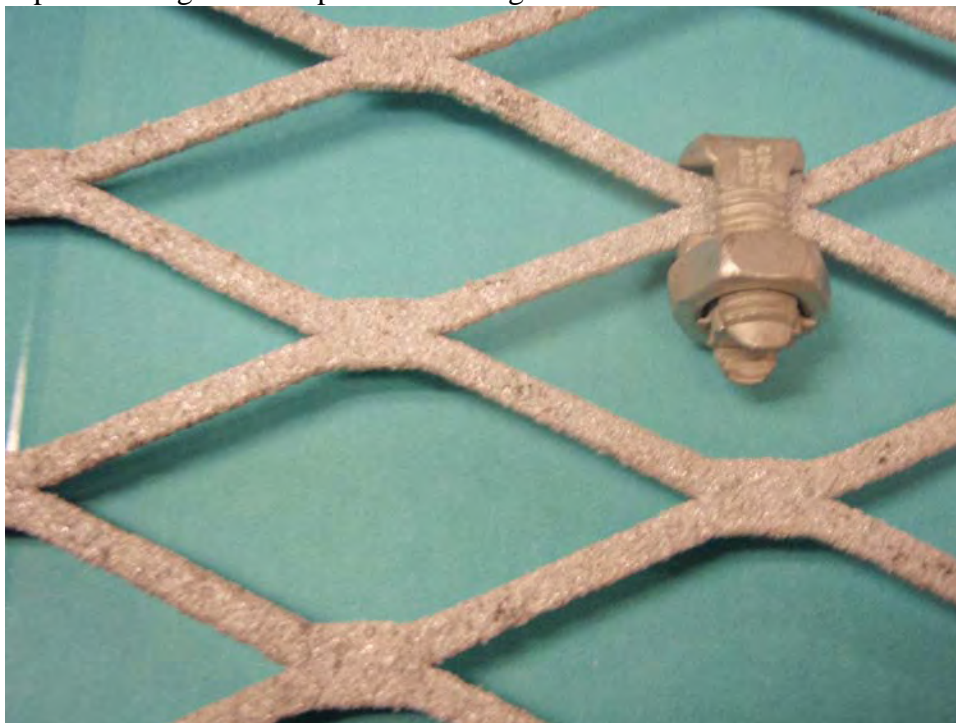


Figure 5: Close up of anode showing grainy texture of arc sprayed on particles of the Al – Zn – In alloy. This increases the surface area of the mesh thousand of times. Also shows clamp as used to attach 4' x 8" sheets together.



Figure 6: Gas bubbles from cement reacting with Al-Zn-In coating on anode appeared before final finishing of the overlay.



Figure 7: Close up of gas bubbles coming up after surface textured.
Note: one on left in middle has popped and a black pin hole can be seen in its center. Does it go all the way through the 2" thick overlay?

The data showed that the anode is working and producing sufficient current to protect the rebar.

One area of concern is that the anode is very active in the wet concrete and produces gas bubbles from self corrosion. These bubbles ceased after a while and do not appear to extend down to the anode. Missouri DOT used a boiled linseed oil to seal the deck

Missouri DOT and Corpro will monitor these to determine if they have any effect on the bridge. Missouri DOT obtained core samples at the one year anniversary of the system. Cores, 4” diameter, were drilled over visible air wholes left in the concrete. Three of the four cores, #1, #2, #4 all had the anodes disbonded from the concrete. Only core #3 had the anode firmly embedded in the overlay.



Figure 8: Core #1 –anode disbonded.



Figure 9: Core #2 – gas bubble hole in center.



Figure 10: Core 3 – only one with anode imbedded in concrete.



Figure 11: Core 4 – anode disbonded.

Annual Surveys

Electrical Readings:

The initial current between the anode and the rebar in the bridge deck was measured one month after installation and annually each year for five years. Corrpro provided an initial report and a one year progress report which was required for an NCHRP-IDEA 100 Contract they had entitled “Evaluation of Al-Zn-In Alloy for Galvanic Cathodic Protection of Bridge Decks” of which this MoDOT bridge was a part.

Corrpro’s Original Data Sheet

Table 1. System description

Anode type..... Aluminum @ 80 percent zinc @ 0.2 percent indium alloy thermally sprayed onto 0.060 inch thick alloy 3003 aluminum expanded metal mesh with 1 inch x 2.75 inch diamond pattern openings

Al-Zn-In thickness, inch per side 0.010
 Anode area installed, sq ft553
 Reference electrode 1*Located at top bar at old patch
 Reference electrode 2 Located at bottom bar, old patch
 Reference electrode 3 Located at top bar, new patch
 Reference electrode 4 Located at bottom bar, new patch
 Initial anode potential, volts 1.2
 Resistance, anode to steel, ohms . 0.3
 Initial anode current, mA..... 1,248 after 15 minutes or 2.25 mA/SF
 1 week anode current, mA 756 or 1.27 mA/SF
 * All reference electrodes are silver-silver chloride

Table 2. Initial Potential and depolarization data.

Reference Cell	E _{CORR} native mV SSC	Depolarization			
		Initial, mV*	1 week, mV**		2 Hr. Diff.
1	302	277	211		91
2	270	157	110		160
3	318	199	159		159
4	285	135	103		182

* 15 minutes, ** 2 hours

(The criteria set by NACE, National Association of Corrosion Engineers, is that there should be a 100 mV depolarization shift within 4 hrs. after the system is disconnected. Cell 1 had a shift of 91mV and the other three well over that in 2hrs.)

The table below shows output current and the depolarization for each annual inspection. The complete Corrpro initial report from October 13, 2005 and the electrical reading data compiled by MoDOT is available in Appendix A.

Table 3: Summary of Output Current Readings and Depolarization Tests for Bridge No. A12112

	Date	Anode Current	Current Density	Half Cell #1	Half Cell #2	Half Cell #3	Half Cell #4	
		mA	mA/SF	2hrs. Depol	2hrs. Depol	2hrs. Depol	2hrs. Depol	
Original Native	9/21/2005	1,248	2.25					
1 week	9/27/2010	756	1.57	-214	-111	-159	-107	
4 months	1/19/2006	233	0.42	0	-22	-50	-42	
				-11	-31	-72	-57	4hrs. Depol
6 months	4/4/2006	1,243	2.25	-224	-150	-136	-108	
8 months	5/30/2006	997	1.87	-18	-32	-65	-51	
10 months	7/18/2006	1,363	2.55	-252	-158	-157	-121	
1 yr 4 months	1/31/2007	35	0.07	-53	-33	-16	-10	
2 years	9/5/2007	235	0.44	-132	-100	-74	-65	4hrs. Depol
3 years	10/2/2008	280	0.52	-108	-92	-54	-45	
4 years	11/4/2009	6.3	0.12	-58	-36	-57	-45	
				-63	-41	-63	-51	4hrs. Depol
5 years	10/18/2010	23	0.04	-76	-57	-135	-96	

The current density required for cathodic protection of the rebar in the deck is between 1mA/SF to 2 mA/SF. The readings showed this much current, 1-2 mA/SF, only until the 10 month reading. However, it should be noted that the times that the anode was not creating this much current output was in January at times when corrosion is mostly inactive because of the cold weather so a smaller output is expected such as the 4month reading of 0.42 mA/sf, This is all the current that was required of the passive galvanic system to protect the rebar on January 19, 2006 because the corrosion rate of the rebar is much lower in the cold dry weather.

The criteria set by NACE, the National Association of Corrosion Engineers, that the system is supplying enough current to protect the rebar is that there should be a 100 mV depolarization shift within 4 hrs. after the system is disconnected. The 100 mV depolarization criterion was met at 6 months and 10 months, the same time as the high current outputs of over 2 mA/sf. In the cooler weather because of the conditions in the bridge deck, cold and dry concrete, the concrete doesn't act as a good electrolyte to draw power to the rebar. However, it requires much less current because the rebar's rate of corrosion goes way down and it virtually stops corroding in freezing weather. The one date's readings which are the hardest to explain are for the 5th year taken on October 18, 2010 when the temperature was 67°F. The 0.04 mA/SF is very low, but

this year was a very dry year with a drought since the spring, compared to a prior three very wet years. Moisture in the deck is one of the three things needed to set up a corrosion cell in a reinforced concrete deck:

- 1.) difference in potential between the two mats of rebar,
- 2.) an electrolyte (moisture, i.e. salt contaminated water) and
- 3.) oxygen. (There is always enough oxygen available unless it is very dense concrete).

It also tended to get later in the year that testing was done. Ideally two readings per year not just annually should have been done; one done in the spring (April) when weather and deck conditions make corrosion most active, and one done in the fall (October) near the anniversary date when it was originally connected.

It has been shown that the anode has produced enough galvanic current to protect the rebar over the last five years and that it has in fact done so as shown by the depolarization readings over this time. How long the anode will last at this rate of corrosion is not as easy to estimate. Will it last another five years making its life expectancy to be 10 yrs. or another 15 years giving it a 20 year expected design life similar to an induced current or externally powered system. This may be a mute point because of the process by which the anode was made and the problems caused when it reacted with the plastic concrete while placing the concrete overlay.

Deck Soundings:

An area of concern since the beginning is that the anode was very active in the wet concrete and produces gas bubbles from self corrosion. Not only does this affect the life expectancy of the anode but more significantly there was a fear this might cause early debonding of the new concrete overlay just placed on the repaired deck. As shown by the damage from coring the deck the fears of areas of concrete delamination at the level of the anode showed up in the first year and continued to grow every year. The first year the deck was sounded was on July 18, 2006. At that time 90.5 Sq. ft. of area were found hollow or the concrete overlay debonded from the deck. This was 16.6 percent of the area over the 544 sq. ft. of anode but only 2.7 percent of the area over the whole size of the overlay placement of 3360 sq. ft. of which only 8 sq. ft.(0.2%) was found delaminated in the deck area without the anode. (This is the only area outside the anode ever found.) After five years 45.6 percent of the concrete overlay above the deck area with the galvanic anode was delaminated. There has been no spalling of the concrete in this area but it luckily is only on the shoulder which gets no significant traffic load. Table 3 shows the areas found delaminated at each annual sounding of the shoulder on Bridge No. A12112. It should be noted that 100 percent of the area on the east end of the 10 ft. shoulder without the anode are still well bonded.

Sounding of Outside 10 ft. Shoulder A12112		
Date	Delaminated Square Ft.	Delaminated %
7/18/2006	90.5	16.6%
9/5/2007	122.9	22.6%
10/8/2008	240	44.1%
11/4/2009	194	35.7%
10/18/2010	248	45.6%

* - 544 SF Anode area

The maps of the deck soundings can be found in Appendix B.



Figure 12: October 2010 photo of concrete deck overlay above the Al-Zn-In anode (outlined in red), five years after installed. There are few cracks and no spalling on the surface but 46% of the concrete overlay is debonded over the anode (outlined in yellow). See maps in Appendix B for additional debonded areas.

Conclusions:

It is MoDOT's opinion that the gas bubbles that made it to the surface of the concrete overlay did leave small holes that went down to the top of the mesh. The linseed oil sealer and later emulsion sealer may have sealed off the holes but that doesn't matter. As shown by the cores taken the gas bubbles that collected around the surface of the anode that were trapped there did cause a problem of keeping the wet concrete overlay from bonding to the mesh surface and to the deck surface below. The subsequent disbondment continued to occur year after year. This was the most detrimental effect of using the thermally sprayed mesh anode.

The design life was estimated by Corrpro as 25 years². The projected life is not known but is presumed to be 10-20 years. The shorter life span is due to the thermal sprayed Al-ZN-IN alloy, which appears to have corroded at a faster rate both during placement in the wet concrete and during the first year where it was shown to be providing excess current. The lifetime could be estimated by the amount of coating left on the mesh which could be checked by additional coring. MoDOT does not want to core into the overlay covering the mesh for fear it might start spalling off the concrete that is already delaminated.

Recommendations:

Galvanic Cathodic Protection System

If Corrpro could come up with an anode that provides the adequate amount of galvanic current and be safe to the concrete decks they would have a very important breakthrough. A galvanic anode like this could replace expensive induced current CP systems and open up a much larger market for cathodic protection of reinforced concrete structures.

- Disbondment of the overlay caused by the anode is the main reason it is recommended that MoDOT doesn't use this galvanic anode again. At least not in this configuration.
- MoDOT should keep open to trying cathodic protection systems, especially galvanic ones, to protect not only decks but bridge substructures. There are some very old substructures, some which even have new decks on them, which continue to deteriorate. This is caused by corrosion of the black (uncoated) reinforcing steel. Cathodic Protection is the only process that will stop corrosion according to the FHWA.

² Highway IDEA Project 100 – see Bibliography

Maintenance of Bridge A12112

As far as bridge A12112, although the outside shoulder has almost half of the overlay debonded on the area over the experimental CP anode, the overlay remains in place with no noticeable distress. Since there is seldom any vehicle loads on it, it could be a long time until any deterioration occurs.

- As any potholes appear they should be cleaned up, the anode removed if necessary and patched in place with an approved patching concrete.
- If cracking appears to worsen the area should be sealed with a crack sealer as per normal bridge maintenance procedures. The bridge has already been sealed with Pavon Indeck once and should be sealed again to keep moisture and salt out of this vulnerable area especially. This overlay is now over five years old and it is expected that it will last the remaining 15 years of its design life until 2025 with some minor patching of the outside shoulder.

Bibliography:

“Evaluation of Al-Zn-In Alloy for Galvanic Cathodic Protection of Bridge Decks”, Final Report for Highway IDEA Project 100, Prepared by : WalterT. Young, P.E., Clem Firlotte, P.E., Miki Funahashi, P.E., Corpro Companies , Inc for Transportation Research Board of the National Academies

Link to full report:

http://onlinepubs.trb.org/onlinepubs/idea/finalreports/highway/NCHRP100_Final_Report.pdf

Appendix A
Corrpro Progress Letter October 13, 2005
and
Five Years of MoDOT Electrical Readings:

October 13, 2005

IDEA Program Officer Transportation Research Board



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The Keck Center WS401
500 Fifth Street NW
Washington, DC 20001

Attn: Inam Jawed, Room KECK-W401 (via email)

SUBJECT: Evaluation of Al-Zn-In Alloy for Galvanic Cathodic Protection of Bridge Decks
Contract NCHRP-100
Progress Report

Dear Mr. Jawed:

This letter is to update you on our progress. This report presents both the status of the field trial, laboratory tests and a schedule for completion.

Field Trial

As reported in our letter of August 1, 2005, we installed a galvanic anode mesh on bridge deck in Missouri on Interstate 44 at mile marker 212, Cuba, MO (about 1 hour west of St. Louis). These anodes were activated and recently, depolarization tests conducted. The dates of the anode installation for the field trial are as follow:

July 22, 2005 œ anode mesh installed September 20, 2005 œ anode connected to deck reinforcing and initial data obtained September 27, 2005 œ first depolarization tests performed

Table 1 presents a description of the anode system and Table 2 presents the potential and depolarization data. Note that the anode was embedded for about two months before being connected. Photos of the anode installation were included with our August 1, 2005 letter. Figure 1 shows the test station.

The data show that the anode is working and producing sufficient current to protect the rebar. One area of concern is that the anode is very active in the wet concrete and produces gas bubbles from self corrosion. These bubbles ceased after a while and do not appear to extend down to the anode. Missouri DOT used a boiled linseed oil to seal the deck. Missouri DOT and Corrpro will monitor these to determine if they have any affect on the bridge. Missouri DOT has offered to obtain core samples at the one year anniversary of the system.

We will continue to monitor the performance of the anode for 12 months.

Table 1. System description

Anode type..... Aluminum ø 80 percent zinc ø 0.2 percent indium alloy thermally sprayed onto 0.060 inch thick alloy 3003 aluminum expanded metal mesh with 1 inch x 2.75 inch diamond pattern openings

Al-Zn-In thickness, inch per side 0.010

Anode area installed, sq ft553

Reference electrode 1*Located at top bar at old patch

Reference electrode 2 Located at bottom bar, old patch

Reference electrode 3 Located at top bar, new patch

Reference electrode 4 Located at bottom bar, new patch

Initial anode potential, volts 1.2

Resistance, anode to steel, ohms . 0.3

Initial anode current, mA..... 1,248 after 15 minutes or 2.25 mA/SF_c

1 week anode current, mA 756 or 1.27 mA/SF_c

* All reference electrodes are silver-silver chloride

Table 2. Potential and depolarization data.

Reference Cell	E _{CORR} native mV SSC	Depolarization			
		Initial, mV*	1 week, mV**		
1	302	277	211		
2	270	157	110		
3	318	199	159		
4	285	135	103		

* 15 minutes, ** 2 hours Laboratory Tests

The two 2 ft. x 2 ft. test slabs with embedded expanded metal anodes (Al-Zn-In thermally sprayed onto aluminum mesh) are also performing well after almost 15 months in test.

The current generated by the large mesh anodes is on the order of 2 mA/ft² (of slab surface) and the current generated by the small mesh anode is about 1.3 mA/ft².

Anode-to-reference electrode potential measurements are:

Large mesh: 0.947 volt E_{ON} (to silver-silver chloride reference electrode)
1.00 volt after 3 hrs depolarization

Small mesh: 0.737 volt E_{ON}
0.933 volt after 3 hrs depolarization

There is no indication of cracking or other distress in the slabs. We took cores after about 13 months of operation to examine the anodes and found that the anode material is still intact. These slabs are monitored periodically and will continue in test at our West Chester facility.

Production of Aluminum Alloy Sheet

Zinco has failed to deliver on their agreement to produce an anode sheet and we have been unable to locate another manufacturer willing to produce the material. The problems include the high purity of the aluminum needed and the use of a high concentration of indium. The high purity anode grade aluminum is outside the ability of suppliers to produce without cleaning their furnaces. The high concentration of indium needed would contaminate their furnaces. The relatively small quantity of material that would be produced does not make it attractive for suppliers to overcome the other two obstacles.

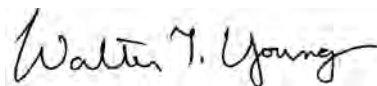
While the laboratory tests and field trial of the thermally sprayed mesh anode show that this anode is a good anode, the cost of production is high. That is because there is too much waste in spraying the aluminum-zinc-indium alloy onto a mesh substrate. However, we are working on an alternative production plan whereby the anode alloy is applied to a solid pure aluminum sheet using thermal spray. The solid sheet is expanded to produce the anode mesh. We have lined up a supplier of the pure aluminum sheet and a fabricator to produce the anode mesh. Since our contract funds have been depleted in the development work so far, we might be requesting additional funding to pursue this additional work.

Schedule The proposed revised schedule based on completion of the field trial already begun is as follows:

Completion of field trial.....	September 20, 2006
Quarterly Progress Report.....	January 12, 2006
Quarterly Progress Report.....	May 12, 2006
Quarterly Progress Report.....	September 12, 2006
Draft Final Report	October 12, 2006
Final Report	January 12, 2007

Please let us know if this is acceptable and do not hesitate to contact us if you have any questions.

Very truly yours,



Walter T. Young, P.E. Principal Engineer

Cc: Dr. Y. Paul Virmani, via email

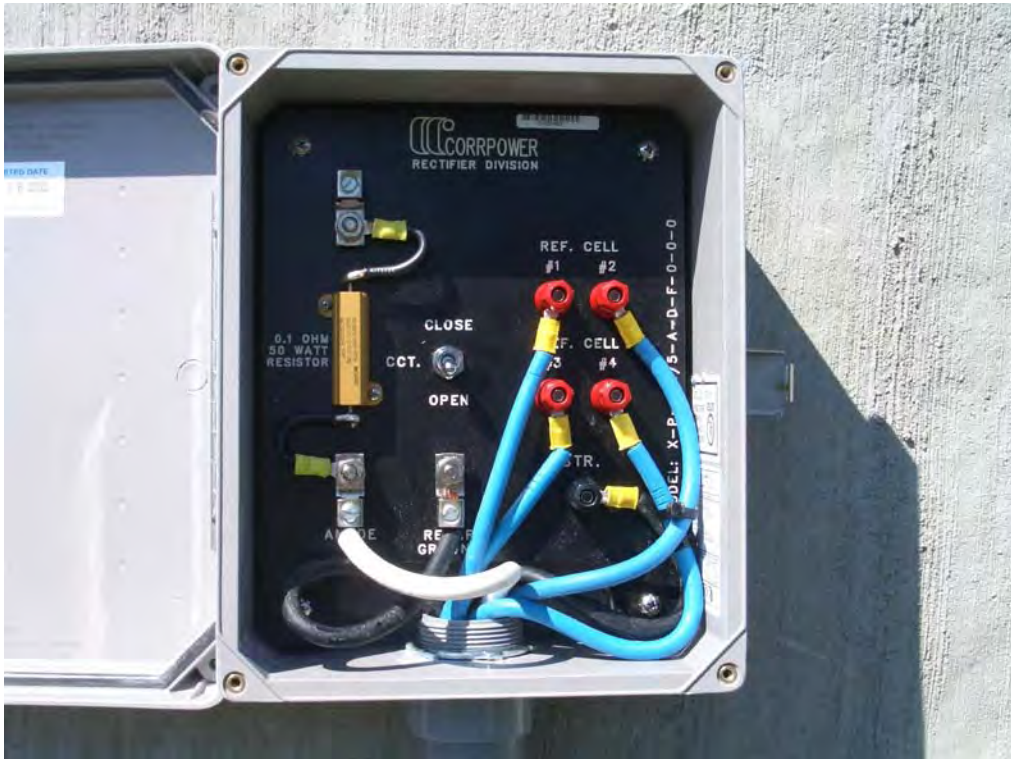


Figure 1. Anode junction box

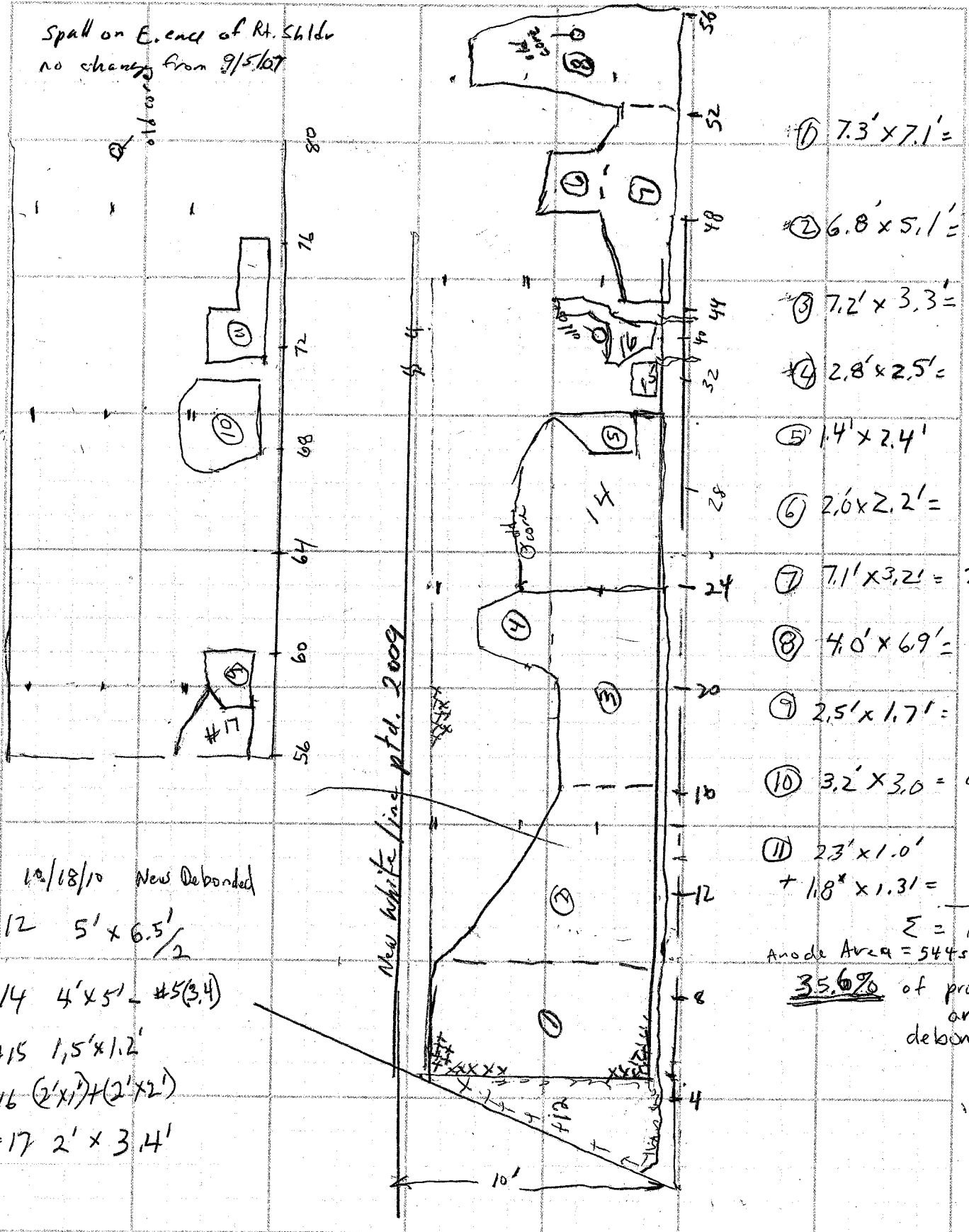
Appendix B
Maps of Deck Sounding:

Subject 11/4/09

R104-030

Br. A122 Crawford Co.

Spall on E. end of Rt. Shldr
no change from 9/5/07



- ① 7.3' x 7.1' = 51.83
- ② 6.8' x 5.1' = 34.68
- ③ 7.2' x 3.3' = 23.8
- ④ 2.8' x 2.5' = 7
- ⑤ 1.4' x 2.4' = 3.4
- ⑥ 2.6' x 2.2' = 4.4
- ⑦ 7.1' x 3.2' = 22.7
- ⑧ 4.0' x 6.9' = 27.6
- ⑨ 2.5' x 1.7' = 4.25
- ⑩ 3.2' x 3.0 = 9.6
- ⑪ 2.3' x 1.0' = 2.3
+ 1.8' x 1.3' = 2.34

$\Sigma = 19880'$
Anode Area = 544sf
35.6% of protected area debanded

- 12/18/10 New Debanded
- #12 5' x 6.5' / 2
 - #14 4' x 5' - #5(3.4)
 - #15 1.5' x 1.2'
 - #16 (2' x 1') + (2' x 2')
 - #17 2' x 3.4'



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Organizational Results
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