LAB TEST METHODS FOR COMPARISON OF CORROSION PROTECTION PRODUCTS

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ABSTRACT

Bare metal connectors can be susceptible to corrosion especially in humid and saline environments. Various methods of cold-applied corrosion protection are available - silicone grease, paint-on coatings, mastics, self-fusing tape, and gel-based sealant strip. Some simple lab tests can be used to evaluate their comparative corrosion performance, and their respective effectiveness compared with no protection.

The paper describes 1)test sample preparation, including sources for materials. Samples range from thin metal films, metal discs, and wrapped metal bars, to connectors installed on short cable lengths. 2)how to calculate a corrosion rate for carefully prepared samples. 3)corrosion rates and other data for several methods of protection in various environments. These environments are : ASTM artificial seawater at 60degC, 5% sodium chloride solution, ASTM salt fog, "CASS" accelerated salt fog, and weatherometer (combined UV and water spray) exposure.

Other factors relating to product lifetime should also be considered when selecting a corrosion protection product. This paper focuses on corrosion performance as a key factor. All of the corrosion environments described require relatively long-term testing. The fastest method is 60degC seawater - which can be set up at low cost, using simple samples, to give a good comparison between various corrosion protection products.

INTRODUCTION

Cable television systems are becoming more complex, extensive utilities. System lifetimes are crucial not only to reduce maintenance and enhance cash flow, but also to maintain a pleased, growing customer base. Interactive systems will place still higher demands on reducing downtime. Since cable television is a serial system, reliability is a function of the weakest link. Corrosion is often the cause of that weak link. In aerial structures, salt fog and salt spray environments in coastal areas can rapidly deteriorate unprotected metals. Ground boxes and manhole systems face additional problems with ground water and, in northern areas, saltwater runoff from snow covered roads.

The predominance of aluminum in these systems can complicate corrosion problems. Aluminum is high on the galvanic series, therefore it sacrificially corrodes when electrically coupled to metals lower in the series such as steel. Inadvertant couples in ground boxes and manholes can result in catastrophic corrosion.

The corrosion process is complex. It can involve faster corrosion on hot metal such as amplifiers, and crevice corrosion in stressed areas such as coaxial cable bends or coupling threads. Acid rain will also affect corrosion rates and temperature cycling complicates the analysis of corrosion problems. A black body on a pole in Pittsburgh, for example, can reach 140°F during a sunny fall day and drop to 30°F during a cool night 12 hours later.

Corrosion, like fire, requires three conditions to happen. First, two metals or the same metal at different energy levels, must be present. This always occurs because of slight differences in stress level during manufacture for example. Second, the two metal areas must be electrically connected. In a serial system, they always will be. Finally, there must be electrolyte present. Water or water vapor in the environment is an electrolyte—especially if any salt is present. By cutting off one of the three conditions, corrosion can be stopped. In a serial system, the only practical method is to eliminate electrolyte—by coating to reduce the presence of water (or humidity) at the metal surface.

Finding the "best" corrosion prevention product involves evaluating its ability to withstand temperature extremes of the environment, ease of installation in a variety of conditions, applicability to a variety of equipment, the need to re-enter for maintenance, and the key ability to prevent water reaching metal structures.

A simple lab test is needed to compare corrosion prevention products; preferably a test to take into account the above conditions, in a reasonable time period. Several test methods are available ranging from visual observation to quantitative measurements.

TEST METHODS

Various test samples and standard environments were tried. Samples included

a) new distribuition connectors installed between sections of half inch jacket coax cable

b) copper mirrors-a thin layer of vacuum deposited copper on a glass slide

c) 120 grit finish 1" diameter 1010 steel discs, 0.06" thick

d) smooth barstock 1018 steel mandrels, 0.38" diameter, 5" long

Distribution connectors were evaluated visually to determine whether the corrosion protection had allowed water to corrode the connector (which over time would cause electronic noise and eventually metal failure).

Copper mirrors yielded a pass/fail rating after exposure—they either corroded away or were intact. Both the steel discs and steel mandrels were used to give a quantitative measure of corrosion rate in terms of mils of material gone on average over one year—mpy, or mils per year. Mild steel was used because of its susceptibility to water and a faster corrosion rate than aluminum. Enough samples were used to allow samples to be removed from the test at various time intervals to measure corrosion rates vs. time. For quantitative work, careful sample preparation was required. First, the metal was cleaned:

1. degrease in isopropyl alcohol
2. wash with detergent such as MICRO-SOAP
3. rinse in distilled water; dip in dilute hydrochloric acid (about 20 seconds)
4. rinse; rinse in acetone
5. dry in a dessicator

The samples were not touched with bare hands, which could leave corrosion sites, and were accurately weighed when completely dry. After covering with the corrosion protection and exposing the sample to a corrosive environment, each sample was rinsed in cool tapwater and blotted dry before removing the corrosion protection. The metal was gently cleaned with a nylon scourer to remove any surface corrosion products. Note: the presence of any pitting should be recorded in this kind of test, since it invalidates the corrosion rate calculation and can itself be a severe corrosion problem. In these tests the corrosion was a uniform layer. After gentle abrasion the samples were dipped in dilute hydrochloric acid until signs of rust had just disappeared.

This was followed by rinsing in water, then acetone, and thorough air-drying. Accurate weighing enabled the weight loss to be calculated. The equation used to calculate the corrosion rate was:

$$\text{corrosion rate (mpy)} = \frac{534 \times W}{D \times A \times T}$$

where W = weight loss of the sample, in milligrams
D = density of the metal used, in gm/cc
A = surface area of the sample, in square inches
T = time in the corrosive environment, in hours

Methods of applying the corrosion protection obviously varied. For tape-like products, mandrels were wrapped and discs were "sandwiched" between two flat layers with or without overlap seams. These sandwiches were securely clamped around the edges of the tape product to ensure that only the tape, or the overlap seam, was tested. The clamp was a pair of plastic rings somewhat larger than the diameter of the steel disc, bolted together with PVC nuts and bolts. The same kind of sandwich procedure was used for copper mirror samples. A variety of test environments was used. Standard ASTM D2565 weatherometer testing involved intense ultraviolet exposure plus alternating wet and dry cycles to simulate outdoor conditions. Salt fog tests using a 5% NaCl mist were done in accordance with ASTM B117. Accelerated salt spray (CASS) used 5% NaCl mist with copper chloride and acetic acid to accelerate corrosion, in accordance with ASTM B368. To simulate manhole conditions, saltpool immersion testing was done at 30°C, in a four foot depth of circulating 5% NaCl solution.

For small lab samples, a 5% solution of ASTM artificial seawater at 60°C was a good corrosion test. The seawater solution and samples were contained in wide-mouth polyethylene jars with a loose cover to reduce evaporation; the jars were maintained at 60°C in a simple heated water bath.

For all connector testing, thermal cycling was run before the sample was corrosion tested. Thermal cycling consisted of 20 cycles between -40°F and +140°F to simulate environmental conditioning. Three cycles a day, with three hours at each temperature extreme, were run. This is sometimes referred to as "Bell" cycling since it originated in the phone system.

RESULTS

The corrosion rates over time for various environments are shown in Figure 1, for both unprotected samples and ones protected with silicone gel tape. Immersion in 60°C saltwater gave the fastest quantitative results, with reproducible corrosion rates after 1000 hours. Salt fog and weatherometer tests were useful, but required more expensive test facilities. The samples referred to in the graph were mild steel discs and mandrels, which gave the same rates. Copper mirrors yielded a semi-quantitative result—the time that corrosion failure was delayed was indicative of how much the corrosion process had been slowed down—see Table 1.

Several different corrosion protection products were compared in the lab. For example see Figure 2 which gives corrosion rates for various products wrapped on mild steel mandrels and immersed in 60°C seawater solution.

Simple exposure to a corrosion environment indicates how good a seal is obtained when first applied. For outdoor applications a more realistic evaluation includes thermal cycling. This was found to be very important when comparing corrosion protection methods--mastic tapes, self-fusing rubber tapes, paint-on compound over vinyl tape, silicone grease and silicone gel tapes.

During thermal cycling the coated-over vinyl tape contracted, allowing subsequent water ingress and corrosion. The installation process was also time consuming, although re-entry was reasonably quick. Self-fusing hydrocarbon rubber tapes split during thermal cycling. Since they did not bond to the metal substrate they allowed water ingress under the tape, visible as a spiral corrosion path along the aluminum to the connector. Badly corroded areas were noted under the splits; re-entry was easier than mastics. The mastic tapes were easy to apply and seemed to give good installations. Samples were placed very carefully in the thermal chamber because of the tendency of mastics to get very sticky when warm. After corrosion testing—and after much difficulty removing the mastic—all five samples showed water ingress and local corrosion underneath.

Silicone grease, while messy to apply, did somewhat better. Apart from corrosion on sharp edges where it was difficult to ensure coverage, the connectors and cables were mostly dry and shiny. There was a tendency for the grease to crack during thermal cycling—which could lead to longer term problems. Of course the grease was also very susceptible to removal and damage, and was messy to re-enter.

Gel tapes were easy to apply and remove. When applied correctly they gave excellent performance through thermal cycling and corrosion testing. Due to the softness of the material it was easily scuffed. However, any corrosion was limited to the area of metal exposed; water did not travel under the tape to other connector areas.

Table 2 is a summary of tests in the three fastest corrosion environments--CASS accelerated salt fog, standard salt fog, and saltpool immersion. Unprotected samples showed severe corrosion—in places right through the aluminum sheath—after 900 hours in saltpool or salt fog, or after 275 hours in CASS salt fog. Corrosion of the taps looked similar to the degree of corrosion seen in coastal cable TV systems after typically 6 months to 2 years unprotected.

CONCLUSIONS

Bell temperature cycling following by saltpool immersion is a good method for cable television engineers to try out corrosion protection products, on standard connectors. Applying and removing the products also indicates the ease of use in the field. This test does take about 1000 hours (6 weeks) and requires a temperature cycle chamber plus a saltwater tank. An accelerated test is CASS salt fog, which will give useful results in as little as 275 hours (12 days) after thermal cycling. However, it requires a special chamber to provide a carefully controlled salt fog.

At present there are no cable TV industry standards for corrosion protection products, and we do not claim to know all of the requirements for such applications. It is very clear that temperature cycling is a crucial test. Without it products may give good lab results and fail during field use. The test can be run automatically with a suitable environmental chamber, or it could be approximated using a simple oven and home freezer, changing the samples between the two manually three times a day.

For small lab samples a simple well-controlled corrosion test can be done using mild steel mandrels, and a 60°C seawater or saltwater solution corrosion test. This requires only simple lab facilities—a water bath, accurate scales (for corrosion rates) and simple chemicals for the cleaning procedure.

With more expensive complex cable television systems, corrosion effects on lifetime can be crippling. In this paper we have concentrated on simple corrosion testing as a key test. We have not evaluated signal quality after corrosion. Also in comparing product performance the specifying engineer should consider evaluation of such things as long-term effects of heat, cold, ultraviolet exposure, etc. By using a series of simple tests, the engineer can easily decide on the best corrosion prevention product for their system.

SOURCES OF MATERIALS

1. Copper mirrors (0.25" x 1.0" x 0.06" glass substrate):
   Evaporated Metal Films, Inc.
   701 Spencer Road
   Ithaca, NY 14850
   (607) 272-3320

2. 1010 steel discs (1" diam., 0.06 thick 120 grit finish):
   Metal Samples, Inc.
   P.O. Box 8
   Munford, Alabama 36268
   (205) 358-4202

3. Artificial seawater compound (ASTM D1141):
   Lake Products Co., Inc.
   P.O. Box 498
   Ballwin, MO 63011
   (314-536-1600

Table 1
Time to onset of corrosion of copper mirrors

environment	time for unprotected mirrors	time for mirrors protected by silicone gel strip
weatherometer	200 hr	3200 hr
60°C seawater	24 hr	3000 hr

Table 2
CORROSION PREVENTION PRODUCT TESTING RESULTS

Corrosion Prevention Product	Salt Fog Time (hrs)	Salt Fog No. of Samples	Results	Saltpool Immersion Time (hrs)	Saltpool Immersion No. of Samples	Results
Mastic Tape	1000*	1	Poor. Sample wet & corroded. Difficult to remove.	930	4	Poor. Sample wet & corroded. Difficult to remove.
Vinyl Tape with Paint-On Compound	1000*	1	Poor. Vinyl pulled open during cycling. Corrosion	910	2	Poor. Vinyl opened up. Connectors wet & corroded.
Silicone Grease	300**	2	Good. Grease had cracked. Corrosion only at sharp edges Difficult to apply evenly.	910	2	Fair. Some cracking & corrosion at cable jacket.
Self-Fusing EPR Tapes	275**	8	Poor. Split during cycling. Water ingress and corrosion under tape.	930	11	Poor. Split during cycling. Corrosion at cable jackets with water spiraling to connector.
Silicone Gel Tapes	275**	16	Excellent. No corrosion. One sample slightly scuffed with no corrosion at damage	930	16	Good to Excellent. Corrosion where product scuffed off; but corrosion limited to scuffed area.
	670**	4	Excellent. No corrosion			

*Standard Salt Fog
**CASS Accelerated Salt Fog

FIG. 1—CORROSION RATES vs. TIME, VARIOUS ENVIRONMENTS

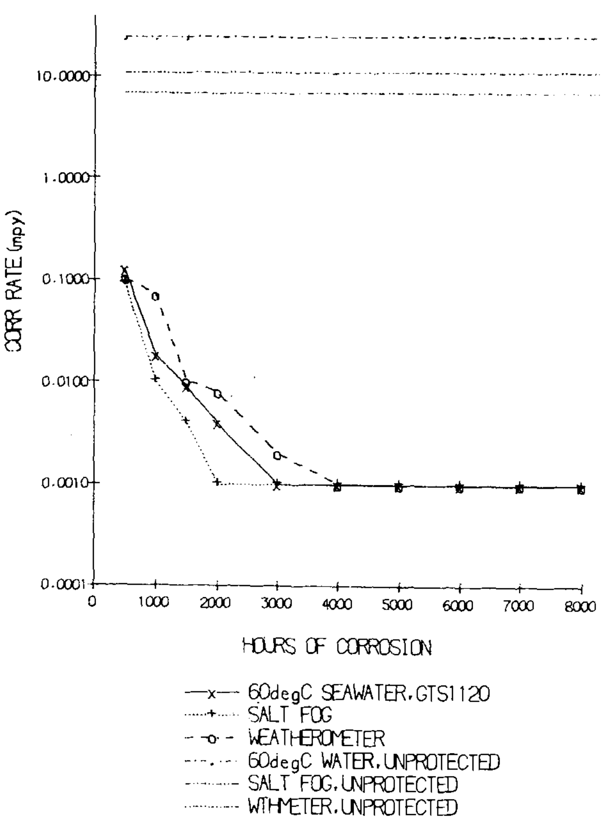

FIG. 2 – CORROSION RATES FOR VARIOUS PRODUCTS 60degC SEAWATER