

Development of an Improved Cosmetic Corrosion Test for Finished Aluminum Autobody Panels

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ABSTRACT

A task group within the SAE Automotive Corrosion and Protection (ACAP) Committee continues to pursue the goal of establishing a standard test method for in-laboratory cosmetic corrosion evaluations of finished aluminum auto body panels. The program is a cooperative effort with OEM, supplier, and consultant participation and is supported in part by USAMP (AMD 309) and the U.S. Department of Energy. Numerous laboratory corrosion test environments have been used to evaluate the performance of painted aluminum closure panels, but correlations between laboratory test results and in-service performance have not been established. The primary objective of this project is to identify an

accelerated laboratory test method that correlates with in-service performance. In this paper the type, extent, and chemical nature of cosmetic corrosion observed in the on-vehicle exposures are compared with those from some of the commonly used laboratory tests

INTRODUCTION

Although aluminum closure panels have been used on numerous vehicles for several years, the degree of confidence in predicting service performance has not been high due to the lack of an accelerated corrosion test that mimics field performance. Automotive manufacturers and their suppliers often rely on accelerated corrosion test that were developed for

evaluating steel, but these tests are not always consistent with in-service aluminum closure panel performance.

In order to address the need for an accelerated aluminum corrosion test, a group comprised of representatives from the US automotive manufacturers, aluminum suppliers, coating suppliers, and other associated suppliers was formed in 2000. The goal of this group has been to identify and implement a standardized accelerated corrosion test for cosmetic corrosion of aluminum that exhibits that same appearance, severity, and corrosion products that are exhibited on in-service aluminum components. The purpose of this paper is to provide an update on the efforts of this group.

EXPERIMENTAL

MATERIALS

In 2001, the first step in the development of a new cosmetic corrosion test occurred with the establishment of a reservoir of painted panels. These panels would then be used in the subsequent evaluation of all test methods. As listed in Table 1, the substrate materials, metal finish and paint processing variables were selected to give a range of cosmetic corrosion performance. Several aluminum alloys used in the Unites States and in Europe, both current and historical, were included. Electro zinc coated steel and uncoated cold rolled steel were included as reference materials. Two of aluminum alloys were processed to simulate metal finishing in an automotive assembly plant body shop.

Table 1. Materials

Panel Code	Alloy	Substrate	Metal Finish	Paint System
A or 1	AA6111-T4PD		Mill	Standard
B or 2	AA6111-T4PD		Mill	Low F
C or 3	AA6111-T4PD		Mill	Ecoat Only
D or 4	AA6111-T4PD		Sanded	Standard
E or 5	AA6016-T4		Mill	Standard
F or 6	AA6022-T43		Mill	Standard
G or 7	AA2036-T4		Sanded	Standard
H or 8	EG 60 Steel		Mill	Standard
I or 9	Cold Rolled Steel		Mill	Standard

Two sizes of panels, 2" x 4" and 4" x 6", of each of the materials were painted with a typical automotive paint system. This paint system included zinc phosphate pretreatment, medium-build cathodic electrophoretic priming (E-coating), and spray painting with a primer surfacer and white basecoat/clear topcoat system for a total paint film thickness of approximately 100µm. One set of 6111 panels (Panel Code B) was processed through the phosphate pre-treatment with lower fluoride

concentration (comparable to the fluoride level used for steel only vehicles which results in lower phosphate coating weight). Also, since qualification testing is often done on panels that are processed only through the electrophoretic primer (E-coat) step, another set of 6111 panels (Panel Code C) was processed only through the E-coat step (i.e. standard fluoride for Al but no basecoat or clear coat applied). Panel code C was evaluated in accelerated tests only (no on-vehicle or proving ground exposures).

Panels were prepared as needed for testing with two parallel scribes penetrating through the coatings to the substrate. The panels were provided to the testing laboratories as fully prepared painted and scribed panels. Triplicate sets of the painted and scribed samples have been exposed in a variety of environments, including laboratory, static outdoor exposure, proving ground, and on-vehicle tests.

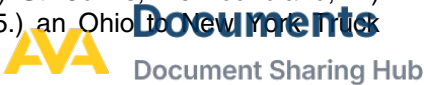
EVALUATION METHOD

For this study, an optical imaging system developed by Atlas Material Testing Technology LLC was employed to quantitatively interpret the degree of cosmetic corrosion. The imaging system employs controlled illumination conditions, high-resolution digital image capture and advanced algorithm-based image and data analysis methodologies. [2].

Four geometrical attributes of the cosmetic corrosion were measured: area of corrosion, maximum length, minimum length and average length. The area of corrosion was found to be the most representative and comprehensive measurement. Because the size of the panels and therefore the scribe lengths for the lab tests were different from the other tests the corrosion area was normalized to the length of the scribe (i.e. area per length). The normalized corrosion areas for triplicate panels (2 scribes per panel) were then averaged and the results are reported as "normalized average area".

ON-VEHICLE (IN-SERVICE) EXPOSURES

It is critical when developing a laboratory based test that test-to-field correlation be performed. In an effort to capture real-world data in developing this test it is necessary to expose these panels to severely corrosive environments that represent "worst case" real-world service environments. Suitable environments exist in the northeastern United States, southeastern coastal areas of the United States, and southeastern Canada. The five sites selected for this study were: 1.) Detroit, Michigan, 2.) Florida 3.) St. Johns, Newfoundland, 4.) Montreal, Quebec and 5.) an Ohio to New York truck Route.



Two sets of 2" x 4" test panels are exposed on each vehicle (two vehicles per site). Each set of 24 (three each of eight material variables) are attached to a mounting panel (16" x 12") using double-backed tape prior to mounting on the vehicle. At the Detroit, St. Johns, and Montreal sites one set is mounted on the hood of each vehicle (horizontal orientation) and one set on the right front door of each vehicle (vertical orientation). At the Florida and Ohio-New York sites the panels are mounted beneath the trailer frame behind the front wheels (vertical orientation only). Each panel contains 2 diagonal scribe lines which are 2" long and 1" apart. The panels will be exposed for a total of 5 years of in-service exposure. Intermediate evaluations will be conducted when possible.

LABORATORY TESTS

Several rounds of laboratory testing have been conducted to date. A list of the accelerated laboratory tests that were evaluated and reported previously is given in Table 2.

In 2007 the following laboratory tests were conducted:

- Repeat of ASTM G85-A4 [3] - Constant salt spray test acidified by periodic introduction of SO₂
- GM9511P [4] - GM Scab Test 60C/85%RH exposure with daily cycles of neutral NaCl immersion and weekly cycles of thermal shock to -25C
- GM9682P [5] - GM wheel filiform test w/ 6hr CASS + 4 weeks @60C and 85%RH (CASS = 5%NaCl + 0.25g CuCl₂·H₂O acidified with acetic acid)
- Modified ASTM G85-A2 [6] - Cyclic spray/RH test with acidified (acetic acid) NaCl with following modifications:
 - substitute H₂SO₄ for acetic acid
 - pH of 3.5 or 5.0
 - add 0.1% CaCl₂
- Modified ASTM G85-A4 [3] - Constant salt spray test acidified by periodic introduction of SO₂ with the following modifications
 - substitute H₂SO₄ for SO₂
 - pH of 3.5 or 5.0 (two tests)
 - add CaCl₂

Table 2. Laboratory Test Evaluated in Initial Round of Testing

Test Procedure	Exposure (s)
SAE J2334	40, 60 & 80 cycles
Ford APGE	35 & 70 cycles
ASTM D2803 (50,80 & 100% RH)	6 weeks
ASTM G85 Annex 2	3 weeks
VDA 621-415	10 cycles / 70 days
ASTM B117	500 & 1000 hours
CCT IV	70 cycles
HCI Dip	8 weeks
KWT	6 weeks
Ford APGE (Manual & Automated Humidity Cycle)	70 cycles
ASTM G85 Annex 2	1 & 2 weeks
HCI Dip	3 & 6 weeks
ASTM G87	20 cycles
ASTM G85 Annex 4	500 hours
ASTM G85 Annex 5	500 hours
GM9511P	4 weeks
GM9682P	4 weeks

CORROSION PRODUCT ANALYSIS

Corrosion product analysis was performed on selected panels to determine the extent of cosmetic corrosion and its morphology, and the composition of the corrosion products. For the top down analysis of the corrosion products, the paint layer was stripped in 1-methyl-2-pyrrolidone solvent. Water was not used during the stripping procedure so as to preserve any chloride/sodium species present within the corrosion product.

The panels were examined using a Leo 440 scanning electron microscope (SEM) equipped with a Quartz XOne energy dispersive X-ray (EDX) analysis system. SEM/EDX technique was chosen for this examination because the amount of corrosion product on aluminum closure panels is very small, making more traditional analytical procedures impractical. In addition, the use of SEM/EDX allows not only for a measurement of the chemical species present, but also for an analysis of the distribution of these species in and around the corroded area on the panel.

RESULTS AND DISCUSSION

ON-VEHICLE EXPOSURE RESULTS

A consistent result from the on-vehicle exposures conducted to date is that panels D, G, and I exhibit more corrosion than the other substrates, as illustrated by the images in Figure 1.