DULUTH SUPERIOR HARBOR STEEL STRUCTURE ALTERNATIVE REPAIR INSTALLATION & PROTECTION REPORT

Prepared for Wisconsin Sea Grant Institute, Contact # 034K786

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AMI Job #081072

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SUMMARY OF TEST INSTALLATIONS

Two principal types of steel structure protection systems were studied during this test: jacketed pile and cathodic protective systems. Two different styles of jacketed pile protection systems commercially available were installed, and a separate test utilizing sacrificial anode cathodic protection was put in place. The systems will be monitored by AMI Consulting Engineers (AMI) throughout 2009 and a final report will be issued in December 2009.

JACKETED PILE PROTECTION SYSTEMS

Purpose of Tests

The purpose of this study was to explore alternative options for protecting steel structures from corrosion. There has been much focus put on marine coatings for steel structures in recent years without a great deal of attention given to alternative repair and protective options other than marine coatings. This study was designed to investigate several alternative corrosion protective systems, install the alternatives, and monitor their longevity and ability to protect the steel structures from corrosion within the Duluth-Superior Harbor.

Procedures Used for Underwater Installations

The AMI Engineering 4-man dive team consisted of one professional engineer, one graduate engineer, one engineer technician and one commercial diver. Surface supplied diving techniques were utilized during all phases of the inspection process to meet OSHA and Coast Guard standard regulations for commercial diving. The inspectors used an underwater helmet mounted video camera to document the complete installation for future review by project team members. Pertinent photos and tables will be used in the report to illustrate the installation of the pile jacket systems. Additional photos and video clips are included with the project team master report.

Products Used For Alternative Repair Options

Denso – SeaShield Series 2000 FD Jacket – Pile Protection Only

The SeaShield Series 2000 FD Jacket is manufactured by Denso and is made from a high-density polyethylene (HDPE) material. This jacket utilizes a petrolatum paste to fill large pits in the steel. This paste is a soft petrolatum paste containing water displacing, corrosion inhibiting and flow control additives, plus broad spectrum biocides. This paste displaces water and fills large pits and depressions.

The other major component to this test was the SeaShield Marine Piling Tape which is composed of a non-woven synthetic fabric carrier, fully impregnated with a compound based on petrolatum containing inert fillers, water displacing agents and wide spectrum biocides. It is backed with a thin high density polyethylene film. The tape provides the primary corrosion protection in the SeaShield 2000 system.

A HDPE skin is then wrapped around the steel pile which is a tough, ultraviolet-resistant jacket that provides protection to the tape against abrasion, wave action, and accidental impact. The jackets are secured with 316 stainless steel threaded bolts. The approximate material only cost per foot for this system is $80.00. See Appendix A for specific product information. A schematic of this jacket can be seen below in Figure 1.

The Denso – SeaShield Series 2000 FD Jacket system was chosen for its ability to protect pipe piling against corrosion in rugged environments, low coefficient of friction, apparent ease of installation, and durability. The system's cost per unit is also significantly less than other products on the market.

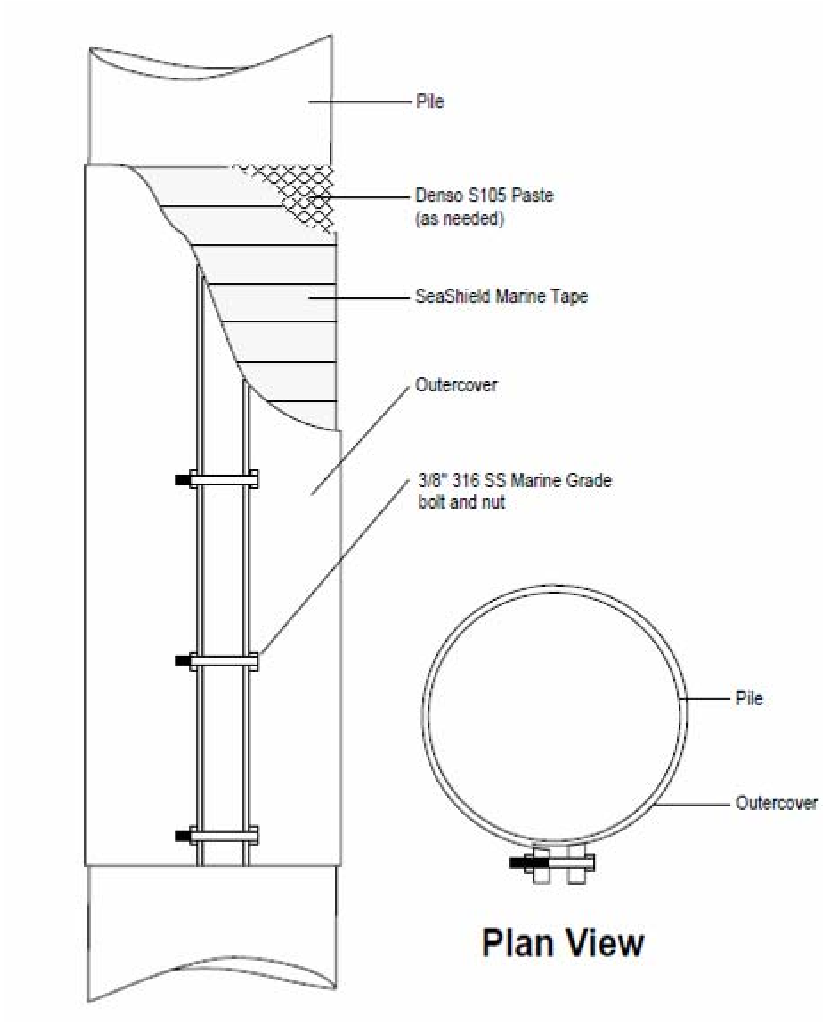


Figure 1: SeaShield Series 2000 FD Jacket System

Denso – SeaShield Series 500 H-Jacket– Pipe Protection & Structural Repair

The typical SeaShield Series 500 Jacket is a Fiberform Jacket which is composed of a Fiberglass Reinforced Plastic (FRP) shell which closely wraps around the pile. SeaShield 550 Epoxy Grout is then pumped into the void between the pile and the jacket which forms a bond to the steel and the FRP shell and protects the steel from corrosion or decay. See Appendix A for specific product information.

This series jacket was chosen for the test because of its low cost, durability, low coefficient of friction, ease of installation, and because it provides some structural benefits in addition to corrosion prevention.

A prototype H-jacket was specifically designed for the H-piles at the Midwest Energy wharf in Superior, WI. In 2005, a similar prototype jacket was installed on an H-pile which was in the shape of a square rather than an H. This square jacket has performed well since its installation, but was viewed an uneconomical alternative since significantly more of the SeaShield 550 Epoxy Grout needs to be used.

Since the SeaShield 550 Epoxy Grout is an expensive component of the Series 500 jacket system, the new H-jacket was designed to eliminate as much of the grout as possible. This new H-jacket design consumed approximately 40 percent of the grout that was used in the square jacket design - significantly reducing the overall cost of the jacket by eliminating material and labor costs of mixing and installing the extra material. The approximate material only cost per foot for this system is $186.67. A schematic of this pile jacket can be seen below in Figure 2.

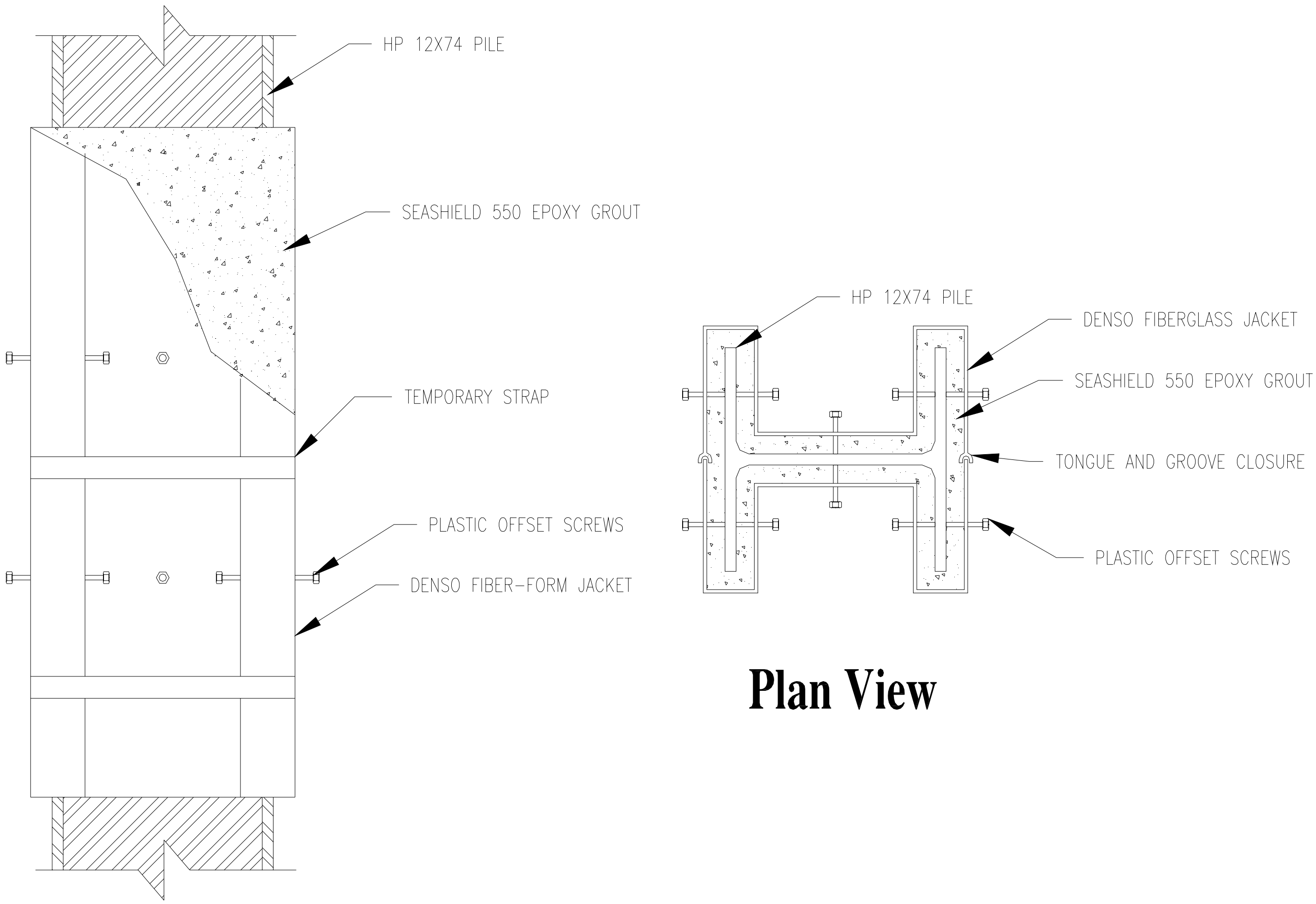


Figure 2: SeaShield Series 500 H-Jacket

Installation Details

The Series 500 H-jacket and the Series 2000 FD jacket were both installed November 4 and 5 at the Midwest Energy wharf located in Superior, WI which is within the Duluth-Superior Harbor. This site was primarily chosen because they have hundreds of steel piles supporting their wharf which are severely corroded. This site is also along the main channel in the harbor which sees a lot of ice build up and ice impact which will put the jackets to the ultimate test. Exact locations can be viewed on the Map of Project Locations and on the plan of the Midwest Energy Wharf which are both located in Appendix A.

The jackets which were both installed on steel piling required that all marine growth and rust be cleaned from the steel prior to installing the jackets to SP7/NACE No. 4 level. A picture of the diver performing a high pressure water blast cleaning can be seen below in Picture 1. The blast cleaning is performed using a 4500 psi pressure washer which removes any marine growth and the majority of corrosion both above and below the water.

Picture 1: Diver Performing Blast Cleaning

Denso – SeaShield Series 2000 FD Jacket

1. The steel pile was blast cleaned to remove any marine growth and existing corrosion to SP7/NACE No. 4 level.
2. Divers inspected piling for any major damage.
3. Denso S105 Paste was applied to any large or deep pits on the surface of the steel piling. The paste is applied to the steel with either a gloved hand or stiff bristle brush.
4. Denso Marine Piling Tape was spirally wrapped around the steel pile with a minimum 1" overlap. For severely corrosive environments (as in our environment), a 55% overlap is recommended. While wrapping, air pockets were pressed out and lap seams were smoothed. For additional mechanical protection, an overwrap may be used to increase impact strength and electrical resistance. The tape should be rolled out so there are two inches of tape protruding from the top and bottom of the jacket. A picture showing a diver installing the Denso tape can be seen below.

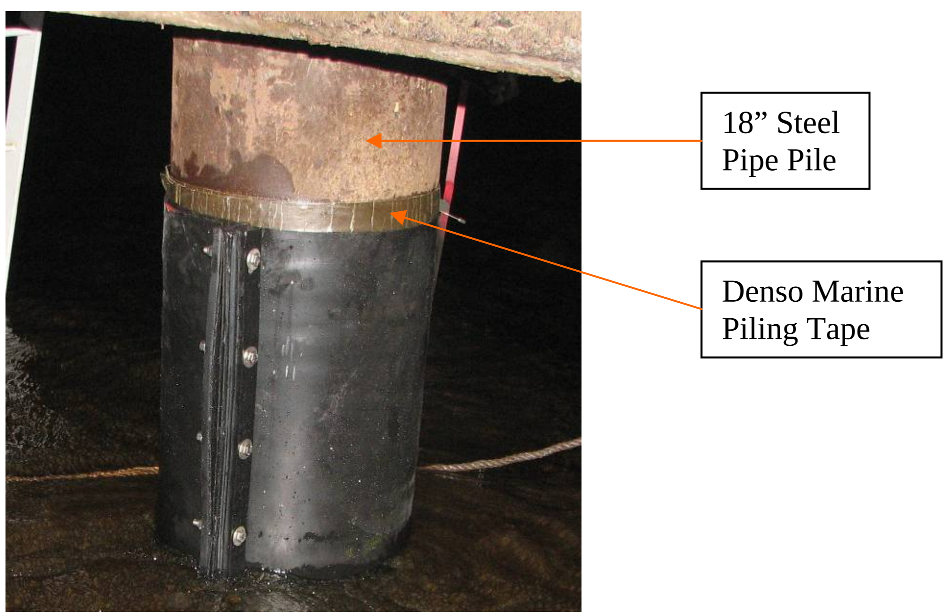
Picture 2: Diver Installing Denso Marine Piling Tape

5. The SeaShield Jacket is a tough, ultraviolet-resistant jacket that provides protection to the tape against abrasion, wave action and accidental impact. The jackets are secured with 316 stainless steel threaded bolts. The bolts are be tightened with an impact wrench or with hand wrenches. The jacket is initially installed by using a hydraulic pump jack to squeeze any water or air out from between the pile, tape, and jacket. The jacket stretches around the pile and tape when the bolts are fully tightened with an impact wrench or hand wrenches. The diver using a hydraulic jack can be seen below in Picture 3.

Picture 3: Diver Installing Jacket with Use of Hydraulic Pump

6. Permanent 316 bolts are installed and tightened by impact or hand wrenches.

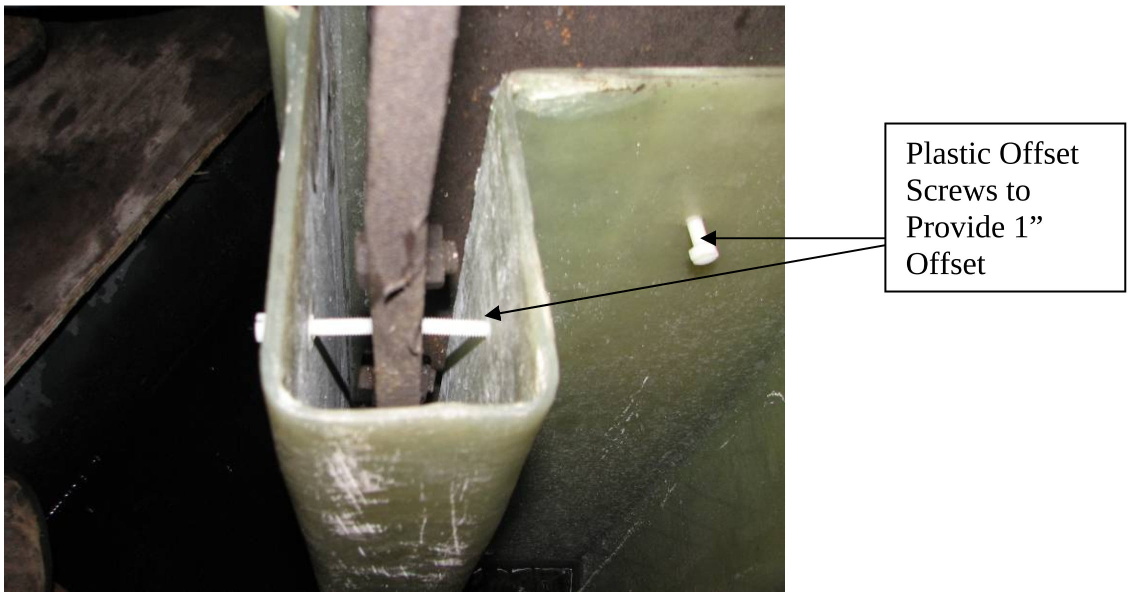
7. The installation is completed and inspected to assure proper fit up. The jacket for this test was installed on an 18” steel pile as shown in picture below.



Picture 4: SeaShield Series 2000 FD Jacket Complete Installation

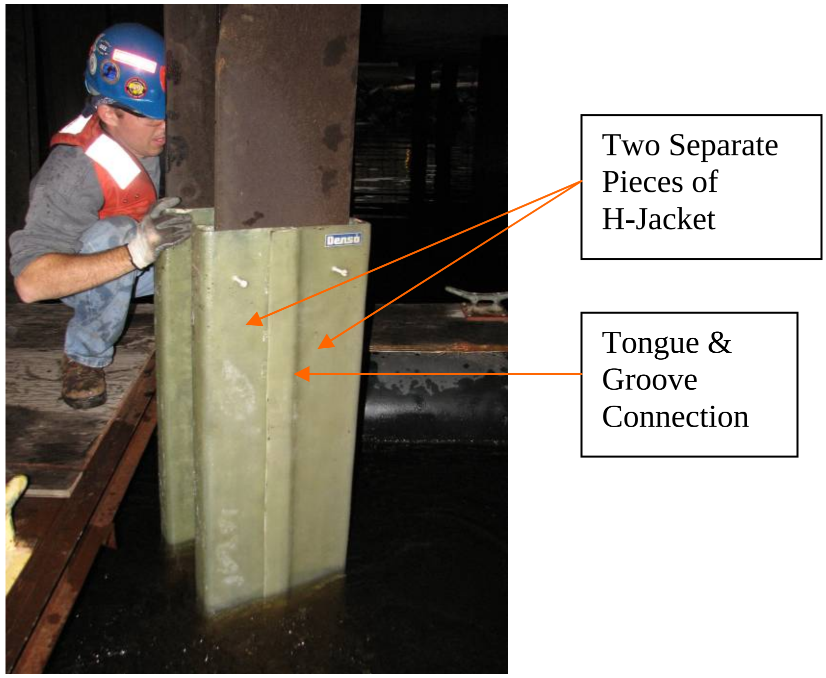
Denso – SeaShield Series 500 H-Jacket

1. The steel pile was blast cleaned to remove any marine growth and existing corrosion to SP7/NACE No. 4 level.
2. Divers inspected piling for any major damage.
3. The jacket comes pre-tapped with threaded holes for the plastic offset screws shown below in Picture 5. This particular prototype H-jacket has a 1” annulus space between the H-pile and the H-jacket, therefore the screws need to be inserted into the pre-tapped holes and adjusted so there is approximately 1” of the screws protruding into the inside of the jacket. This can be done while the jacket is on dry land.



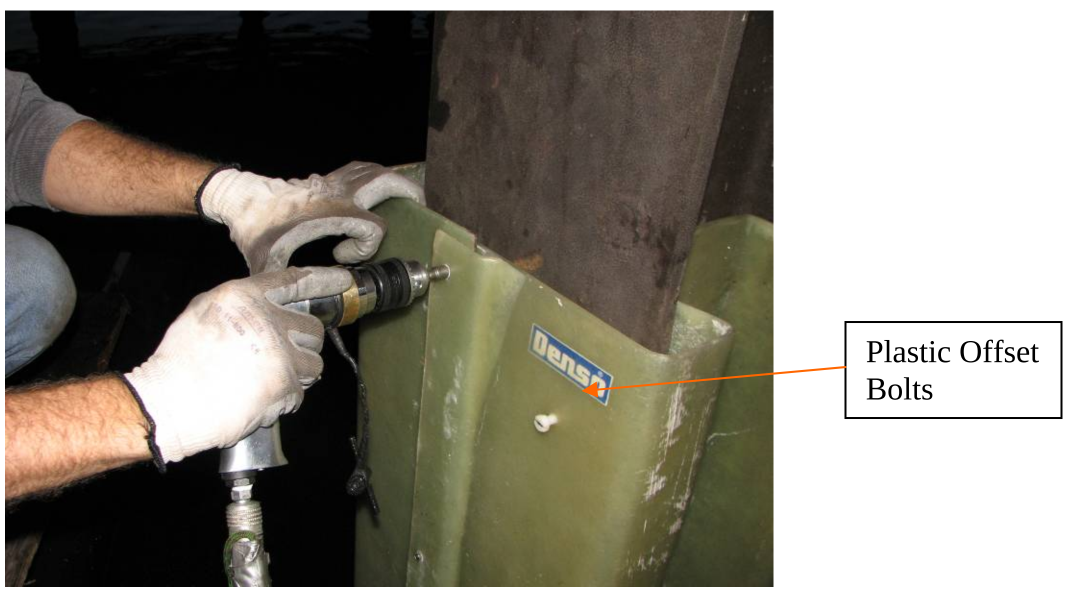
Picture 5: Plastic Offset Bolts with 1” Annulus

4. The SeaShield Series 500 H-Jacket comes in two pieces and fits together using a tongue and groove system. The bottom of the jacket must terminate either below the mudline to form a seal so no grout leaks out or a base plate must be produced for the jacket. Since our jacket did not terminate into the mudline, a base plate was built from two pieces of 1” angle, two threaded rods, and a piece of plywood cut to fit around H-Pile. Any voids between the plywood base and the jacket are then sealed with plumbers epoxy to prevent the grout mix from leaking through any cracks. The two pieces of the jacket being put together can be seen in Picture 6 below.



Picture 6: Installing 2-Pieces of H-Jacket Around H-Pile

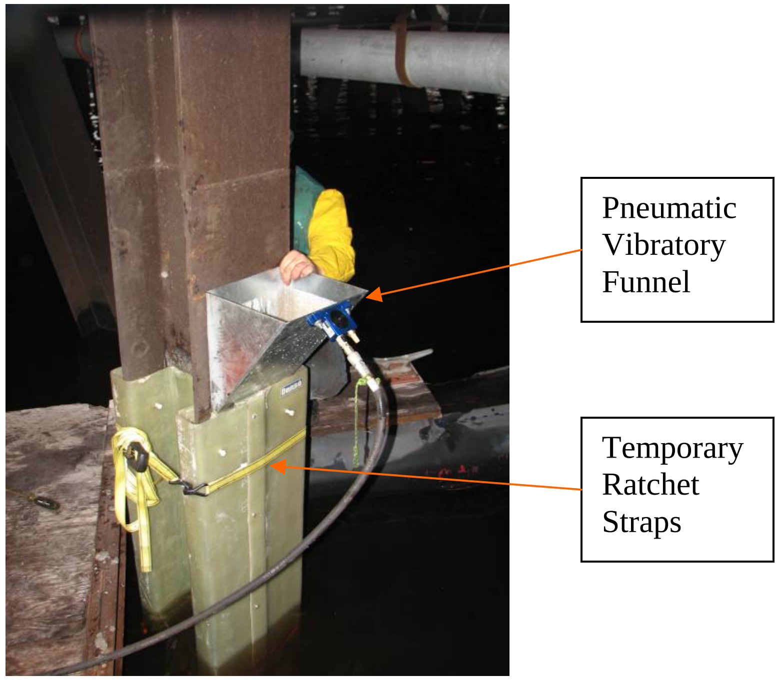
5. Once the two sides of the jacket are put together on the base plate the tongue and groove system is fastened together using self tapping screws installed every 18” which can be seen in Picture 7 below.



Picture 7: 2-Pieces of Series 500 H-Jacket Being Fastened Together

6. All of the plastic offset screws are then tightened so that there is a 1” offset along the length of the top and bottom of the jacket around both the flanges and web of the H-Pile.

7. Ratchet straps are then installed around the jacket every 18” or as required as a temporary measure to help hold the jacket together while being filled with SeaShield 550 Epoxy Grout. This can be seen in Picture 8 below.



Picture 8: H-Jacket with Ratchet Straps and Vibratory Funnel

8. SeaShield 550 Epoxy Grout is used to fill the annulus between the H-Pile and the H-Jacket. SeaShield 550 is a 3-component water displacing epoxy resin/aggregate formulation which provides a durable, well bonded repair to both concrete and steel below water. The 3-components of this grout mix are; Component “A”, which is a resin which comes in a can, Component “B”, which is a hardener which comes in a can, and Component “C”, which is an aggregate which comes in a 44lb bag. These 3-components are then mixed together using a mixer until a homogenous mixture is achieved which can be seen below in Picture 9.

Picture 9: Mixing SeaShield 550 Epoxy Grout

9. Once the SeaShield 550 Epoxy Grout is mixed it can be placed into the H-Jacket one of two ways.
    - A pneumatic vibratory funnel can be used to pour the mixed grout into the top of the jacket as can be seen in Picture 10 and Picture 11 below. The grout should be consolidated and vibrated where possible. This process is used when there are only a few jackets to be filled.
    - When there are several jackets to be filled, a peristaltic pump should be used. Immediately after mixing, the grout should be transferred into the hopper of the peristaltic pump. For this application, special inserts are built into the jacket for the hose from the pump to be connected as can be seen in picture below. The grout is then pumped up to ensure all air and water voids escape from the annulus space.

    Approximately 12" of grout should first be placed into the bottom of the form and allowed to set, typically overnight. Placement of remainder of the grout in the jacket shall not commence until bottom seal is fully cured. In both methods of placement, it is recommended that SeaShield 550 A & B should be stored at 68ºF to 86ºF for 24 hours prior to use for optimum pumping and placement productivity.

Pictures 10 & 11: Placing SeaShield 550 Epoxy Grout

10. The pumping equipment is best cleaned with SeaShield equipment cleaner solution. Recirculation using a sponge "pig" is an efficient cleaning procedure. Use cleaning solvent such as Acetone, MEK, or Simple Green for all other equipment.

Installation Assessment and Future Installation Suggestions

This section of the report is intended to be used to make contractors, manufacturers and others involved in the installation process aware of difficulties encountered during the installation of the products. The intent of this discussion is not to degrade any products, but rather to shed light so others do not encounter the same difficulties during installation. This was the first time AMI installed jackets of these specific types and unforeseen obstacles are to be expected. Overall the installation of these products went well but the difficulties encountered were:

Denso – SeaShield Series 2000 FD Jacket
The only obstacle encountered with the installation of the Series 2000 FD jacket was during the application phase of the Denso Paste S105. The temperature of the water during the time of application was 44ºF, which is not the optimum temperature for this product. When the diver attempted to apply the paste to the deep pitting on the steel pipe pile, the paste would not stick to the steel surface. At this temperature there was no possible way the paste was going to stick to the steel so this process was negated after numerous attempts and the SeaShield Marine Piling Tape was applied directly to the bare steel. There was no opportunity to try applying the paste at higher temperatures so it is unknown what the lowest water temperature the paste should be applied. Future installation of this product should be researched for cold water conditions and / or existing alternative products designed for the colder temperatures should be utilized.

The taping process and the installation of the jacket itself went very well. The 18” pipe pile was at the size where it was difficult for the single diver to apply the tape alone and while not impossible, is the limit for a single diver. The process would be more efficient if 2 divers are utilized on piles 18” in diameter and up. The tape rolled out very easily and stuck to itself as it should. There was no trouble getting a tight fit with no air or water bubbles behind the tape.

The installation of the jacket itself with the use of the hydraulic pumps went well. The pumps were able to stretch the jacket and to squeeze the bolting flanges together without a problem in order to get the stainless steel bolts into the flanges and tightened. Once the bolts around the hydraulic pumps were installed the other bolts were also easily installed. This system is very simple to install and appeared to provide a very tight fit, which should seal out any water and air from the steel.

Denso – SeaShield Series 500 H-Jacket

The entire installation of the Series 500 H-jacket went well. A few items that can be completed prior to the installation of the jacket to make the process go as smoothly as possible include the fabrication of the base plate pieces for the jacket to sit on if not embedded into the mudline and assembly of the jacket halves with the offset screws. The easiest base plate AMI created was made from two pieces of angle, two pieces of rod and two pieces of plywood cut to fit around the pile. A sketch of this base plate can be seen below in Figure 3. A thick neoprene pad should be glued or stapled onto the plywood to help form a seal at the base of the jacket to prevent the need for plumbers epoxy. This base plate should be set so it is perpendicular to the H-pile flanges and tightened. Once the H-jacket is set onto the base plate then the base plate angles could be adjusted if necessary so there is a tight seal along the bottom of the jacket.

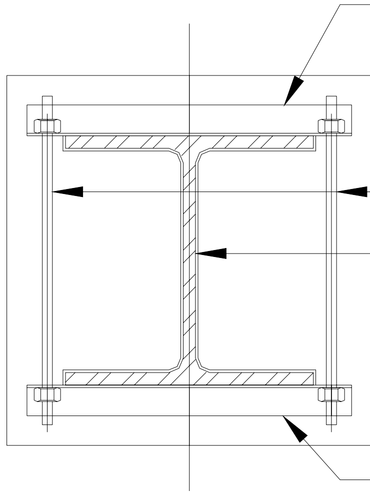


Figure 3: Series 500 H-Jacket Base Plate Detail

The remaining installation process, once the base plate is set, was accomplished efficiently. It is recommended that if the epoxy grout is being mixed and placed by hand, then an industrial high efficiency mixer should be utilized.

Conclusion

The installation of the jackets was accomplished without any major obstacles or difficulties. Both jacket systems appear to be viable alternative repair products. Time will be the ultimate judge as to whether or not the jackets are durable enough to effectively withstand the harsh winter conditions in the Duluth-Superior Harbor, which will include ice impact during spring and fall months as well as ice thermal expansion and contraction forces. A benefit of installing a large number of pile jackets at one time would include improvement in installation time by a contractor.

CATHODIC PROTECTION

Purpose of Test

Determine the degree of sacrificial cathodic protection required for steel support structures in the Duluth - Superior Harbor. The effectiveness of sacrificial Corrosion Protection Systems (CPSs) used in the test will be compared to data obtained at other fresh water installations. The knowledge gained will be used to assist in anode quantity and spacing calculations and for making recommendations on full scale CPSs in the future.

Methodology

Sacrificial CPSs work through the sacrifice of an anodic metal (in this case magnesium) attached to the steel structure it is protecting. Because the anode has a greater negative electrochemical potential relative to the steel, it accepts electron exchange with the water preferentially over the steel it is protecting. This prevents electrical exchange from occurring between the water and steel as well as the resulting corrosion.

The other prevalent type of cathodic protection systems used in marine applications are impressed current CPSs. These systems use direct current applied to the anodes from an external source to drive the steel structure surface to an electrical state that is cathodic in relation to the metals in the water.

This test will study and compare the corrosion on (5) mild carbon steel pipe samples with varying degrees of protection and grounding immersed in the Harbor at the Cenex Harvest States site in Superior, Wisconsin.

Samples include one pipe coated with cathodic protection, one left uncoated with cathodic protection, one uncoated without protection and attached to existing sheet pile, one coated without protection, and one uncoated without protection. Details of the pipe configurations can be found in the next sections of this report.

The installation of the test samples was finalized on December 31, 2008 and the test will be run for one year. Once per week, the following data will be collected at the test site and recorded: water conductivity, water temperature, electrical flow between pipe samples and anodes, and electrical potential between pipe samples and water.

Periodically throughout the test, the pipe samples and anodes will be raised out of the water to visually inspect corrosion, anode consumption, and integrity of cables and connections. If an anode has been consumed to the point where it may be fully depleted prior to the next anticipated inspection, it will be replaced with another unit as to assure continuous protection.

At the conclusion of the test in December 2009, each pipe will be weighed and thickness tested for comparison to original conditions. The anodes will also be weighed to determine total material consumption.

All weekly data collected will be compiled and included in a final report detailing findings discovered throughout the year long test period.

Test Material Details

Pipe Test Samples

Information common to all (5) pipe samples:

- Samples were manufactured from 3” diameter x 6’ long Schedule 40 ASTM Grade A53 carbon steel pipe, chemically similar to H-Section or sheet pile typically installed.
- The pipe samples were sandblasted to white metal prior to commencement of test and/or coating (SP5).

Test samples shown after sandblasting and prior to installation of coating, wires, and hardware.

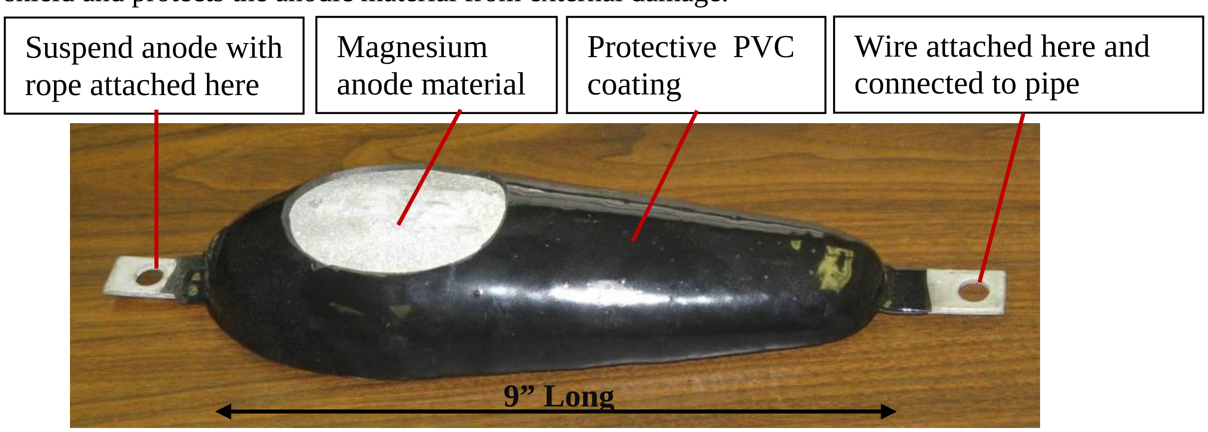
Picture 12: Sandblasted Pipe Samples

- Pipe samples were weighed without any hardware (bolts, caps, etc.) attached. The two coated samples A and D were weighed after coating. The original pipe and anode weights will be compared to those found at the end of the trial as part of the overall analysis.
- Pipe ends were capped with Schedule 80 PVC threaded caps and thread sealant.

Cathodic Protection Anodes

Two samples (A&B) were installed with sacrificial anodes attached via coated copper wire for corrosion protection during the test. The anodes used were high magnesium Model GA-MG-JR manufactured by the Galvotec Alloy, Inc. typically used for protecting hulls of vessels.

The anodes are provided with a polyvinyl chloride (PVC) coating which acts as a current barrier shield and protects the anodic material from external damage.



Picture 13: High Magnesium Anode Used for Trial

Reference Electrodes

Samples A & B were installed with reference electrodes attached to allow the electric voltage potential between the steel pipes and water to be measured and recorded. This test data in conjunction with conductivity measurements will assist in the recommendations for full scale CPS's.

The electrodes used were copper / copper / sulfate Model Stelth 1 SRE-002-CFY manufactured by Borin Manufacturing Inc.

The reference electrodes (shown with protective red cap) were inserted through holes in the bottom pipe caps of samples, glued to caps, and sealed.

Picture 14: Reference Electrodes Used for Monitoring Voltage Potential

Test Pipe Sample Details

- Test Sample A: This pipe was sandblasted and coated with a 5 mil thick industrial coating. A 1/8" wide scribe to bare metal was created the entire length of the pipe to allow some corrosion to occur on the exterior of the pipe. The pipe was attached to a magnesium anode suspended in the water approximately 1 foot horizontally from the pipe as shown in Figure 4 below to provide cathodic corrosion protection.

  In actual full scale applications, anodes would typically be attached directly to the steel structures they are protecting. In this case they were attached with a 12 gage copper stranded wire connected between the pipe and anode to allow monitoring of electric current between the two. Wires were attached to the interior of the pipe to protect the wires and connections from damage (typical of all samples).

  The wire was then passed through a series of electrical components, including resistors which will allow monitoring and recording of the electrical current between the two components. The wires were connected in a weather proof cabinet to facilitate measurements during the trial.

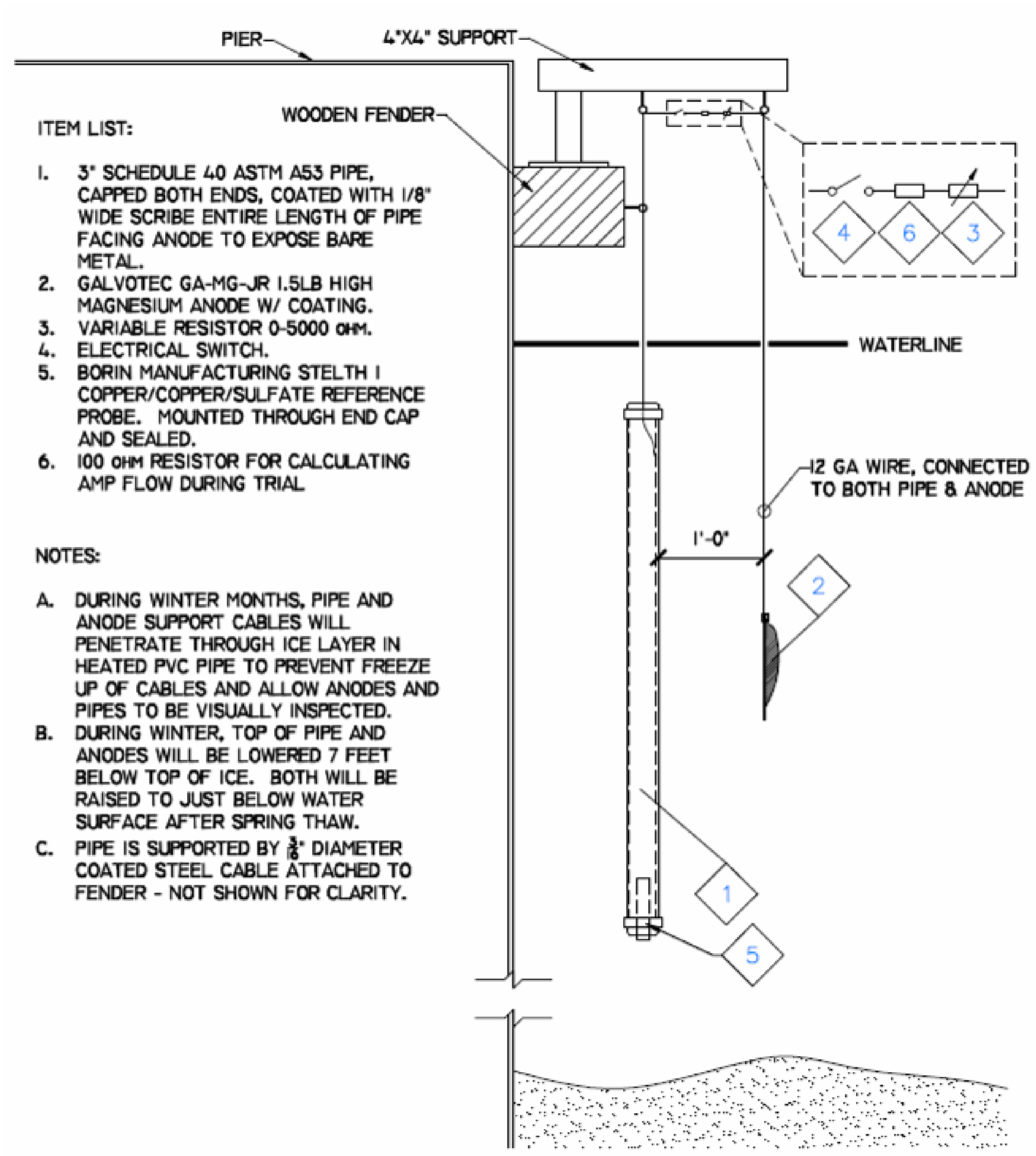


Figure 4 – Sample A Installation Schematic

A copper / copper / sulfate reference electrode was mounted through the bottom end cap of the pipe to allow monitoring and recording of the electrical voltage potential between the pipe and water.

Because the samples were installed in the winter, the cables supporting the pipe and anode were individually run through heated PVC pipes to keep ice from forming around the support cables and allow anodes and pipes to be inspected in the winter. The open water surface created in the PVC pipes will also be used to measure water conductivity during the trial.

Details and pictures of the coating preparation, weather proof electrical cabinet, heated PVC pipe, field installation, etc. can be found in the next section of this report.

- Test Sample B: This pipe was sandblasted but left uncoated and placed 10 feet down the pier from Sample 1. All other installation parameters (anode, reference electrode etc.) were identical to Sample A. Data collected around this sample will be compared to with that of Sample A to show if anode material use is linear with the area exposed bare metal being protected and for cost / benefit analysis for installation of both coatings and CPSs.

- Test Sample C: This pipe was sandblasted but left uncoated similar to Sample 2 but without cathodic protection. It was then attached to an existing sheet pile via 12 gauge copper wire. This sample will show if new steel installations are more susceptible to corrosion when not insulated from existing corroded pile structures. The sample was installed 10 feet down the pier from Sample B.

- Test Sample D: This pipe was sandblasted, coated, and scribed similar to Sample A, and installed 10 feet down the pier from Sample C. This sample was installed without cathodic protection, and corrosion will be compared to that found on Sample A.

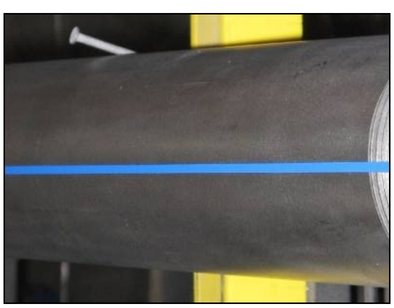
- Test Sample E: This pipe was sandblasted but left uncoated and without cathodic protection and installed 10 feet down from Sample D. The pipe's corrosion will be compared to Samples B and C.

Installation Details

Pipe Sample Coating

Pipe samples A & D were coated with Carboline Bitumastic 300 M coal tar based coating commercially used for protecting pile systems. A 1/8" wide scribe to bare metal the entire length of pipe was created to allow corrosion on a portion of the exterior of the pipes.

Pipes were sandblasted and cleaned before any coating was applied.



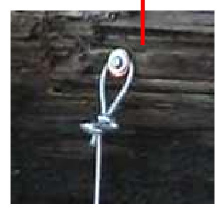
A 1/8" wide vinyl tape was applied the length of pipe prior to coating.

After coating the tape was removed and a 1/8" scribe line results the length of the pipe.

Pictures 15, 16, & 17: Pipe Sample Coating w/ Scribe Line

Pipe Supports

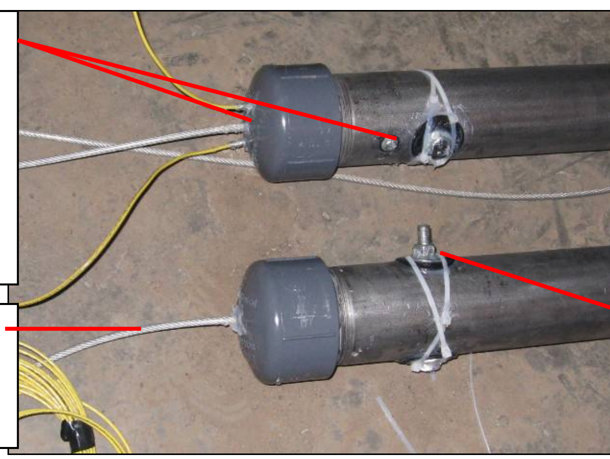
Pipes were suspended with 3/16” diameter vinyl coated steel cables attached to a timber fender running along the pier. Loops were made at the end of each cable and clamped with (2) standard 3/16” galvanized cable clamps at each cable end.



Pictures 18 & 19: Pipe Sample Cable Support Installation

Pipe Sample Sealing

Penetrations for mounting bolts, wiring, and reference probes were sealed to prevent water from entering and causing corrosion to interior of pipe.



Picture 20: Pipe Sample Sealing

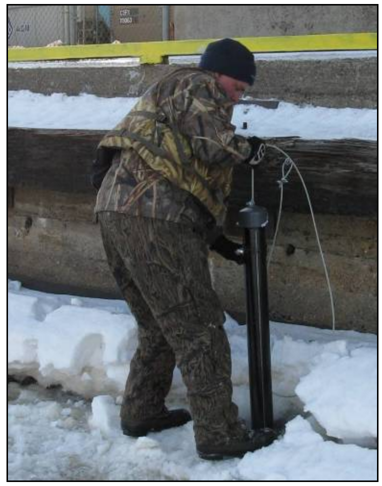
Pipe Installation

10” diameter holes were drilled through the ice to allow pipes and anodes to be lowered into the water. Pipe samples were attached to a timber fender running above the water line along the pier with 3/16” diameter vinyl coated steel cables.

Initially the pipes were installed such that the top of the pipes (and anodes) were 7 feet below the top of the ice surface to prevent them from freezing into the ice and to allow corrosion to occur during the winter months.

After spring breakup, the pipes and anodes will be raised such that their tops will be just below the water surface as experience has shown greatest corrosion in this region. The pipes and anodes will again be lowered in the Fall of 2009 before freeze up.

Individual holes were drills for each pipe and anode (ice was ~4 feet deep along pier).



Sample D shown being lowered through hole in ice along pier.

Pictures 21 & 22: Installation of Pipes Though the Ice

Samples were installed 10 feet apart from each other along pier to avoid any electrical interference between individual pipes. All except C were isolated from existing steel structures.

Picture 23: Pipe Sample Spacing

Sample C was attached to existing sheet pile with 12 gage copper stranded coated wire.

Wire was attached to interior of pipe, run through cap, and attached to existing pile at end of pier.

Pictures 24 & 25: Sample C Attached to Existing Sheet Pile

Winter Freeze Protection

Because testing will occur during winter months, Samples A & B were installed with ice freeze protection to allow the pipes and anodes to be removed and inspected during winter months.

Each individual pipe and anode on these two samples (4 in total) was lowered through a 10 foot long heated PVC pipe installed through the ice and supported from above.

10' long 6" diameter PVC pipes were wrapped in self regulating electric heated cord typically used for rain gutter de-icing. Each cord has 300 watts capacity.

Picture 26: Heat Tape Applied to 6" PVC Pipe

The 6" diameter pipe was then installed in and attached to an 8" corrugated PVC pipe (typically used for culvert installations). The top void between the two was sealed with expanding foam insulation to prevent heat loss from between the two pipes.

Picture 27: Heated PVC Pipe Installed in 8" Pipe & Insulated

The PVC pipes were then lowered through holes in the ice and supported such that their tops were ~30" above the ice surface. Insulated plastic barrels were then placed around the two pipes to prevent holes from freezing. Batted fiberglass insulation was placed in the top of each 6" pipe for further insulation (not shown in picture).

Picture 28: Heated PVC Pipes Installed in Insulated Barrel

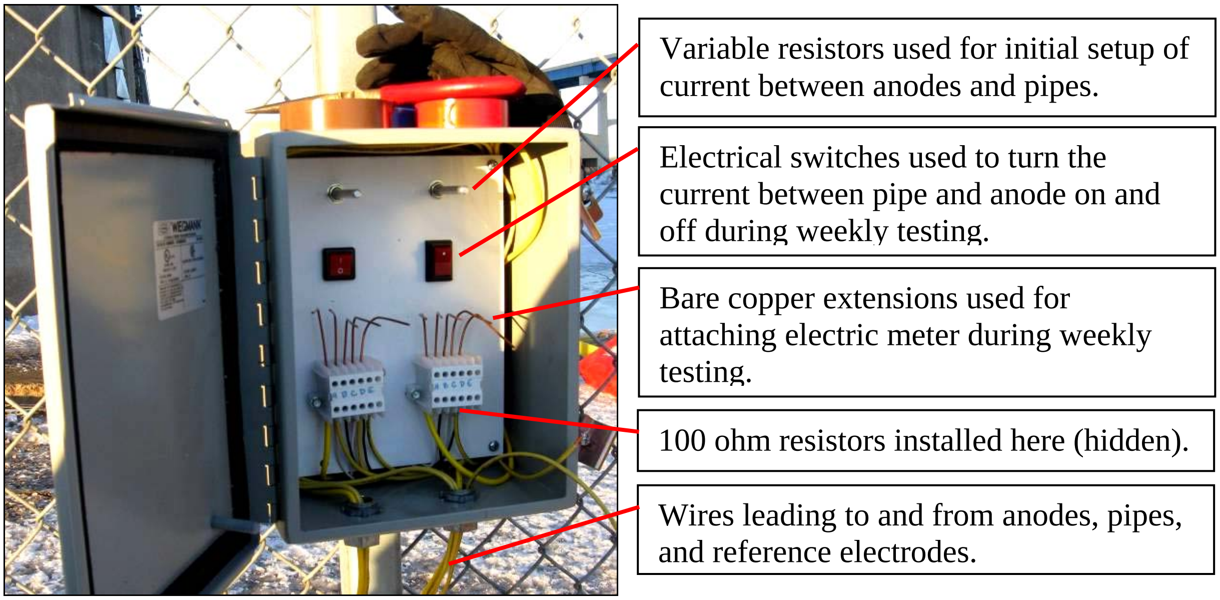
Each barrel cover was insulated for further freeze protection. The covers can be removed to allow pipes & anodes to be removed and inspected during winter months as well as allowing water conductivity measurements.

Slots were cut to allow the wires, cables, and rope to pass through and covers to be removed.

Picture 29: Insulated Barrel Installation Complete

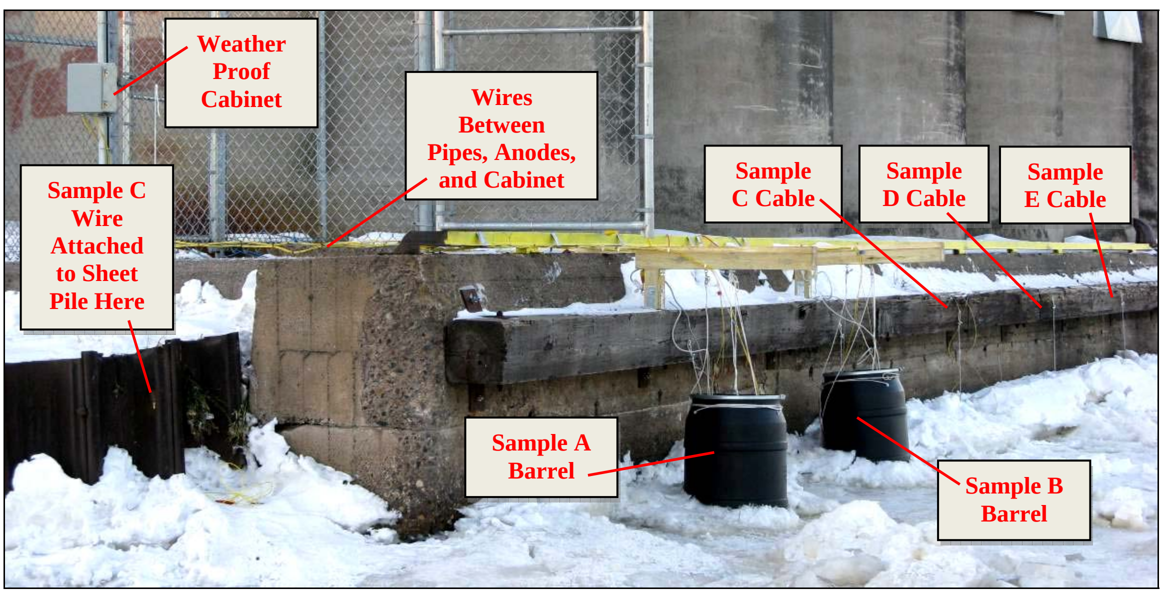
Weather Proof Testing Cabinet

All wires between the anodes, pipes, and reference electrodes were run to a weather proof box mounted near the samples but accessible year round. It also housed the electrical resistors and switches used for the trial. The enclosure will ease the weekly testing and will protect the electrical devices from the elements.



Picture 30: Weatherproof Testing Cabinet Installation

Overall Installation



Picture 31: Overall Installation

Testing Procedures

Once per week, the electrical current flow between the anodes and pipes on Test Samples A & B will be measured and recorded. The electrical voltage potential between the steel pipes and water will also be measured utilizing the connections between the reference electrodes and pipes.

Water temperature and conductivity will also be recorded for interpretation of anode consumption and analysis for future CPS recommendations.

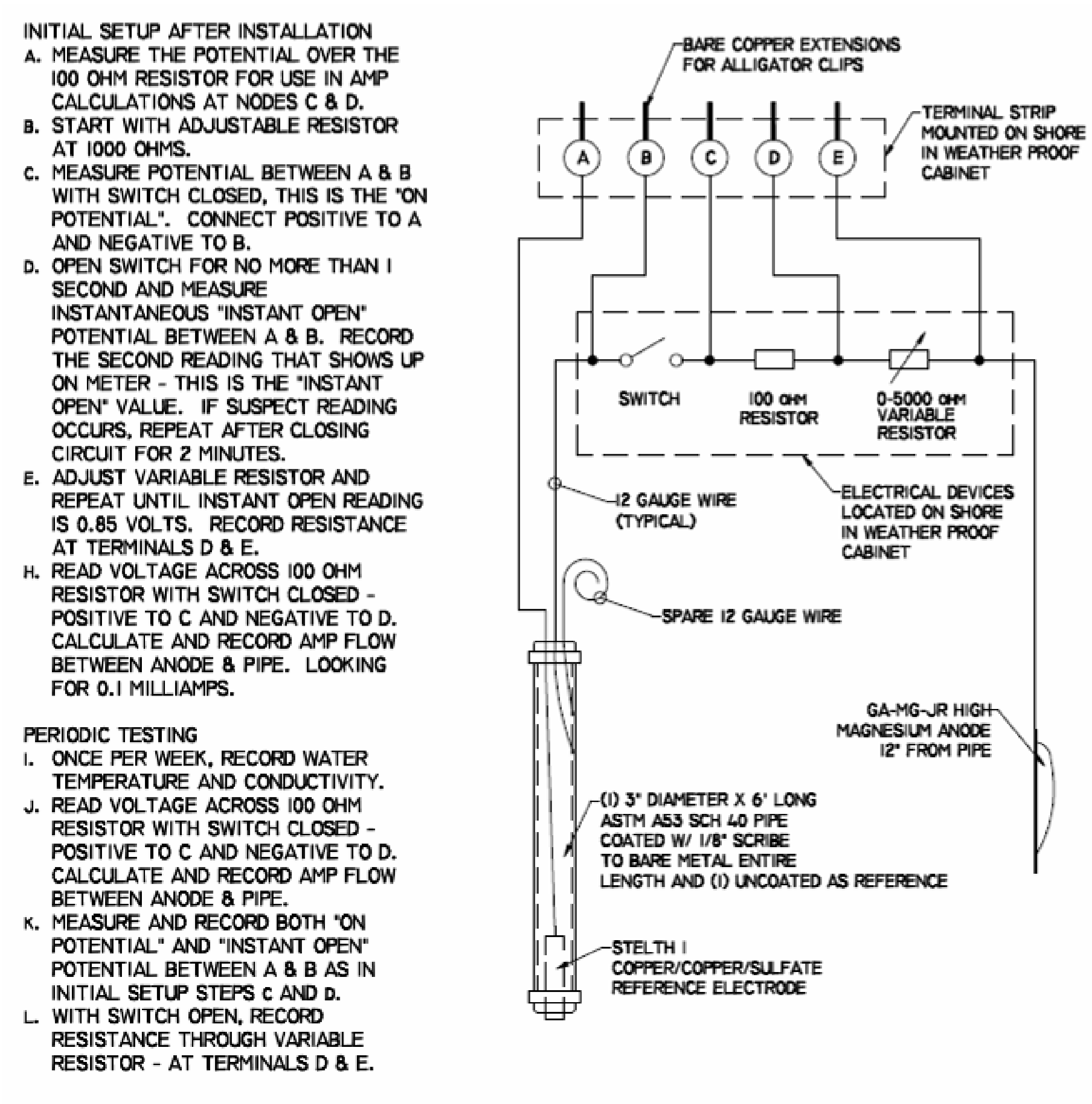


Figure 5: Testing Procedures & Electrical Schematic

Conclusion

The data collected, in conjunction with experience learned at other fresh water sites, will be used at the conclusion of the trial in December 2009 to assist in the analysis of the degree of sacrificial cathodic protection levels required for steel structures in the Duluth – Superior Harbor. The information will also be able available for the analysis and recommendations of other types of CPSs such as the more complex impressed current systems.

Respectfully Submitted,

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Reviewed By,

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APPENDIX A

Pile Jacket Product Data

Materials:

Series 500 H-Jacket:	**Denso SeaShield Series 500**
	Denso SeaShield Series 500 Spec Guide
	Denso SeaShield 550 Epoxy Grout
Series 2000 FD Jacket:	**Denso SeaShield Series 2000 FD**
	Denso SeaShield Series 2000 HD Spec Guide (2000FD Spec Guide not yet available)
	Denso Paste S105
	Denso SeaShield Marine Piling Tape
	Denso Hydraulic Tensioning Rig for SeaShield 2000FD Operating Instructions

Pile Jacket Installation Plans:

MERC Jacket Location Plan S1.0

H-Pile Base Plate Detail S1.0

Map of Project Locations

APPENDIX B

Cathodic Protection Information

Map of Project Locations

Original Pipe and Anode Information

Pipe Sample Information

Pipe Coating Information

Anode Information

Reference Electrode Information

End Cap and Wire Connection Sealing

Heat System for Winter Installation

Weather Proof Electric Cabinet

Test Procedure and Electric Circuits