Performance of Prepainted Sheet Steel with Different Polymer Top Coats in Roofing & Cladding Applications

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Abstract

The performance of silicon modified polyesters, PVDF, and plastisol polymer top coats applied over zinc coated steel sheet in a continuous coil coating line is discussed. The performance was based on roll formed roofing and cladding installed on buildings up to 20 years old and evaluated regularly. Based on this real life data, an accelerated laboratory test was chosen to predict the performance of prepainted zinc coated sheet steel. The importance of incorporating weathering factors in an accelerated laboratory corrosion test is demonstrated through the use of this test. The test has the ability to properly rank prepainted galvanized and 55% Al-Zn coated steel, and replicate the failure modes that are experienced in service, thus providing a valuable tool to evaluate the corrosion performance of steel building products. Salt spray results are also shown for comparison, and to demonstrate the misleading results they provide.

1. INTRODUCTION

For the past 40 years North American steel companies have been supplying the market with prepainted steel for roofing and cladding of commercial, industrial and institutional buildings. The major product supplied to commercial and industrial market has been coil coated steel prepainted with Silicon Modified Polyester (SMP) paint systems. High profile institutional buildings in the US and Canada have typically used Polyvinilidene diFluoride (PVDF) paint systems using Kynar^{R} resin mainly because these projects require higher chalk and fade performance and command higher pricing.

For building projects in severe industrial or marine environments, 200 micron thick Plastisol paint systems are used to provide the needed durability and improved corrosion performance of the roofing and cladding. Prepainted steel using plastisol systems are only a small, but specialized part of the overall market and, therefore, will not be discussed further in this Paper.

2. PERFORMANCE OF ROOFING & CLADDING IN CANADA AND THE NORTH EASTERN UNITED STATES

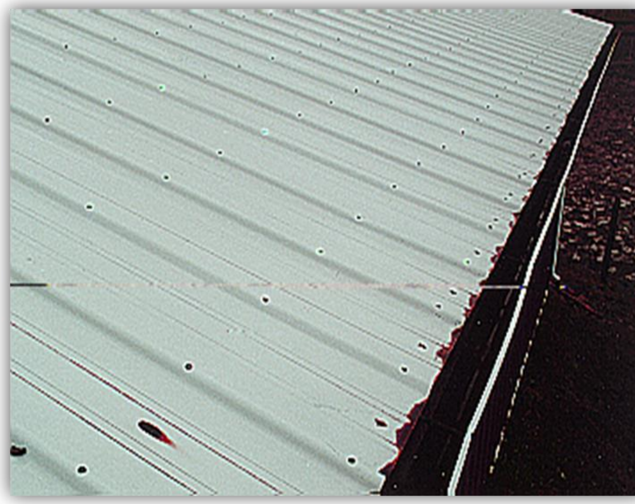
There is a huge inventory of different types of buildings in North America which have SMP or PVDF roofing and cladding and approximately 30 of these buildings have been monitored for the past 25 years by the author during his working career.

As part of normal product development, several buildings in the north eastern US and Canada were selected for long term monitoring of the paint system as well as the metallic coating substrate. In 1996 and 1999, and again in 2002, the corrosion performance of a significant number of prepainted sheet steel buildings (roofing and wall cladding) located in acid rain regions of the north eastern USA and Ontario, Canada was evaluated. The buildings were evaluated using the now published NamZAC building inspection protocol(9) and included both, galvanized and Galvalume™ metallic coated steel substrates. The paint system was a Silicon Modified Polyester (SMP) in most cases.

Photographs 1 – 4 show the performance of the roofing panels after being in service for up to 16 years. One can clearly see the significant amount of red rusting at the drip edge and at the major and minor tension bends.

Photograph 1: Drip Edge Condition

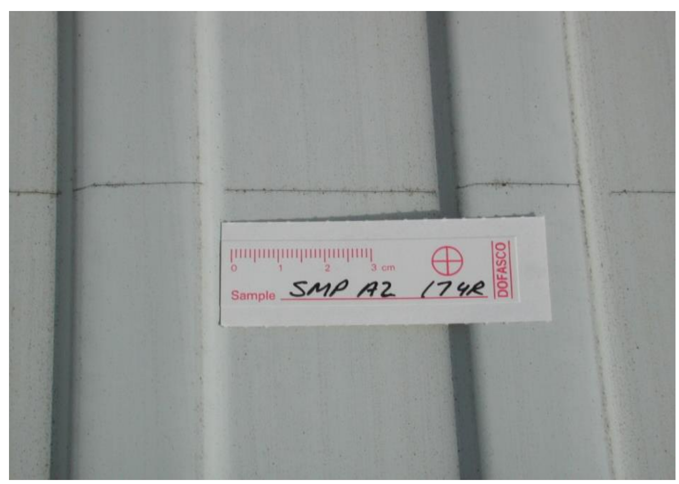
Prepainted Galvalume - 16 years



Prepainted Galvanized - 14 years

Photograph 2: Southern Ontario – SMP

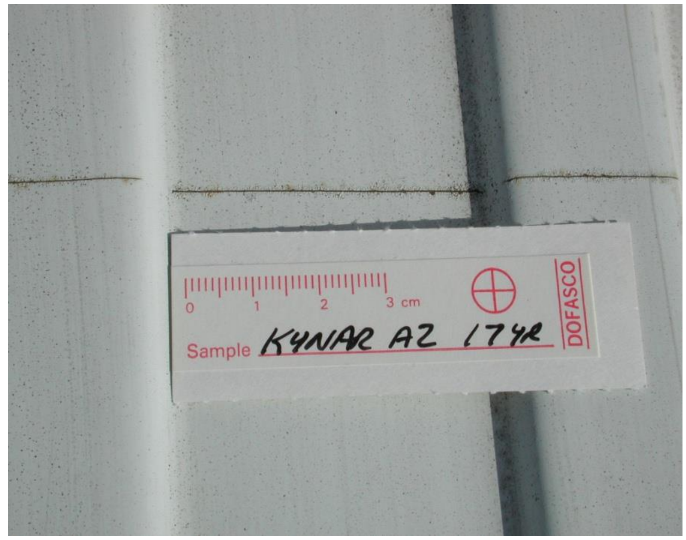
Galvanize – 17 years



Galvalume – 17 years

Photograph 3: Southern Ontario – PVDF

Galvanize – 17 years



Galvalume – 17 years

Photograph 4: South Eastern Ontario SMP

Galvanize (steep slope) – 20 years

Galvalume (low slope) – 20 years

3. NATURAL EXPOSURE TESTING OF FORMED SAMPLES

Long-term natural exposure testing of commercially supplied SMP and PVDF coil coated steel is conducted by just about every manufacturer of prepainted steel who supplies to the construction market for roofing and cladding applications. This is done to help determine the in-service performance and to evaluate the overall durability of the prepainted steel system. Small scale samples are exposed on test racks at an exposure angle of 45 degrees, facing South. Regular inspections of the samples are made and paint delamination at the drip edge, tension bend rusting and undercutting corrosion at the scribe are typically measured. The samples are cut from commercial coils and formed with a variable T-bend, a reverse impact button, and scribed to the steel substrate.

4. PROHESION TEST (ASTM G85-98, METHOD A5)

While all manufacturers agree that natural weathering testing is the most reliable predictor of actual performance, it takes many years to determine the durability, as well as the fading, chalking, and film integrity behaviour of prepainted sheet steel … a luxury no one can afford. Therefore, short-term accelerated laboratory tests were developed and are performed to reliably assess the performance of new and existing prepaint systems as well as to enable product development by the paint companies to advance at a much faster pace. One of the most popular accelerated laboratory tests, the ASTM B117 salt spray test, has been widely criticized for being unable to reproduce the type and extent of degradation similar to natural weathering.[1-4] Other ASTM laboratory tests such as Humidity, and Sulphur Dioxide, measure the response of paint systems to moisture and aggressive pollutants, but they too bear no resemblance to natural weathering. The most crucial elements of a meaningful laboratory test are that it should simulate the relative performance ranking of materials in service and it should produce failure modes consistent with field experience. It should also be reasonably quick, reproducible and be sensitive enough to differentiate changes made to the paint pretreatment, primer and topcoat.

The development of the Prohesion Test started in the 1960s[5] when J.B. Harrison and T.C.K. Tickle decided to use a diluted mixture of sodium chloride and ammonium sulphate to replace the 5% sodium chloride solution used in the salt spray test. F.D. Timmins[6] further refined and diluted J.B. Harrison's test solution to its presently used concentration, and decided that lowering the solution temperature to **ambient** (instead of 35°C) would correspond more closely to natural weathering. It was F.D. Timmins who coined the acronym "Prohesion" for **Pro**tection is Ad**hesion**.

In the 1980s, S.B. Lyon[7] further refined this method as did B.S. Skerry, to the point when it was recommended to ASTM for adoption in 1994. It is currently issued as ASTM Standard G85 (Standard Practice for Modified Salt Spray [Fog] Testing). The current version of this standard is ASTM G85 - 12[8].

“Prohesion” testing is now performed using ASTM G85, Method A5, which uses a solution of 0.35% ammonium sulphate and 0.05% sodium chloride. This method is typical of an industrial environment commonly found in the acid rain regions of North America and is capable of discriminating each component of the entire prepaint “system” which comprises the metallic coating, the pretreatment, the primer, and topcoat.

Table 1 describes the differences between the key factors in natural weathering (i.e.

typical corrosive elements in acid rain environments, time of wetness, pH, etc.) and those in ASTM B117 Salt Spray Test and ASTM G-85, Method A5 Prohesion Test. One can clearly see that the key factors in the "Prohesion Test" more closely follow the conditions in natural weathering from the standpoints of the corrosive elements, pH, temperature, time of wetness and the corrosion mechanism. On the other hand, the Salt Spray test conditions do not resemble those found in natural weathering.

Table 1

Accelerated Corrosion Test Conditions vs. Atmospheric Corrosion

Key Factor	Atmospheric Corrosion	Prohesion ASTM G85, Method A5	Salt Spray ASTM B117
Corrosive Elements	Chlorides ppm Sulphates ppm	.05% Chloride .35% Sulphate	5% Chloride
pH	4.3 - 5.3 (acidic)	5.0 - 5.4 (acidic)	6.5 - 7.2 (neutral)
Time of Wetness	Cyclic Wet and Dry	1 hr Wet 1 hr Dry	Continuous Wet
Temperature	Ambient	Ambient	35°C
Corrosion Mechanism	Anodic dissolution (acidic)	Anodic dissolution (acidic)	Cathodic Disbondment (alkaline)

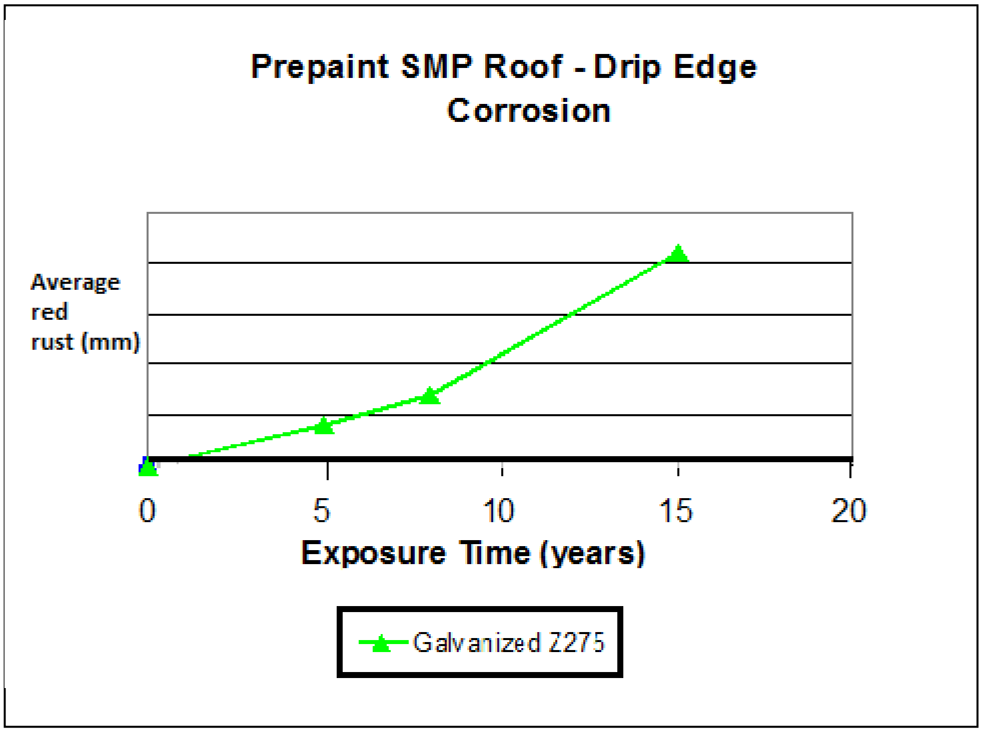
ASTM G85, Method A5 procedure was performed using a Q-Fog test cabinet.

5. RESULTS OF BUILDING INSPECTIONS

Figure 1 shows the roof drip edge data for SMP prepainted galvanized buildings. The roof drip edge is generally regarded as the worst case condition on a building and is used as the benchmark against which the Prohesion test data is compared. Obviously, the walls typically experience less corrosion because of their vertical orientation but can be expected to show the same performance behaviour as the roofs, given sufficient time. Note that the average red rust measured at the roof drip edge for SMP prepainted galvanized is over 20 millimeters after 15 years.

Figure 1

Building Inspections - Acid Rain Environment



6. CORRELATION OF PROHESION TEST WITH NATURAL WEATHERING

SMP prepainted Z275 galvanized substrate for roofing and cladding applications has been supplied since the 1970's. In 1985, a large exposure test program was initiated at that time to evaluate performance of the product. Subsequently, in 1998, a major improvement to the SMP paint system was undertaken. The change involved switching from Bonderite 1303 complex oxide pre-treatment to zinc phosphate (Bonderite 1421) pretreatment, and changing from an epoxy primer to a flexible polyester primer. The components of the topcoat chemistry were also modified to improve its overall durability.

Figure 2

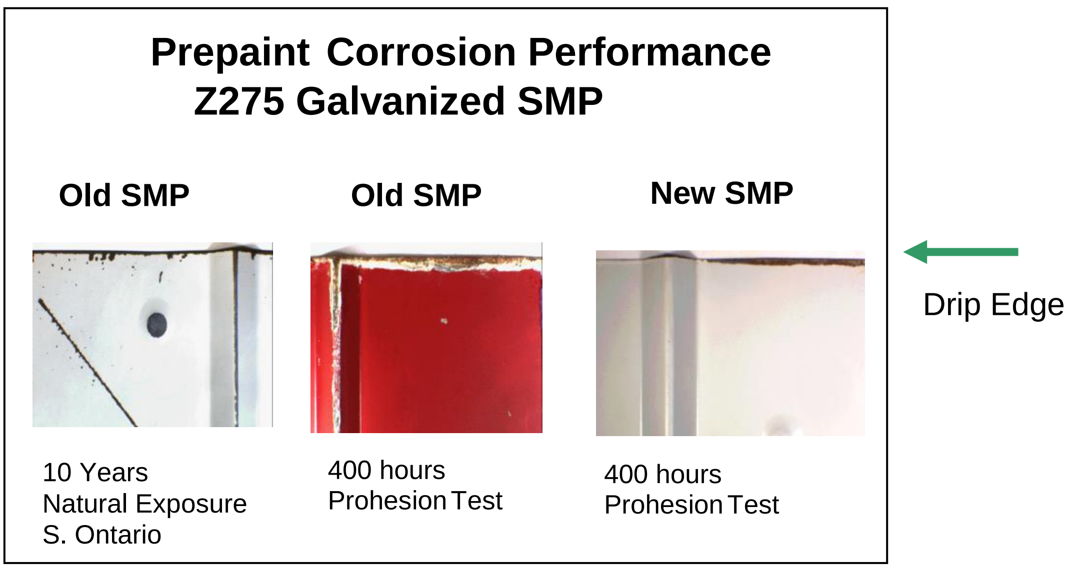


Figure 2 above shows the performance of commercially produced Z275 galvanized with the 1970's SMP paint system exposed for 10 years to natural weathering in a light industrial environment in Southern Ontario. Note the presence of red rust in the scribe, on the reverse impact button, the variable V-bend and particularly the drip edge. Comparing the performance of the same SMP after 400 hours in Prohesion Test, one can see that red rust appears on all the areas typically seen in the 10 year old natural exposure samples. These Bonderite 1303 pre-treated samples also demonstrate a weakness in undercutting corrosion resistance of the paint particularly along the drip edge and the variable V-bend. To improve the overall corrosion performance, the formulation was changed:

- From a complex oxide (Bonderite 1303) pretreatment to zinc phosphate (Bonderite 1421) to improve the undercutting performance of the paint.

- From an epoxy primer to a more flexible polyester primer to improve the performance at the tension bends.

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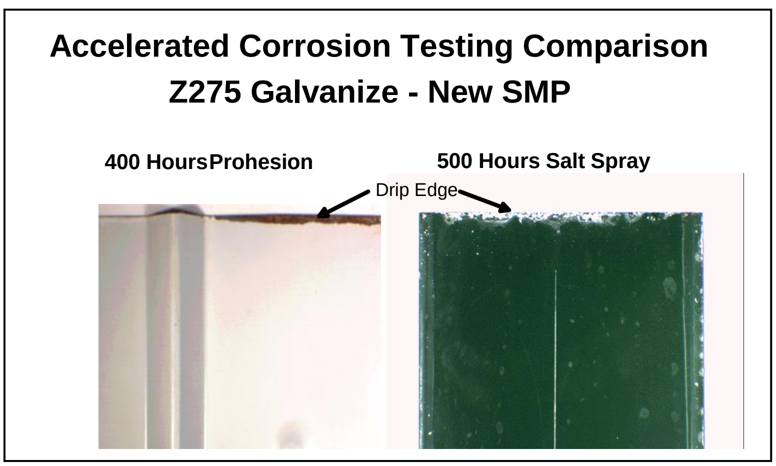
Figure 2 shows the benefits of these changes and the improvement in the performance of 1990's SMP pre-painted galvanized in the Prohesion Test, gained through the use of zinc phosphate pre-treatment (improved edge creep) and the flexible polyester primer (improved V-bend performance). These improvements are now being monitored on actual buildings.

The Prohesion Test, therefore, is a good discriminating test that ranks material performance in the same order as found in actual building inspections; it also replicates the corrosion mechanism observed in service (anodic dissolution of the zinc leading to paint undercutting).

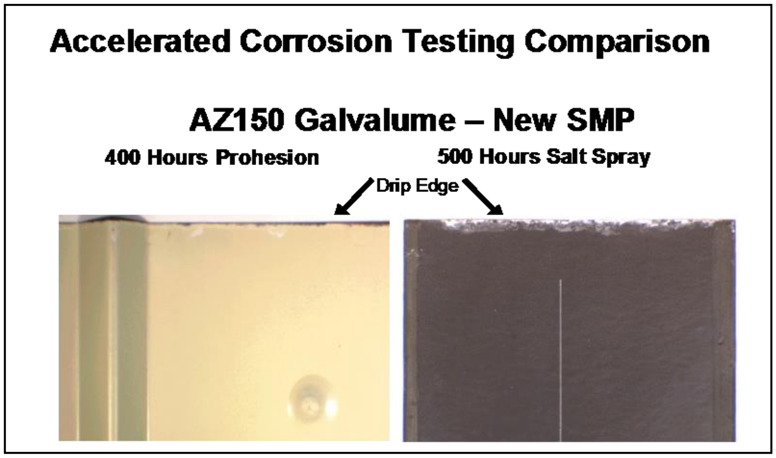
Figure 3 shows the comparison between the Prohesion Test and the ASTM B-117 Neutral Salt Spray test. Close inspection of the neutral Salt Spray test samples shows significant paint blistering in the field and along the drip edge (caused by cathodic delamination of the paint) but there is no red rust in the scribe or at the drip edge. This is completely the reverse of what is observed in natural exposure and in the Prohesion Test. The same visual conclusions are seen when the same series of tests are conducted on SMP prepainted AZ150 Galvalume.

Figure 3



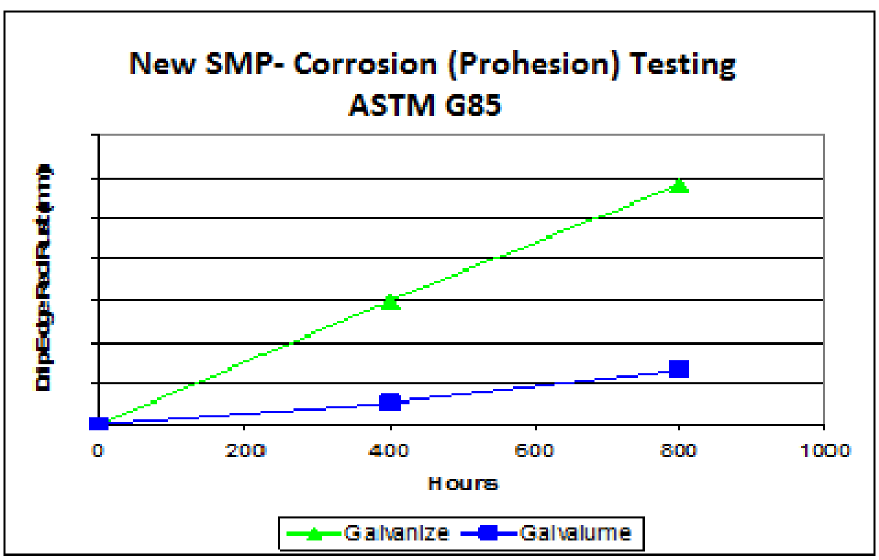
The results of the Galvalume samples are shown in Figure 4.

Figure 4



Finally, Figure 5 is a plot of performance of SMP prepainted galvanize and Galvalume after 400 and 800 hours in the Prohesion Test. One can see the similarities in the performance trends between the Prohesion test and the building inspections shown earlier in Figure 1. Note also that while the amount of red rust at the drip edge is considerably lower in the Prohesion test, the ranking of the materials, the failure mode, and the diverging performance between the substrates follows that seen in actual building inspections.

Figure 5



Figures 6 and 7 are pictures of the roof drip edge on a couple of buildings from the inspections in the United States.

Figure 6

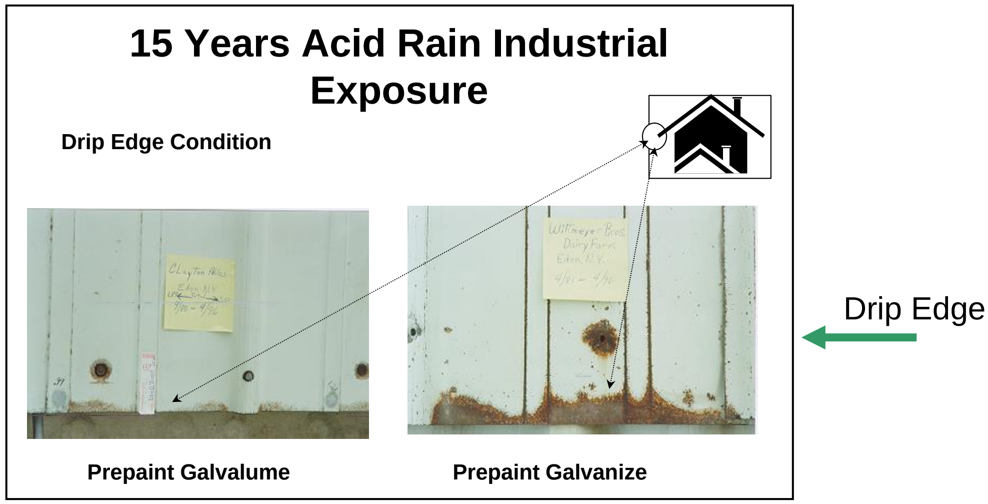


Figure 7

SUMMARY

In conclusion, there is sufficient data to support the claim that the "Prohesion Test" as specified in ASTM G85, Method A5, is a good accelerated laboratory test that ranks materials and paint systems similar to that witnessed in actual service. More importantly, this test also replicates the failure mode seen in actual service. The ASTM B117 salt spray test, on the other hand, does not replicate actual service performance. The Prohesion Test is now a nationally recognized standard test in Canada and is published by the Canadian Sheet Steel Building Institute as specification CSSBI S8-2001, "Quality and Performance Specification for Prefinished Sheet Steel Used for Building Products" [10]

ACKNOWLEDGMENTS

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REFERENCES

1. J.B Harrison & T.C.K. Tickle, "New Aspects of the Atmospheric Corrosion of Steel and their Implications," JOCCA Volume 45, No. 8, 1962, page 571.
2. W. Fumke, "Corrosion Tests for Organic Coatings – A Review of their Usefulness and Limitations," JOCCA Volume 62, No. 2, 1979, page 63.
3. B.R. Appleman & P.C. Campbell, "Salt Spray Testing for Short Term Evaluation of Coatings, Part 1 – Reactions of Coatings in Salt Spray," Journal of Coatings Technology. Volume 54, No. 3, 1982, page 17.
4. H.M. Brown, I.D. MacGregor & L.A. MacIsaac, "Comparison of Accelerated and Natural weathering of Coil Coated Galvanised Steel," Construction & Building Materials, Volume 5, No. 3, 1991, page 123.
5. N.D. Cremer, "Prohesion Compared to Salt Spray and Outdoors," presented at the Federation of Societies for Coatings Technology 1989 Paint Show.
6. F.D. Timmins, "Prohesion – The Key to Metal Protection" ICI Mond Division, Ref: GC/8924/8594/R1/1ED/12/780, page 4.
7. S.B. Lyon, J.D. Scantlebury & J.B. Johnson, "Realism in Cyclic Cabinet Corrosion Testing of Coil Coated Steel for Building Applications" ASTM, STP 1238 pages 3 – 17.
8. American Society for Testing and Materials, ASTM G85-12, Method A5
   NamZAC Building Inspection Protocol.
9. Canadian Sheet Steel Building Institute, CSSBI S8-2001 Specification, "Quality and Performance Specification for Prefinished Sheet Steel Used for Building Products".