NATIONAL RADIO ASTRONOMY OBSERVATORY
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VLBA Antenna Memo Series No.62

St. Croix Corrosion Report

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1.0 Introduction

The St. Croix Antenna is situated in the "atmospheric zone" near the coast. In this zone the corrosion rate of unprotected steel is typically 8 - 20 mills per year. For comparison most steel structures placed inland are situated in zones where the corrosion rate is only 1-2 mills per year. A corrosion rate of 20 mills per year means that a ¼" thick steel plate is 50% consumed in just three years. Because of the high corrosion rate, steel structures near the ocean require substantially more maintenance than inland structures. For Example, The Golden Gate Bridge is painted every year.

There are two corrosion mechanisms at work on the St. Croix Antenna Structure. These are the well known galvanic corrosion that occurs between dissimilar metals and differential environmental corrosion (crevice corrosion) which occurs due to different levels of oxygen content or different salinities.

Crevice corrosion has been the most destructive corrosion mechanism on the St. Croix antenna. "Crevice corrosion is a localized attack which is initiated by the extremely low availability of oxygen in a crevice where a buildup of chlorides can occur".[2] Crevices typically occur between nuts and washers or around the threads of a screw or on the shank of a bolt. To avoid crevice corrosion at bolted connections, it is recommended to avoid water penetration by filling crevices with adherent sealant or mastic. Crevices can also occur under deposits on the steel surface. To avoid crevice corrosion under deposits, periodic cleaning is recommended. Crevice corrosion also occurs under rust because the rust shields the underlying metal from free access to oxygen. Therefore, it is extremely important that the existing rust be removed. This means that corroded bolts must be removed and the rust between them and the structure must be eliminated.

The other corrosive mechanism on the antenna is the more familiar galvanic corrosion. Galvanic corrosion occurs when two dissimilar metals are connected to each other in an electrolyte (i.e. salt water). Current flows through the electrolyte from the more reactive metal (anode) to the less reactive (cathode), thereby corroding the anode area. One would think that since the VLBA structure is all the same material (steel) galvanic corrosion would not occur. However, galvanic corrosion can occur due to localized impurities. On steel structures galvanic corrosion also occurs because: (1) new steel is anodic to old steel, (2) brightly cut surfaces (i.e. pipe threads) are anodic to uncut surfaces, (3) steel is anodic to its own mill scale, and (4) highly stressed areas are anodic to less stressed areas.

Galvanic corrosion is usually moderated by the use of coatings. In marine environments, these include a zinc rich primer, epoxy intermediate coating and a polyurethane topcoat.

2.0 Inspection Results

On January 31, through February 1, 2006, the author visited the St. Croix antenna. With the help of the local VLBA site technicians, Ken Klose and Greg Worrel, we performed a top to bottom inspection of the antenna structure. In this section I will document the findings from this inspection.

2.1 Apex

The picture below shows corrosion developing on the lower part of the

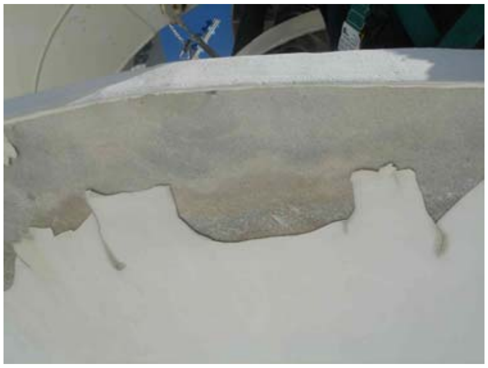
structural brackets used to connect the FRM to the quad legs. This appears to be galvanic corrosion.

Quad Leg - The next picture shows the quad leg corrosion damage before it was repaired during the April 2005 maintenance visit. The corrosion was localized at the bottom of the quad leg because debris accumulated on the lip inside the leg. This allowed crevice corrosion to consume the leg from the inside. To prevent this type of corrosion from reoccurring, access doors would need to be installed on the quad legs so that their insides could periodically be cleaned.

As you can see from the following picture, the corroded steel was removed and steel plates were welded over the damaged area during the 2005 maintenance visit.

In less than one-year, rust is appearing at the weld on the quad leg patch. This illustrates how the weld material is anodic to the surrounding steel. The silver paint is a product called Rust Bullet that was supposed to eliminate all rust. As you can see, this product is beginning to fail with less than one-year of service. The patches have effectively repaired the damage. However, the paint system on the patches must be repaired or the welded area will rapidly corrode.

<u>Subreflecto</u>r – Both the reflective silver paint and the white overcoat paint on the outer eight inches of the subreflector has peeled off. The carbon fiber substrate is now exposed. The paint will continue to peel until the antenna is unusable. The subreflector that was removed from the Brewster Antenna should be repaired and swapped with this one as soon as possible.



The following list describes several minor items at the apex that also need repair due to corrosion.

• Flex shaft hangers need replacement;
• Dry air flex lines have cracked fittings;
• Screen door springs on cable wrap need to be replaced with stainless;
• Focus motor bolts 3/8 UNC x 2 inch need to be replaced with stainless;
• FRM counterweights – need cleanup and paint;
•Cable tray brackets need paint;
•The rod end on the dicroic reflector needs to be replaced.

2.2 Backup Structure

The antenna backup structure located just below the dish is where the most serious corrosion damage is occurring.

<u>Vertex Room</u> - The bolts and nuts that attach the vertex room feed house, as shown below, to the structure have severely corroded and need to be replaced with stainless steel.

Bolted Connections – As described earlier, bolted connections are susceptible to crevice corrosion. This is evident in the following series of pictures.

The first picture shows the corrosion on an average bolted connection. This is how the majority of the bolted connections look. It is evident in this picture that the paint system has failed and crevice corrosion is beginning to consume a majority of the bolts.

The next picture shows one of the more seriously corroded bolted connections. On this connection, most of the bolt heads have corroded to the point where they will need to be replaced. I estimate that approximately 10% of the backup structure bolts have corroded such that they will need to be replaced.

From my experience with the St. Croix Antenna, the next picture illustrates the time scale on which the corrosion occurs. The upper left hand nut is beginning to show a slight discoloration as the paint system is compromised. The remaining nuts going clockwise show how the corrosion progresses in one year intervals. The third-year after the paint is compromised, the nut rapidly begins to fail. Bolts which have corroded similar to the second bolt in this series need to be replaced. This is because once crevice corrosion begins, it will continue its attack even if it is painted over.

Trusses – The truss members have lost minimal steel due to galvanic corrosion.

The corrosion on the truss members does not seem to be rapidly progressing even though the paint system has failed as evinced by the above picture.

Another place on the trusses that will require attention is the joint underneath the intersection between the third and fourth row of panels where the trusses trap water and debris. These boxes need to be modified so that the water traps are eliminated.

Tanks – The access doors on the large enclosed box sections of the backup structure were opened up and inspected from the inside.

These box sections had severe rust in pockets where water collects. All of the box sections on the antenna will need to be opened, cleaned and painted. Holes should be drilled in the structure to allow water to drain. These drain holes need to have clean edges and then must be properly covered with paint. The drain hole shown below was cut with a torch. Corrosion has severely attacked the hole demonstrating the need for clean painted holes.

The I-beam inside the antenna "tank", as shown in the next picture is severely corroded. The top of the flange of the I-beam will need to be reinforced to restore the I-beam to its original strength. There are a few other places on the structure that will also require reinforcement.

Counterweights – Remedial measures by the site technicians have greatly slowed the rate of corrosion. However, there are places where water accumulates that need to be cleaned and repainted. Some of the bolts in these areas may need replacement as well.

Star Structure – The paint needs to be restored on several of the star structure bolts. Places where water collects have corroded excessively and will also need to be restored.

2.3 Lower Structure

The site technicians have done an excellent job controlling the corrosion on the lower part of the structure. The site technicians are able to reach this part of the structure to apply Chemprime and paint during observing. Chemprime is the brand name for product containing phosphoric acid that is sprayed on to dissolve and remove rust.

Catwalks and Stairs – Repairs done on the catwalks and stairs have mostly alleviated the corrosion problems. However the paint system on these areas needs to be improved to impede further corrosion.

Large Tubes - The large structural tubes supporting the antenna show only minimal corrosion at the flanges where they are bolted together.

Rail – When the rail began to show accelerated corrosion, the site technicians initiated an extensive corrosion control program. The rail was treated with Chemprime for several days and then repainted. Their efforts have mostly eliminated the corrosion problems on the rail.

Pintle Bearing – The washers under the pintle bearing nuts were replaced with galvanized washers and repainted during the 1999 maintenance visit. The new paint has performed well and there is very little corrosion in this area.

2.4 Ancillary Systems

Drive Systems – The corrosion on the drive motors and gearboxes is mostly superficial. This area will require repainting.

Roof – The roof of the control building has corroded through in a couple of places. When the roof fails, a local contractor should be used for replacement.

Propane tank – The propane tank was repainted by the site technicians. The tank shows very little sign of corrosion.

Generators 150 and 75 KW – During this visit, the site technicians repainted the generators. With the site technicians continued efforts to mitigate corrosion, the generators should not fail due to corrosion until they are near the end of their anticipated useful life. At that point they will need to be replaced.

Power Transformer – The utility transformer door has corroded through. A patch should be installed over the corroded hole to keep vermin out of the transformer.

Weather Station- The weather station did not show any severe corrosion except on one of the guy wire anchors. This anchor should be treated and coated to prevent further corrosion.

HVAC -The site technicians initiated a program where they regularly wash the HVAC condensers with fresh water. The HVAC components are also plated with anti-corrosive coatings before they are installed at St. Croix. These steps have greatly increased the service life of the components but they will still need to be replaced on an accelerated schedule.

3.0 Remediation

This section details the steps needed to return the structure to full strength and to moderate the effects of corrosion.

3.1 Steel Repair

The first step in the rehabilitation of the antenna is to reinforce the corroded the steel and replace the corroded bolts. The next step is to eliminate places that trap water and debris. The most effective way to eliminate the water traps is to seal them by covering them with steel plates. The steel plates are welded over the water pocket and an air tight box is formed in its place. This should be done wherever possible. Water traps that can not be completely sealed should have drain holes added to them. They should also have additional coatings applied to help mitigate future corrosion. I am currently researching coatings that would give additional protection in these areas. The Navy uses a brushed on coal tar type paint. This may provide additional protection on the antenna.

3.2 Paint System

Refurbishing the paint system is currently our best option to slow the corrosion on the antenna structure. In the past, NRAO has hired contractors to spot repair the paint system. Spot repairs were also performed with limited success during the maintenance visits by NRAO personnel. In both cases, adequate time and resources were not available to properly prepare the surface before painting. If any rust at all is left under the paint, it continues to attack the structure. The rust then swells causing the paint to crack. Once the paint cracks, the corrosion begins consuming the steel at an intensified rate.

The corrosion on the St. Croix antenna has now progressed to the point where there are so many corroded areas that it will be easier to repaint the entire antenna.

3.2.1 Surface Preparation

The surface preparation is the single most important parameter in relation to coating life and protection of the steel. It is the degree of cleaning (removal of rust, mill scale, oil/grease, soluble salts etc.); the roughness (anchor pattern); and preparation (rounding and grinding) of sharp edges, welding seams and other imperfections in the steel work, that is critical in this phase. Paint adheres better to a clean and rough surface and as a result will last longer.

The first step in the surface preparation is to remove the soluble salts from the surface and crevices of the structure. This is accomplished by high pressure rinse or steam cleaning. A soluble salt remover may be added to the washing solution.

The next step is to sand blast the structure. NRAO has traditionally only used water blasting on antennas in preparation for painting. There is a concern that the sand will find its way into the bearings and vulnerable parts of the machinery. However, water blasting will not yield an adequate surface for the degree of protection required at St. Croix. Therefore, I propose sand blasting the St. Croix antenna. We must make certain that all of the vulnerable areas are covered before the blasting begins.

The antenna should be sand blasted to a SSPC SP-10 surface. "In this method, all oil, grease, dirt, mill scale, rust, corrosion products, oxides, paint or other foreign matter shall be completely removed from the surface by abrasive blasting, except for very light shadows, very slight streaks or slight discolorations caused by rust stain, mill scale oxides or slight, tight residues of paint or coating. At least 95% of each square inch of surface area shall be free of all visible residues, and the remainder shall be limited to the light discolorations mentioned above." [5] An SP-10 surface is illustrated in the picture below.

3.2.2 Coating System

The paint system on the St. Croix antenna must be replaced with a high quality protective coating to mitigate future corrosion. The military uses the following paint scheme on their offshore structures. I suggest we use a similar painting procedure.

1) A zinc rich primer is applied to the structure as soon as possible after sand blasting to prevent rust or soluble salts from forming on the steel. A stripe coat is then applied by brush to hard to reach areas such as corners, crevices, angles and welds.

2) Next an epoxy intermediate coat is applied within the "recoat window" of the primer coat. A strip coat is also applied to hard to reach areas.

3) A polyurethane topcoat is then applied to protect the epoxy from UV deterioration.

4) A joint sealant is applied to back-to-back steel joints that are not seal welded. This sealant is applied to each side of the joints within 48 hours of the topcoat.

The joint sealant is needed to protect bolted connections and places where cracks in the paint can allow water to get into crevices and initiate crevice corrosion. The Navy also seal welds to eliminate crevices. Seal welding would be an ideal way to eliminate crevices in the backup structure. However, this should be avoided as it could cause considerable warping of the structure thereby degrading the dish surface accuracy.

4.0 Cost and Schedule

It is estimated that the repainting and restoration of the St. Croix antenna will take four men 12 weeks with the labor breakdown as follows.

Task	Man Hours
Steel and bolt repair/replacement	160
Bolted connection surface preparation	360
Sand blasting structure	240
Primer coat	320
Intermediate coat	320
Top coat	320
Cleanup/ miscellaneous	120
Total	**1840**

The following table lists the cost of rental equipment, shipping, paint and travel expenses for two men. This assumes that the VLBA site technicians' labor will be available for the painting period. This table is only a rough budgetary estimation.

Equipment	Cost/wk	Total
Man lift	$2500	$25000
Air compressor	$500	$5000
Sandblaster	$500	$5000
Paint		$25000
Shipping		$20000
Travel (2 men)		$40000
Misc. (bolts, spray tips, tools and etc		$10000
Total		**$130,000**

5.0 Conclusion

The paint system on the St. Croix antenna has been compromised and corrosion is consuming the steel at a rapid rate. I estimate that if left unchecked the St. Croix antenna structure would suffer a critical failure due to corrosion in less than 5 years. The corrosion is most destructive and prominent at the bolted connections. These bolted connections will require extensive surface preparation to eliminate the existing crevice corrosion before they can be repainted

It is critical that we schedule a major maintenance visit to St. Croix during the next fiscal year. It is also very important that the site technicians continue their corrosion mitigation efforts in the near term.

6.0 References

[1] Unified Facilities Guide Specification, UF-09971 Exterior Coating of Steel Structures (09-2001), Naval Facilities Engineering Command (NAVFAC)

[2] Army TM 5-622, Maintenance of Waterfront Facilities, Departments of the Army, Navy, and Air Force, 01 June 1978

[3] Rasmussun, Soeren Nyborg, Corrosion Protection of Offshore Structures, Hempel A/S

[4] Paul, Scott H, Minimizing Infrastructure Deterioration, Corrosioneering Journal. Oct 2001

[5] www.blastal.com, SP-10 definition, SP-10 picture.

[6] Burleigh, T. David PhD, PE, Materials and Metallurgical Engineering Department, New Mexico Tech Teleconference on 3/1/06

[7] Serna, Rey, NRAO, Conversation on Corrosion Control, 2/28/06