Dennis M. Richards, Technical Consultant, Department for Transport, Energy and Infrastructure

THE COATING OF GALVANIZED STEEL & OTHER "DIFFICULT" METAL SUBSTRATES

Fencing Installation. Thermal spray zinc with powder primer and polyester finish coat, Sound performance after 9 years exposure.

BACKGROUND

Hot-dip galvanized steel has traditionally been perceived as a difficult surface to paint, particularly in terms of achieving adhesion. The development of effective water-borne primers for domestic galvanized surfaces, in the 1970's went some way towards altering this perception. Where long term aesthetic performance for structural steel was required, however, doubt regarding the adhesion of heavy duty coatings continued unabated.

The Department for Transport, Energy and Infrastructure (DTEI) had an ongoing need for coated steel with exceptional corrosion protection and decorative performance, which led to the selection of galvanized steel as a preferred substrate. Metal spray had also been proposed as an alternative corrosion protection strategy for steel structures.

A project was initiated to identify coating systems, which would provide the necessary performance over hot-dip galvanized and metal spray substrates. An increasing demand for other the coating of other metal substrates, such as stainless steel, aluminium and Zincalume®, led to an expansion of the scope to include these materials.

METHODOLOGY

Substrates

Five test substrates were used in this project:

1. Stainless steel 316, No. 4 finish, 0.9mm (SS)
2. Zincalume®, 0.8mm (ZA)
3. Aluminium, 1.6mm (Al)
4. Galvanized steel, 6mm (HDG)
5. Thermal zinc sprayed steel, 6mm (TSZ).

All steel substrate was engineering grade 250.

All TSZ panels were degreased and then subjected to abrasive blast cleaning prior to the application of zinc coating. The average profile height for these panels was 85µm, before application of TSZ.

Thickness readings of the zinc layer, for the HDG, TSZ and Zincalume® plates, were taken using an Elcometer 256FN gauge.

Coating Systems

Major coating manufacturers were approached with a view to supplying their best product for each specific substrate. In all, fifteen coating systems were submitted, as detailed in Table 1.

***Table 1:** Coating Systems*

System No.	Substrates	Liquid/ Powder	Manufacturer	Coating System	
				Primer	Intermediate/ Finish
1	All	Liquid	A	Epoxy	Polyurethane
2	All	Powder	A	Powder	Powder
3	All	Liquid	B	Epoxy	Polyurethane
4	Al Only	Liquid	B	Latex Galvanized Iron Primer	Low Gloss Latex
5	All	Liquid	B	Moisture Cure Urethane	Moisture Cure Urethane
6	HDG only	Liquid	C	Epoxy	Epoxy/ Catalysed Acrylic
7	ZA only	Liquid	C	Epoxy	Polyurethane
8	TSZ only	Liquid	C	Epoxy	Polyurethane
9	SS only	Liquid	C	Epoxy	Catalysed Acrylic
10	Al only	Liquid	C	Epoxy	Polyurethane
11	All	Powder	C	Powder	Powder
12	All	Liquid	D	Epoxy	Polyurethane
13	ZA, HDG, & TSZ	Liquid	E	Epoxy	Polyurethane
14	All	Powder	E	Powder	Powder
15	All	Liquid	B	Epoxy	Catalysed Acrylic

It should be noted that the 3 powder coating systems used represented the bulk of the super durable market, and the results achieved may not be representative of cheaper low performance systems.

Panel Surface Preparation

Stainless steel 316: All stainless steel panels were whip blasted using garnet fines at 40psi.

Zincalume®: Duplicate panels were prepared for both adhesion and impact testing, for each system. All panels were degreased using a solution of 1 part rinseable degreaser to 20 parts water, applied to each panel, allowed to stand for 10 minutes, then rinsed and allowed to dry. One of each pair was then subjected to whip blast cleaning using garnet fines at 40psi.

Aluminium: All aluminium panels intended for liquid coating systems were subjected to solvent cleaning using a proprietary product. Those panels scheduled for powder coating, were etch rinsed by immersion, then rinsed with tap water and chromate converted. They were then rinsed with tap water and finally rinsed with demineralised water.

HDG: for each system applied to the HDG, two panels were prepared for both adhesion and impact testing. All panels were degreased using a solution of 1 part rinseable degreaser to 20 parts water, applied to each panel, allowed to stand for 10 minutes, then rinsed and allowed to dry. One of each pair was then subjected to whip blast cleaning using garnet fines at 40psi.

TSZ: all TSZ panels that were to have liquid coatings applied to them were wiped clean. Those to be painted with the powder coatings were lightly sanded before application, to remove zinc peaks.

Note: The term "degrease" has been used throughout this paper. In reality, none of the test surfaces were contaminated with oil or grease but the cleaning processes used were aimed at providing a clean surface only.

Coating Application

All liquid systems were applied by spray, in accordance with the relevant DTEI procedures. All coatings were applied to a target mass to achieve the desired dry film thickness.

All powder coatings were applied using a Miller Thermal Spray Praxair 400 gun.

All dry film thickness readings were taken using an Elcometer 256FN gauge. All thicknesses, including those of the zinc layers for galvanized and TSZ substrates.

All coatings were applied in accordance with the manufacturers' specifications, and all liquid coating systems were cured under routine conditions as described in AS 1580.101.5.

Testing

Panels were subjected to a range of tests aimed at identifying the mechanical properties of the coating systems, as follows:

Adhesion

Adhesion Testing was performed in accordance with AS/NZS 1580.408.5:1994, using an Elcometer 106 Pull-Off Adhesion Tester. Araldite K138 was used as the adhesive.

Testing of liquid coating systems took place at 5 days after application of the last coat. Powder coated panels were tested at 3-5 days after final application. Triplicate tests were carried out on each panel, at each curing period. The supplied support ring plate was used for all tests, to alleviate the effects of plate distortion.

Resistance to Impact - Falling Weight Test

Impact testing was performed using a Gardner Impact Tester, in accordance with AS/NZS 1580.406.1:1993 (method B).

Testing of liquid coating systems took place at 5 days after application of the last coat. Powder coated panels were tested at 3-5 days after final application.

Two impact masses were used, 500g and 910g, with direct impact used for all tests.

The painted metal samples were subjected to QUV accelerated weathering testing in this QUV apparatus.

Accelerated Weathering

These tests were carried out in a QUV apparatus according to AS/NZS 1580.483.1. The test conditions selected were:

Test cycle		4 hours UV/ 4 hours condensation
Test temperature	UV cycle	60°C
	Condensation cycle	50°C
Lamp Type	Lamp Type	UVB340

This testing was aimed at identifying the effects of stress produced by UV and condensation on the integrity of the coating system.

All assessments were carried out in accordance with AS/NZS 1580.481.

RESULTS & DISCUSSION

All test results are detailed in the following pages.

Adhesion

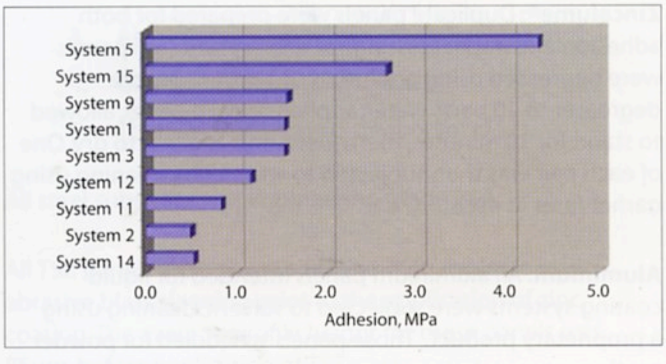
Stainless Steel

All surfaces were whip blasted prior to application of coatings.

All primers, with the exception of system 12, provided levels of adhesion of greater than 1 MPa. Primers 1 and 3 provided very good adhesion.

All liquid systems, provided levels of adhesion of greater than 1 MPa. System 5 provided excellent adhesion (Figure 1). None of the 3 powder coatings 2, 11 and 14, provided acceptable levels of adhesion.

Figure 1: *System Adhesion, Stainless Steel Substrate*



Zincalume®

The Zincalume® substrate was tested degreased or whip blasted.

All primers provided levels of adhesion over the degreased substrate of greater than 1 MPa. Primers 1,13, 15 provided good adhesion levels. All primers, with the exception of system 12, provided levels of adhesion over the whip blasted substrate of greater than 1 MPa. Primers 1 and 13 provided very good adhesion.

All systems, with the exception of system 3, gave levels of adhesion over the degreased substrate of greater than 1 MPa. System 7 provided very good adhesion (Figure 2).

All systems, with the exception of powder coatings 2 and 11, provided levels of adhesion over the whip blasted substrate of greater than 1 MPa. Systems 5 and 7 provided very good adhesion (Figure 3). Note that all systems produced greater adhesion values over the whip blasted substrate than over the degreased substrate.

***Figure 2:** System Adhesion, Degreased Zincalume® Substrate*

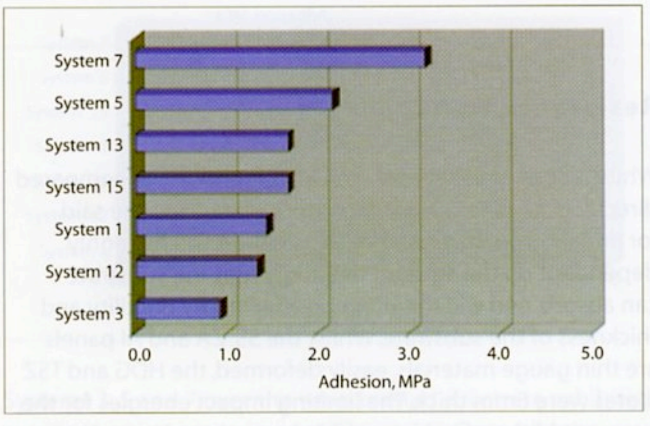
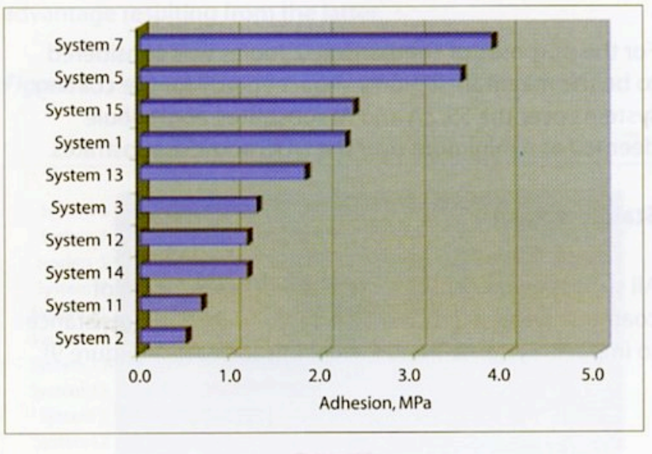


***Figure 3:** System Adhesion, Whip Blasted Zincalume® Substrate*



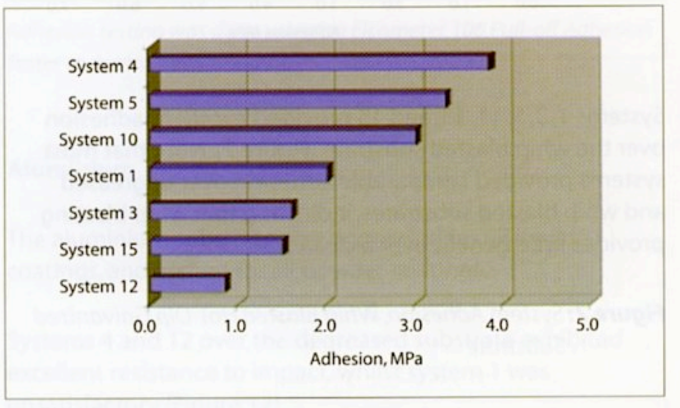
Aluminium

The aluminium substrate was degreased for all liquid systems, etched for all powder coatings.

All primers, with the exception of system 12, provided levels of adhesion of greater than 1 MPa. Primers 1, 3 and 15 provided good adhesion.

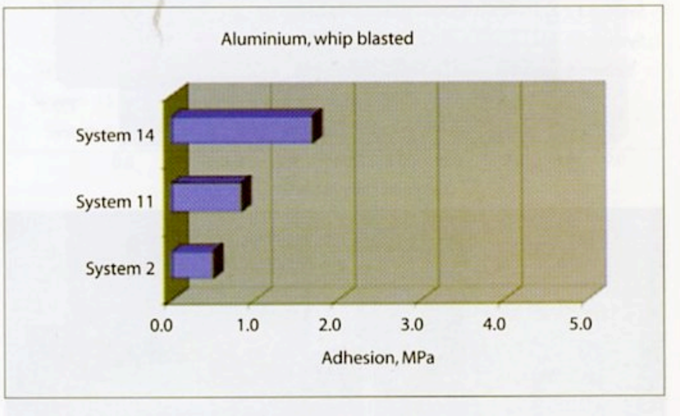
All systems, with the exception of system 12, provided levels of adhesion of greater than 1 MPa. Systems 4, 5 and 10 provided very good adhesion (Figure 4).

***Figure 4:** System Adhesion, Degreased Aluminium Substrate*



Of the 3 powder coat systems tested over etched aluminium, only system 14 provided a satisfactory level of adhesion (Figure 5).

***Figure 5:** System Adhesion, Etched Aluminium Substrate*



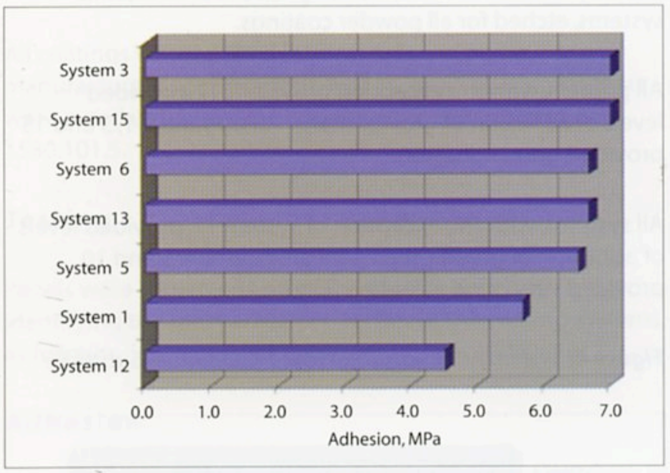
Hot-Dip Galvanized

The Hot-dip galvanized substrate was tested, degreased or whip blasted.

All primers provided excellent adhesion over both the degreased and whip blasted substrates, with all coatings recording greater than 4 MPa.

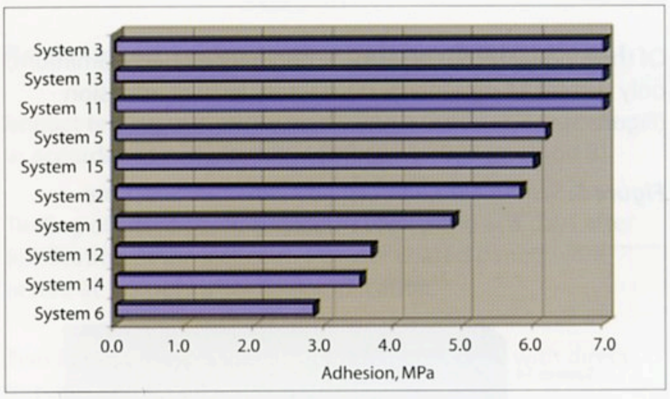
All systems provided excellent adhesion over the degreased substrate (Figure 6).

Figure 6: *System Adhesion, Degreased Hot-Dip Galvanized Substrate*



Systems 1, 3, 5, 11, 13, and 15 provided excellent adhesion over the whip blasted substrate (Figure 7). Note that most systems provided comparable adhesion over degreased and whip blasted substrates, indicating that whip blasting provides little benefit over a clean surface.

Figure 7: *System Adhesion, Whip Blasted Hot-Dip Galvanized Substrate*



All paint systems were impact tested using a Gardner Impact Tester to Australian Standards.

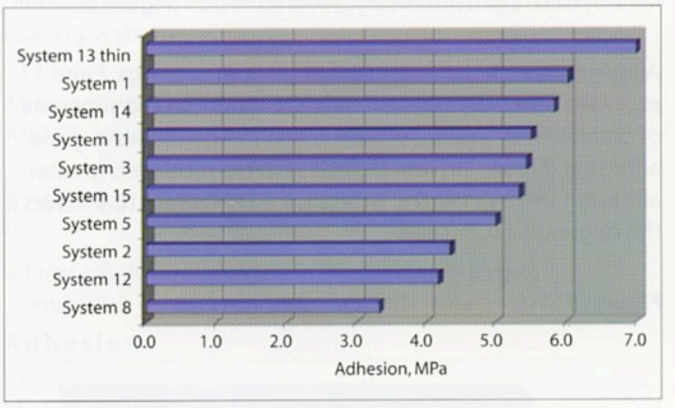
Thermal Spray Zinc

The thermal spray zinc substrate was coated with no further preparation.

All primers with the exception of System 8 gave excellent adhesion.

All systems, with the exception of system 8, provided excellent adhesion (Figure 8). The results indicate that TSZ provides an excellent surface for overcoating.

Figure 8: *System Adhesion, Thermal Spray Zinc Substrate*



Resistance to Impact

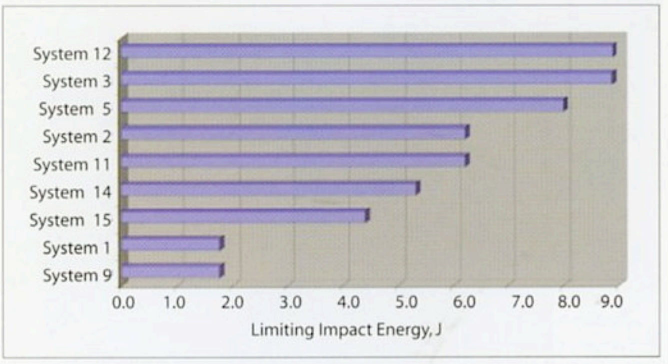
Whilst adhesion results for a given system can be compared directly over all test substrates, the same cannot be said for impact. Impact resistance of a coating will be highly dependant on the amount of energy that the substrate can absorb, and will therefore be affected by ductility and thickness of the substrate. Whilst the SS, ZA and Al panels are thin gauge materials, easily deformed, the HDG and TSZ plates were 6mm thick. The limiting impact energies for the latter could therefore reasonable be expected to be lower as a consequence, with the full brunt of the impact borne by the coating.

For the purposes of comparison, 2 Joules was considered to be the minimum limiting impact energy for the coating systems over the SS, ZA and Al substrates, and 1 Joule deemed as a minimum over the HDG and TSZ substrates.

Stainless Steel

All surfaces were whip blasted prior to application of coatings. Systems 3, 5 and 12 exhibited excellent resistance to impact. Systems 1 and 9 were unsatisfactory (Figure 9).

Figure 9: *Impact Resistance, Stainless Steel Substrate*

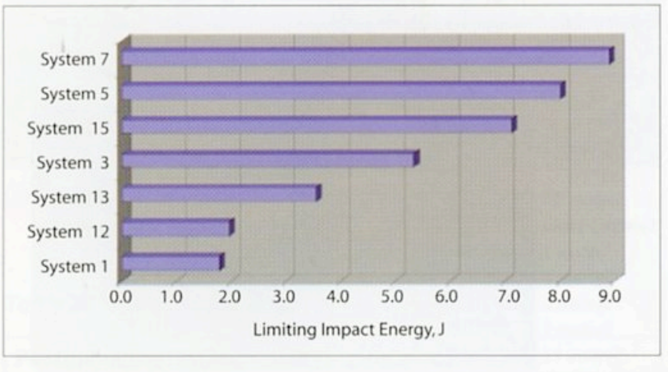


Zincalume®

Zincalume® substrate was degreased or whip blasted.

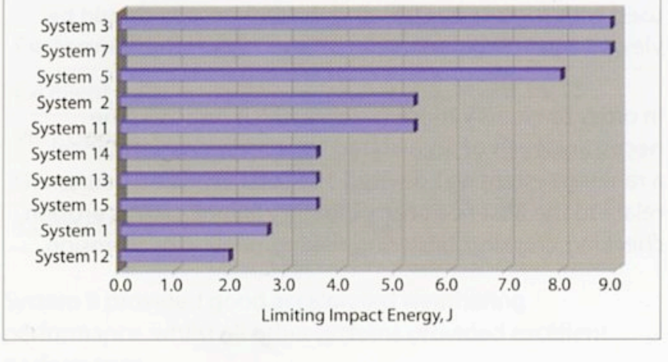
Systems 5 and 7 over the degreased substrate exhibited excellent resistance to impact, whilst systems 1 and 12 were unsatisfactory (Figure 10).

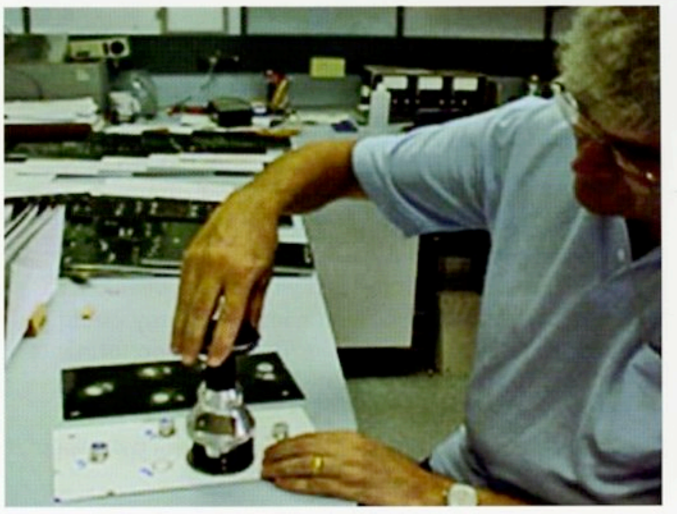
Figure 10: *Impact Resistance, Zincalume® Substrate - Degreased*



Systems 3, 5 and 7 over the whip blasted substrate exhibited excellent resistance to impact (Figure 11). Generally, the impact results were similar for each system over both the degreased and whip blasted substrate, indicating little advantage resulting from the latter.

Figure 11: *Impact Resistance, Zincalume® Substrate - Whip Blasted*





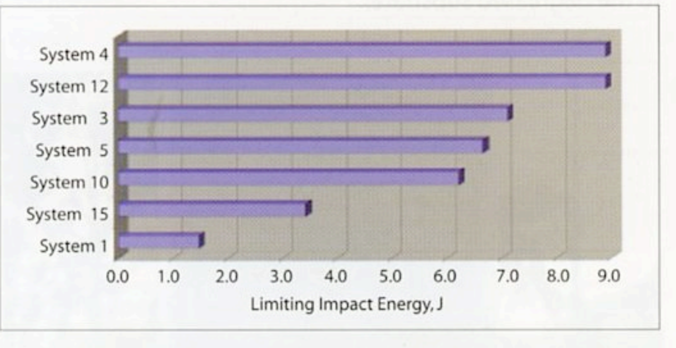
Adhesion testing was done using an Elcometer 106 Pull-off Adhesion Tester to Australian Standards.

Aluminium

The aluminium substrate was degreased for all liquid coatings, and etched for all powder coatings.

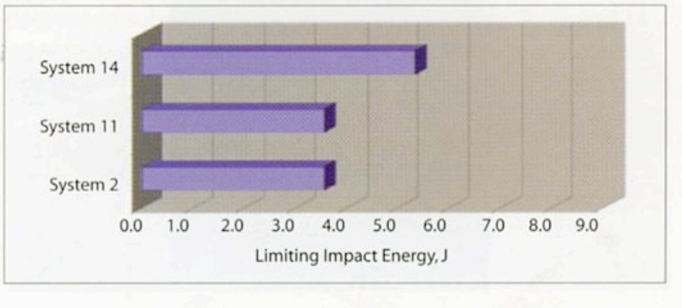
Systems 4 and 12 over the degreased substrate exhibited excellent resistance to impact, whilst system 1 was unsatisfactory (Figure 12).

Figure 12: *Impact Resistance, Aluminium Substrate - Degreased*



Of the powder coatings, system 14 gave good impact resistance, whilst systems 2 and 11 were satisfactory (Figure 13).

Figure 13: *Impact Resistance, Aluminium Substrate - Etched*

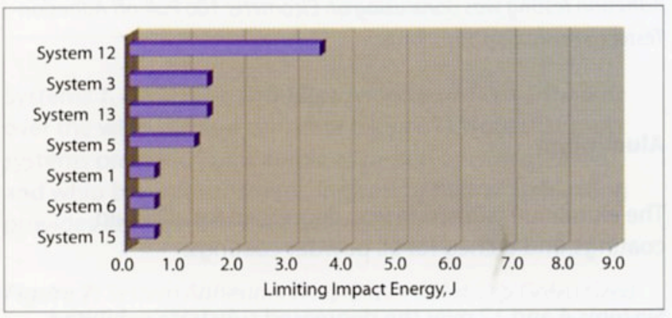


Hot-Dip Galvanizing

Hot-dip galvanized substrate was degreased or whip blasted.

All systems, with the exception of 12, exhibited low resistance to impact over the degreased substrate (Figure 14). The generally low results however reflect the 6mm thick substrate. As the substrate would not absorb any energy through distortion, as would have been the case with the SS, Al and ZA, the limiting impact energy would be expected to be significantly lower. The impact performance of systems 1, 6 and 15 was unsatisfactory.

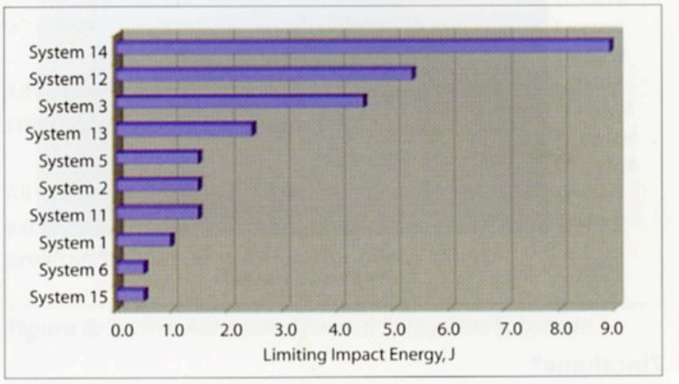
Figure 14: *Impact Resistance, Hot-Dip Galvanized Substrate - Degreased*



System 14 exhibited excellent resistance to impact over the whip blasted substrate, whilst systems 1, 6 and 15 were unsatisfactory (Figure 15). Impact performance was enhanced over the whip blasted substrate when compared to the degreased substrate.

Lamp standard, galvanized steel with epoxy primer/polyurethane finish, showing sound performance after 5 years exposure.

Figure 15: *Impact Resistance, Hot-Dip Galvanized Substrate - Whip Blasted*

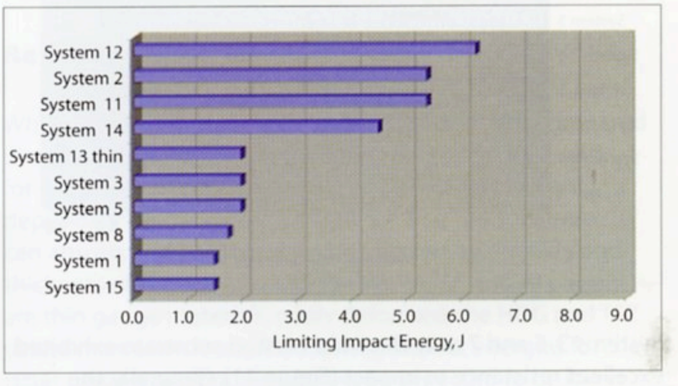


Thermal Spray Zinc

Thermal Spray Zinc was coated with no additional preparation.

All systems provided a satisfactory level of impact resistance, with systems 2, 11, 12 and 14 exhibiting very good performance (Figure 16).

Figure 16: *Impact Resistance, Thermal Spray Zinc Substrate*



Accelerated Weathering

The results provided in the following paragraphs relate to accelerated weathering testing. It should be noted that the test regime adopted was intended to place coating systems under UV, heat and condensation stress. A number of the systems which performed below expectations have been used with success by DTEI, and the QUV results should be viewed accordingly.

In order to identify those *systems*, which provided the necessary levels of accelerated weathering performance, a ranking system was devised. The total exposure hours relate to the absence of any integrity failure such as erosion, checking, cracking, blistering, flaking, peeling or corrosion.

Galvanized steel with powder coating after 9 years exposure.

Table 2: *Weathering Ratings*

Performance Rating	Total Hours
Excellent	>8000
Very Good	6000 to 8000
Good	4000 to 6000
Satisfactory	2000 to 4000
Unsatisfactory	<2000

Stainless Steel

Performance Rating	Systems
Excellent	1, 2, 3, 5, 11, 12, 14, 15
Very Good	Nil
Good	9
Satisfactory	Nil

System 9 provided good accelerated weathering performance, whilst all other systems provided excellent performance.

Zincalume®

Degreased

Performance Rating	Systems
Excellent	3, 5, 7, 12, 13, 15
Very Good	Nil
Good	1
Satisfactory	Nil

Whip Blasted

Performance Rating	Systems
Excellent	2, 11, 14
Very Good	Nil
Good	Nil
Satisfactory	Nil

Aluminium

Degreased

Performance Rating	Systems
Excellent	3, 5, 10, 15
Very Good	1
Good	Nil
Satisfactory	Nil
Unsatisfactory	4, 12

Etched

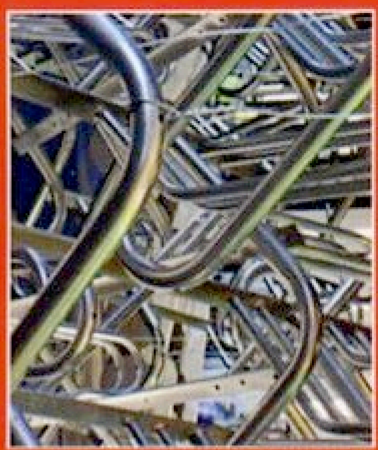
Performance Rating	Systems
Excellent	2,11,14
Very Good	Nil
Good	Nil
Satisfactory	Nil

Systems 3, 5, 10 and 15 were the best performers over the degreased substrate. Only the powder coatings 2, 11 and 14 were tested over the etched substrate, and all gave excellent results.

NOVEMBER 2008
Vol. 15 No 2

CORROSION MANAGEMENT

AUSTRALIAN
STEEL INSTITUTE
TECHNICAL LIBRARY



COVER

This abstract image is a load of hot-dip galvanized hand rails and ladders just out of the galvanizing bath and waiting to be unloaded and inspected.

PUBLISHER

Industrial Galvanizers Corporation Pty Ltd.

EDITOR

John Robinson
Mount Townsend Solutions Pty Ltd.
Ph: +61 (0)2 467 9088
Fx: +61 (0)2 4964 8341
mt.solutions@optusnet.com.au

DESIGN & ADVERTISING

MAP Marketing
Villa Franca, 2 Scott Street
Newcastle NSW 2300
Ph: +61 (0)2 4929 7766
Fx: +61 (0)2 4929 7827
maria@mapmarketing.com.au
www.mapmarketing.com.au

CORROSION MANAGEMENT is published for those interested in the specification, application and performance of corrosion management systems.

CONTENTS

This cable tray column is badly stained by 'white rust' caused by prolonged storage on site in packs during a period of wet weather. Where does the responsibility lie? - Page 24

CORROSION management

NOVEMBER 2008
Vol. 15 No 2
Registered by Australia Post
PP No. 229640/00002

Painting 'Difficult' Metal Surfaces

Steel Framing in Marine Environments

Durability & Liability - Specifiers Risks