



# THE ESSENTIALS OF **GALVANIZING**

Compiled and edited by TS & Associates for the INTERNATIONAL ZINC ASSOCIATION



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FROM THE INTERNATIONAL ZINC ASSOCIATION



International  
Zinc Association

*Zinc...essential for modern life*



## FOREWORD

The primary purpose of hot dip galvanizing is to protect steel in any form including reinforcement for concrete from corrosion. It is a cost effective way of extending its service life in most environments.

ZINC is at the heart of hot dip galvanizing, it is also used in zinc rich paints and in zinc thermal spray anti-corrosion protective coatings where galvanizing may not be possible.

The INTERNATIONAL ZINC ASSOCIATION with the assistance of Terry Smith of TSA (Terry Smith & Associates) ex-Director of the HDGASA has prepared this guide on the ESSENTIALS OF GALVANIZING so that consulting engineers, designers and architects will have the basics of this cost effective coating at their fingertips.

While the compilation of these articles cover most aspects of the coating it however, is not all inclusive but is a selection of the most informative articles published over the past 15 years and where the information still remains valid.

We are grateful to the Hot Dip Galvanizers Association Southern Africa (HDGASA) for the articles in this compilation and acknowledge their contribution.

Kindly contact the INTERNATIONAL ZINC ASSOCIATION for further guidance or information on the use of zinc in corrosion protection.

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May 2020



International  
Zinc Association

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## SPECIFICATIONS AND STANDARDS

### FROM DECISION TO RECEIPT (2013)

From decision (by the end-user/specifier to use hot dip galvanizing as the preferred corrosion control coating) to receipt of the finished components, on-site and the overall experience.

This paper was presented by Terry Smith at a local Johannesburg seminar several years ago and was never published. Its contents are still extremely relevant to the situation in the galvanizing industry today.

Although the HDGASA has many strategic objectives and activities, the three activities that are applicable to this paper are:

- General promotion of hot dip galvanizing and duplex systems, where applicable.
- Getting involved in the design stages of major development projects on behalf of end-users.
- Assisting members and end-users with quality assurance, particularly with coating miss-perceptions.

#### INTRODUCTION

What are the process steps to be followed by specifier's and galvanizers when selecting hot dip galvanizing as a means of corrosion control for a new major project:

Based on recommendations from other end-users/specifiers or past successful project experience, the decision to specify hot dip galvanizing for structural and other steel components for new projects, can be a rewarding one for a number of reasons.

One of the major benefits of hot dip galvanizing is the long-term maintenance free service life that is available to the client, saving enormous sums of money, normally spent on coating maintenance over the prescribed life of the project.

Hot dip galvanized coatings perform very well in most atmospheres and imperfections in the coating, such as lumps, runs; minor protuberances, excessive dross, etc. will not necessary reduce the coating's corrosion control performance. However, in order to avoid these aesthetically unacceptable imperfections, there are a number of steps that must be taken by the specifier and the galvanizer to ensure a greater degree of quality control and all round client satisfaction at the completion of the project.

Three examples of projects in South Africa that have had above average success from a project management perspective:

- Bofakeng Rasimoni Platinum Mine – Anglo Platinum – about 1 000 tons
- MTN Head Office – Phase 2 – Aurecon – about 500 tons (page 51)
- National Library – Jeremie Malan Architects – about 600 tons (page 52)

All three of these projects had an above average involvement by the galvanizer prior to the commencement of the project.

Decision by end-user or specifier based on:

- Acceptance from past project experience.
- Referral by colleague or other authorities.
- Proper value analysis of environmental conditions.
- Proper value analysis of service life requirements.
- Discussion with reputable galvanizer.
- **CORROSION CONTROL SHOULD NOT BE AN AFTERTHOUGHT!**

Next step



		Appropriate (A)	Less Appropriate (B)
1	<b>Check environment</b>	Refer to ISO14713:1 and / or for more aggressive conditions, assess coating thickness of residual hot dip galvanizing on components on site adjacent to the new project (if available) and evaluate their performance in terms of the exposed life of the hot dip galvanizing.	Assume that hot dip galvanizing will perform equally in most applications, including all marine conditions, concentrated SO2 environments, acidic waters (immersed) or in acidic soils (buried).
2	<b>Provide correct specifications / standards</b>	ISO 1461 – General hot dip galvanizing. EN 10240 – Tube hot dip galvanizing. ISO 3575/4998 – Continuous hot dip galvanizing of sheet, <u>specify class of coating</u> . ISO 675/935 – Hot dip galvanizing of wire, <u>specify class of coating</u> .	All items to be “Galvanized” or refer to previous outdated standards. “Electro-galvanized” “Cold galvanized” “Pre-galvanized”
3	<b>Compile Project Specification (PS) and Quality Plan (QP)</b> <b>ISO 1461 Annex A – Information to be supplied by purchaser</b>	ISO 1461 – Annex A. <ul style="list-style-type: none"> <li>Specify steel composition.</li> <li>Identify significant surfaces.</li> <li>A sample or other means of showing the required finish.</li> <li>Any special pre-treatments.</li> <li>Any special coating thickness.</li> <li>Any after treatments.</li> <li>Inspection requirements.</li> <li>Whether a certificate of conformance is required. Note this is only applicable if the steel has been correctly fabricated to the requirements of ISO 14713:2.</li> <li>Required method of repair if necessary.</li> <li>Specify selected site repair material and maximum size of repair allowable.</li> <li>If architectural or duplex – specify packaging if necessary.</li> </ul>	None
4	<b>Negotiate galvanizing price for project</b>	<ul style="list-style-type: none"> <li>Ensure galvanizer is reputable and/or a member of the HDGASA.</li> <li>Ensure that galvanizer is aware of requirements in both 2 &amp; 3.</li> <li>Discuss max sizes of components that can be processed and if necessary adjust to modular sizes.</li> </ul>	Get price from one or two galvanizers who are friends or are conveniently situated, with not necessarily the correct size galvanizing bath. Accept lowest price.
5	<b>Secure order for contract</b>	<ul style="list-style-type: none"> <li>Inform selected galvanizer.</li> <li>Galvanizer to advise on fabrication requirements in terms of ISO 14713:2 and also assist with a pre-galvanizing inspection before the steel components can be delivered to the galvanizing plant.</li> <li>If necessary involve the HDGASA or a reputable third party galvanizing inspector.</li> <li>Discuss roll out of project and delivery programme and size of project.</li> <li>Re-visit project specification requirements.</li> </ul>	Start fabricating, ignoring the requirements of ISO 14713:2 or without reference to the requirements in terms of hot dip galvanizing.
6	<b>Send components</b>	Programme receipt and return of hot dip galvanized components to ensure project roll-out and optimum use of transport facility. Incoming pre-galvanizing inspection, if not already completed at stage 5.	Delays experienced by the fabricator and not keeping the galvanizer informed. Non-conformance of components on receipt by the galvanizer, due to insufficient drainage, vent or filling holes; also weld slag and weld porosity; etc. Components held in quarantine until client is informed. Expect delays in project.

S1

		Appropriate (A)	Less Appropriate (B)
7	<b>Galvanizer experiences delays due to technical problems</b>	Inform customer promptly, renegotiate delivery programme.	No prompt communication by galvanizer. When customer phones on due date he is informed of the delay.
8	<b>Coating inspection and certification</b>	If requested under 3, galvanizer informs customer that components are ready for inspection or have been inspected (as required) and if required a certificate of conformance can be issued.	No plant inspection is arranged, galvanizer arranges transport and delivery. Certification often requested some time after delivery of components to the site and sometimes payment is withheld until a certificate is incorrectly issued.
9	<b>Components loaded on transport vehicle</b>	Particularly for distant deliveries: <ul style="list-style-type: none"> <li>• Ensure packaging is complete – see Project Specification.</li> <li>• Ensure components have adequate and efficient separating dunnage material so as not to rub against one another, particularly at flange/pipe interfaces.</li> <li>• Ensure the components are securely strapped down using soft ropes not uncovered chains.</li> </ul>	Components are bundled onto delivery truck with no separating dunnage, ensuring possible transport damage.
10	<b>Arrival of finished components and offloading on site</b>	<ul style="list-style-type: none"> <li>• Dedicated laydown space prepared.</li> <li>• Sufficient space available for easy offloading.</li> <li>• Correct stacking on dunnage – not on damp soil.</li> <li>• Components inclined to the plane of the ground when stacking to ensure reduced rainwater retention and therefore reduce the incidence of white rust in moist atmospheres.</li> <li>• Correct mechanism for offloading of components.</li> </ul>	<ul style="list-style-type: none"> <li>• Very little site space.</li> <li>• Components have to be stacked or thrown on top of one another.</li> <li>• Potential for coating damage – huge.</li> <li>• Coating inspection is conducted, which may result in non-conformance of coating.</li> <li>• Galvanizers QA personnel is requested to inspect coatings on site.</li> <li>• Galvanizers QA personnel, HDGASA or reputable third party galvanizing inspector to assist.</li> </ul>
11	<b>Acceptance/dispute between galvanizer, fabricator and end-user</b>	<ul style="list-style-type: none"> <li>• Clearance certificate received from galvanizer.</li> <li>• Project on schedule.</li> <li>• No payment delays.</li> <li>• <b>SERVICE AND DELIVERY BY GALVANIZER AND FABRICATOR APPLAUDED BY CLIENT!</b></li> </ul>	<ul style="list-style-type: none"> <li>• Dispute regarding coating damage and defects.</li> <li>• Late delivery.</li> <li>• Project completion delayed (penalties).</li> <li>• Payment withheld.</li> <li>• <b>THE HOT DIP GALVANIZING INDUSTRY RECEIVES A BAD REPUTATION!</b></li> </ul>
12	<b>SUMMARY</b>	<ul style="list-style-type: none"> <li>• Understand environment – Consult ISO 14713:1.</li> <li>• Quote correct specifications, compile project specification/quality plan.</li> <li>• Discuss with galvanizer when negotiating price and confirm when order is secured.</li> <li>• Programme receipt and return of material.</li> <li>• Communicate progress in both directions.</li> <li>• Conduct coating inspection at fabricator or at plant/ coating inspector should be appropriately qualified. Certificate of conformance is to be issued.</li> <li>• Packaging (Architectural/Duplex)</li> <li>• Separating dunnage used when transporting.</li> <li>• Appropriate site offloading and stacking.</li> </ul>	

## ENSURE THE SPECIFICATION IS CORRECT (2011)

S1

The HDGASA was requested to investigate some thinly zinc coated tube that was supposed to have been general or tube hot dip galvanized.

### THINLY ZINC COATED TUBING

Based on the coating thickness readings taken both inside and outside of the tubes, it is apparent that the tubes in question have been manufactured from zinc electroplated sheet. The sheeting may not necessarily have been manufactured in South Africa and the specification may be different to the range manufactured locally. However, the following provides an example of this type of coating and its nominal coating thickness.

Produced by ArcelorMittal in South Africa zinc electro-galvanized steel sheet consists of a cold rolled steel substrate over coated with zinc by electrolytic deposition on a continuous line. Electro-galvanizing allows greater control in coating thickness while also permitting two different coating thicknesses on either face of the sheet. A range of coating thicknesses is offered with the maximum coating thickness being equivalent to a Z100 coating class (7.14µm nominal coating thickness) continuous hot dip galvanized sheet.

Bonding of the coating is purely mechanical and therefore there are no iron/zinc alloy layers.

Table 1 of zinc coatings is taken from the data sheet. While it is difficult to ascertain the exact coating designation in this instance, accurate results will only be achieved if samples of the tube are subjected to a Chemical Stripping (Gravimetric) Test to ISO 1460.

### HOT DIP GALVANIZED TUBE

Tubes in this instance are hot dip galvanized in a semi-automatic production line. Should smoothness of the exterior face not be

critical and additional coating thickness is required, the tubes can be general hot dip galvanized to ISO 1461.

Immediately after withdrawal from the zinc bath in the tube hot dip galvanizing process, excess zinc is mechanically wiped off externally by passing the tube through an appropriately sized air



Photo 1: Hot dip galvanized tube to EN 10240 and thinly zinc coated tube.

Table 1 (below): Zinc coatings taken from the data sheet.

Coating designation	Description thickness per side	Nominal coating thickness per side (µm)	Nominal coating mass per unit area per side (g/m <sup>2</sup> )	Minimum coating mass per unit area per side (g/m <sup>2</sup> )
ZE 25 / 25	Normal coating	2.5 / 2.5	18 / 18	12 / 12
ZE 50 / 50	Heavy coating	5.0 / 5.0	36 / 36	28 / 28
ZE 75 / 75		7.5 / 7.5	54 / 54	47 / 47
ZE 50 / 0	One-sided coating	5.0 / 0.0	36 / 0	28 / 0
ZE 75 / 0		7.5 / 0.0	54 / 0	47 / 0
ZE 100 / 0		10.0 / 0.0	72 / 0	65 / 0



S1



2



3



4



5



6

**Photos 2 - 5:** The outer upper coating thickness (22.3μm), the outer lower coating thickness (13.9μm), the inner lower coating thickness (4.9μm) and the inner upper coating thickness (10.1μm).

**Photo 6:** The discoloration on both the tube ends and electrical resistance welded area on the inner weld bead. The zinc coating has the ability to protect steel both from a barrier perspective and sacrificially in preference to mild steel, however, the life of the zinc coating for both these benefits will be based on its thickness and the environment that it will be exposed to. See typical zinc coating loss in terms of the environment in Table 2.

**Photos 7 - 9:** The hot dip galvanized coating thickness to EN 10240 (91.8; 93.8 and 71.0μm respectively) on the lower batch of tube in comparison to photos 2 to 5.

**Photos 10 - 11:** The hot dip galvanized coating thickness on the stanchions (59.2 and 74.6μm). This is normal as per the requirement of ISO 1461.

**Photo 12:** Hot dip galvanized stanchions to ISO 1461.

**Table 2 (opposite page):** An indication of the zinc coating loss for a certain environment.



7



8



9



10



11



12



ring and internally by a blast of heated steam and/or mechanical mandrill passing down the inside of the tube.

In order that tube be hot dip galvanized in this manner, it must be flangeless and have limitations in diameter and length.

Tube hot dip galvanizing in South Africa is done in accordance with EN 10240, where generally the minimum coating thickness is 55µm.

The coating of tubes by this method comprises of a series of iron/zinc alloys outwards from the steel base, which is generally over coated with a layer of pure zinc.

### HOT DIP GALVANIZED STANCHIONS

Pre-cleaned components hanging from a jig are dipped into a bath of molten zinc at about 450°C.

A metallurgical or chemical reaction between the steel and zinc results in a coating comprising a series of iron/zinc alloys which are generally over coated with a layer of pure zinc.

A number of things influence the coating thickness and appearance, with the chemical composition of the steel as in silicon and phosphorus playing the major role. Steel thickness and surface roughness also have a major influence.

ISO 1461:2009, requires that for steel greater than 3mm thick but equal to or less than 6mm shall have a minimum local coating thickness of 55µm but a minimum mean coating thickness of 70µm.

### CONCLUSION AND RECOMMENDATION

As hot dip galvanizing is known for its corrosion control properties and if appropriately used will provide a reasonably long service life. Coating life of any metallic zinc coating is proportional to its thickness in a given environment. It stands to reason therefore that the thicker the coating the longer the service life.

It is therefore recommended that (in this instance) in order to equalize the individual components service lives the thinly zinc coated tubes be replaced with hot dip galvanized equivalents or alternatively stripped of zinc and re-galvanized to ISO 1461.

Table 2 provides an indication of the zinc coating loss for a certain environment and is based on Table 5 taken from ISO 9223 or ISO 14713:1, Corrosion of metals and alloys – Corrosivity of atmospheres – Classification.

In Cape Town the vicinity of the V&A Waterfront area off Table Bay falls into a C3/C4 atmosphere, whereas from Glencairn to the west of Somerset West off the False Bay coastline up to 3km from the sea is a generous C5 atmosphere. The latter atmospheric conditions are mainly caused by the South Easterly winds, high wave action and flat terrain.

1	2	3	4	5	6	7
				Maintenance free life of the coating		
Corrosion	Description of environment	Corrosion rate (av. loss of steel in µm/yr.)	Corrosion rate (ave. loss of zinc in µm/yr.)	Continuously hot dip galvanized sheeting Coating class – Z275 (±20µm)	Hot dip galvanized coating (85µm) Steel thickness >6mm	DUPLEX COATING SYSTEM Hot dip galvanizing + an appropriate paint system
C1	Interior: Dry	≤1.3	≤0.1	>50	>50 #1	Not required for corrosion protection #2
C2	Interior: Occasional condensation Exterior: Exposed rural inland	>1.3 to 25	0.1 to 0.7	>40	>50 #1	
C3	Interior: High humidity, some air pollution Exterior: Urban inland or mild coastal	>25 to 50	0.7 to 2.1	10 to 40	>40	
C4	Interior: Swimming pools, chemical plant, etc. Exterior: Industrial inland or urban coastal	>50 to 80	2.1 to 4.2	5 to 10	20 to 40	Total coating life of a duplex coating system is the combined sum of the lives of the HDG plus paint coating system x at least 50%
C5-I / C5-M	Exterior: Industrial with high humidity or high salinity coastal	>80 to 200	4.2 to 8.4	2 to 5	10 to 20	
<div>#1 Although mathematically incorrect (coating thickness divided by the corrosion rate), the maintenance free life indicated in column 6 has for practical purposes been curtailed to a maximum of 50 years. General hot dip galvanizing specifications state the local (minimum) and the mean coating thicknesses. The coating thickness actually achieved, varies with the steel composition and this can range from the minimum to at least 100% greater. As life expectancy predictions are normally based on the minimum coating thickness, they are usually conservative.</div> <div>#2 A duplex coating system may also be specified in order to provide a colour for aesthetic reasons.</div>						

# THE 'UNSUNG' GALVANIZING STANDARD (2011)

ISO 14713:2009 Zinc coatings – Guidelines and recommendations for the protection against corrosion of iron and steel in structures. Parts 1, 2 and 3 have recently been released.

We discuss only Parts 1 and 2 in this article, by including the scope, titles of each section and occasionally important copy or part copy within such sections.

## PART 1: GENERAL PRINCIPLES OF DESIGN AND CORROSION RESISTANCE

*(For simplicity sake, the article only addresses issues relevant to hot dip galvanizing and thermal sprayed coatings)*

### 1. Scope

This part of the standard provides guidelines and recommendations regarding the general principles of design which are appropriate for articles to be zinc coated for corrosion protection and the level of corrosion resistance provided by zinc coatings applied to iron and steel articles, exposed to a variety of environments.

### 2. Normative references

### 3. Terms and definitions

### 4. Materials

- 4.1 Iron and steel substrates
- 4.2 Zinc coatings

### 5. Selection of zinc coating

### 6. Design requirements

- 6.1 General principles of design to avoid corrosion
- 6.2 Design for application of different zinc coating processes
- 6.3 Tubes and hollow sections
  - 6.3.1 General
  - 6.3.2 Corrosion protection of internal and external surface
- 6.4 Connections
  - 6.4.1 Fastenings to be used with hot dip galvanized or thermal sprayed coatings
  - 6.4.2 Welding considerations related to coatings
  - 6.4.3 Brazing or soldering
- 6.5 Duplex systems
- 6.6 Maintenance

### 7. Corrosion of different environments

- 7.1 Atmospheric exposure, including Table 1, which expands on corrosivity categories wrt the zinc corrosion rates. Table 2 indicates the coating life to first maintenance in a range of classes.
- 7.2 Exposure to soils, including Table 2, which expands on

the different coatings, coating thicknesses and their relevant durability's in terms of the various classes.

- 7.3 Exposure to water
- 7.4 Abrasion
- 7.5 Exposure to chemicals
- 7.6 Elevated temperatures
- 7.7 Contact with concrete
- 7.8 Contact with wood
- 7.9 Bimetallic contact, including Table 3 (Galvanic series of metals) and Table 4, expected corrosion between zinc and other metals

## 8. Accelerated test methods applied to zinc coatings

## PART 2: HOT DIP GALVANIZING

### 1. Scope

This part of ISO 14713 provides guidelines and recommendations regarding the general principles of design which are appropriate for articles to be hot dip galvanized for corrosion protection.

The protection afforded by the hot dip galvanized coating to the article will depend on the method of application of the coating, the design of the article and the specific environment to which the article is exposed. The hot dip galvanized article can be further protected.

### 2. Normative references

### 3. Terms and Definitions

### 4. Design for hot dip galvanizing

#### 4.1 General

It is essential that the design of any article required to be finished should take into account not only the function of that article and its method of manufacture but also the limitations imposed by the finish. Annex A illustrates some of the important design features, some of which are specific to hot dip galvanizing. Some internal stresses in the articles to be galvanized will be relieved during the hot dip galvanizing process and this may cause deformation or damage of the coated article. These internal stresses arise from the finishing operations at the fabrication stage, such as cold forming, welding and residual stresses inherited from the rolling mill, etc. **The purchaser should seek the advice of the galvanizer (or the HDGASA) before designing or fabricating.**

The purchaser should be aware of the two distinct types of hot dip galvanizing, that of batch or general hot dip galvanizing after fabrication and that of continuous hot

dip galvanizing, where various classes of coating are produced.

#### 4.2 Surface preparation

#### 4.3 Procedures related to design considerations

#### 4.4 Design features

Preferred design features for articles to be hot dip galvanized are shown in Annex A.

**WARNING** – *It is essential that sealed compartments be avoided or be appropriately vented, otherwise there is a serious risk of explosion that may cause serious injury (or death) to operators. This aspect of design should be given careful consideration...*

#### 4.5 Tolerances

### 5. Design for storage and transport

Hot dip galvanized work should be stacked securely so that the work can be handled, stored and transported safely.

Where there is a specific need to minimise the development of white rust or wet-storage staining (primarily basic zinc oxide and zinc hydroxide, formed on the surface of the galvanized coating during storage of work in humid conditions), this should be communicated by the purchaser to the galvanizer at the time of ordering and any relevant control measures should be agreed on. Such measures might include...

### 6. Effect of article condition on quality of hot dip galvanizing

#### 6.1 General

6.1.1 Material composition, including *Table 1* which relates to the desired chemical composition of steel and the likely effects and coating characteristics.

6.1.2 Castings.

#### 6.2 Surface condition

The surface of the basis metal should be clean before dipping into molten zinc. Degreasing and pickling in acid are recommended methods of cleaning the surface. Excessive pickling should be avoided. Surface contamination that cannot be removed by pickling, eg. Carbon films (such as rolling oil residues), oil, grease, oil based paint, welding slag, labels, residual glue from labels, marking materials, fabrication oils and similar impurities, should be removed prior to pickling; this allows for more effective and efficient use of pretreatment materials.

The purchaser is responsible for removing such contamination, unless alternative arrangements have been agreed between the galvanizer and purchaser.

6.3 Influence of steel surface roughness on hot dip galvanized coating thickness

6.4 Influence of thermal cutting processes

6.5 Effect of internal stresses in the basis steel

#### 6.5.1 General

The hot dip galvanizing process involves dipping clean, pretreated, fabricated steel components in the bath of molten zinc/zinc alloy at a temperature of about 450°C, and withdrawing them when the metallurgical reaction developing the coating is complete. Relief of large or imbalanced stresses in the article during the dipping process may occur.

The galvanizer cannot be responsible for any associated deformation of the steelwork during galvanizing (as the specific state of stress in the article at the time of dipping is not in his control) unless the distortion has occurred through inappropriate handling (eg. Mechanical damage or incorrect suspension of the article).

6.5.2 Distortion cracking

6.5.3 Hydrogen embrittlement

6.5.4 Strain age embrittlement

6.5.5 Liquid metal assisted cracking (LMAC) or liquid metal embrittlement (LME)

6.5.6 Large objects or thick steels

6.5.7 Hot dip galvanizing practice

### 7. Effect of hot dip galvanizing process on the article

7.1 Dimensional tolerances on mating thread

7.2 Effect of process heat

### 8 After-treatments

To retard the possible formation of wet storage stain on the surface, articles can be given a suitable surface treatment after hot dip galvanizing. If the articles are to be painted or powder coated after galvanizing, the purchaser should inform the galvanizer before the article is galvanized. For application of duplex systems...

*ANNEX A – Containing a number of sketches and notes on preferred designs of articles for hot dip galvanizing.*

**This standard is highly recommended for any specifier or end-user who is involved in designing, detailing and fabricating articles for hot dip galvanizing.**





# HOT DIP GALVANIZING FOR GENERAL AND ARCHITECTURAL PURPOSES (2012)

The achievement of a quality hot dip galvanized coating, for general and architectural use, is dependent on many issues, some controllable and some not. This checklist addresses the issues that can be controlled by the designer and those controllable by the galvanizer.

**AG** – Architectural Quality additional to ISO 1461. Particularly Annex A.

**GG** – Normal General Hot Dip Galvanizing to ISO 1461. Refer also to Annex A.

**Y/N** – Was this criteria achieved, yes / no?

## DESIGN AIDS

#1: SPG – “Steel Protection by Hot Dip Galvanizing and Duplex Coatings” or “Design for Hot Dip Galvanizing”, wall chart, contact the HDGASA for a copy.

Reference must also be made to ISO 14713-2.

## DUPLEX COATINGS

#2: The application of paint to galvanized surfaces has historically largely been done for aesthetic reasons. For heavy-duty applications, it has been found that the application of appropriately applied durable topcoats can increase the maintenance free life of a structural item by 200-400% over that of a similar item in the same environment that uses either paint or galvanizing independently.

By combining heavy duty industrial paint coatings which are typically at least 100 microns in thickness, with hot dip galvanized coatings which are also around 100 microns in thickness, true zero maintenance coating systems can be produced for steel with corrosion free life expectancies for most aggressive environments of in excess of 50 years.

The application of a duplex coating generally involves two parties, a galvanizer and a paint applicator.

The galvanizer thus may have no input into the painting operation and the painter has no insight into the techniques used by the galvanizer that may affect the quality of the duplex system. It is therefore recommended that these two parties are involved at inception of the project to share the combined responsibility of the coating success. There are a few galvanizers who successfully undertake both operations.

Surface preparation of the galvanizing may include degreasing, surface etching or sweep blasting. The most successful of these methods is sweep blasting.

The intension of sweep blasting is to remove the oxide film and surface contamination and slightly profile the surface with minimal reduction in the galvanized coating thickness (no more than 10µm). The following is extremely important:

- Blast pressure less than 300kPa.

- Abrasive Grade 0.2-0.5mm.
- Angle of blasting to surface 45°
- Distance from surface 300-400mm
- Nozzle type minimum 10mm venturi type.

Further information can be obtained from the HDGASA.

## LEAD TIMES

#3: For medium to large contracts the involvement of the galvanizer with the fabricator and end-user is mandatory to ensure timeous programming and establishment of coating

### IDEAL STEEL FOR HOT DIP GALVANIZING – TABLE 1:

#### Industrial and Mining Applications

Silicon (Si) – 0.15 to 0.3% Max

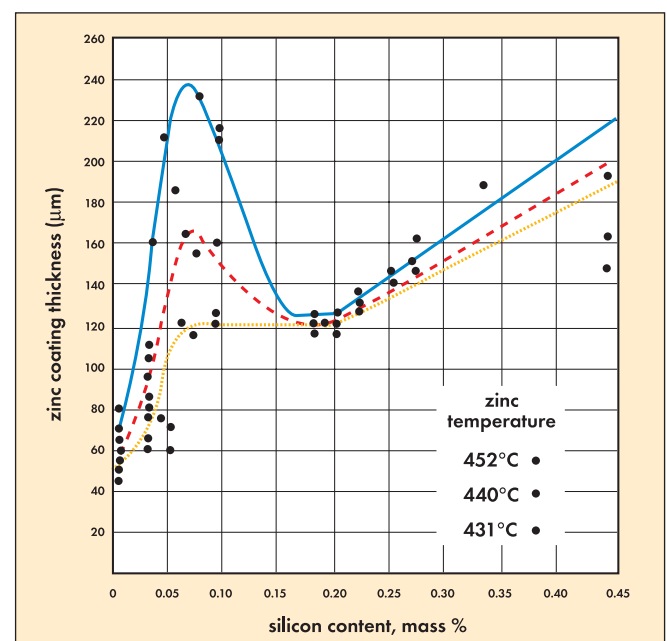
Phosphorus (P) – 0.02% Max

#### Architectural Applications

Silicon (Si) – 0.03 Max with Phosphorus (P) – equal or less than 0.01%

or

Silicon (Si) – 0.15 to 0.25% with Phosphorus (P) – equal or less than 0.02%



The Sandelin Curve refers to the reactivity caused by the silicon content in the steel.

quality. Hot dip galvanizing is normally the final process after fabrication and prior to delivery and erection. If sufficient time for hot dip galvanizing, cleaning, fettling and inspection is not provided in the overall programme, costly delays may occur at the erection stage.

## CERTIFICATE OF CONFORMANCE

#4: A certificate of conformance (in terms of ISO 10474 or if the galvanizer is registered to an appropriate quality assurance standard, such as ISO 9001) is required to ensure that all fettling prior to coating inspection is done by the galvanizer

and not by other parties, who do not necessarily understand the consequence of over cleaning.

## ALUMINIUM VERSUS SILICON KILLED STEEL

#5: Tube and pipe and most plate work 4.5mm thick or less is generally manufactured from aluminium killed steel whereas hot rolled structural steel is silicon killed.

**Note: This checklist is to be used as a guideline and although fairly comprehensive, suitable information may be required to be added.**

No.	THE SPECIFIER AND DESIGNERS CRITERIA:	AG	GG	Y/N
1	Discuss requirements with the selected galvanizer/s before designing commences.	P1	P1	
2	The specifier or designer to ensure all steelwork contractors are informed in writing of the architectural hot dip galvanizing requirements prior to the finalisation of the tender.	P1		
3	Make use of a reputable galvanizer or get a recommendation from the HDGASA.	P1	P1	
4	Make the requirements known to the galvanizer, in writing, together with a sketch or sample, before placement of the order. Further discussion with the galvanizer may be required.	P1		
5	Make use of the Association wall chart – “Design for Hot Dip Galvanizing” plus the design requirements from ISO 14713:2. #1	P1	P1	
6	Choose correct steel type – see table 1. If possible all parties related to the project to purchase the specified steel from the same or specified suppliers. Insist on the steel chemical analysis certificates for record purposes and issue copies to the galvanizer. #5	P1	P1	
7	Ensure components can be dipped in a single immersion, if necessary fabricate in modular lengths or alternatively discuss the impact of double end dipping with the selected galvanizer / HDGASA.	P2	P2	
8	Optimize size of filling, draining and vent holes, see SPG, wall chart or ISO 14713:2. #1	P1	P1	
9	Optimize position of filling, draining and venting holes, see SPG, wall chart or ISO 14713:2. #1 If necessary unwanted holes can be closed after hot dip galvanizing, contact the HDGASA for details.	P1	P1	
10	Should painting of the hot dip galvanizing be specified, ensure that instructions stating “ <b>No passivation is required – substrate is to be painted</b> ”, is handed to the galvanizer, at order stage, unless specifically discussed and excluded. #2	P1	P1	
11	Select significant surfaces, highlight on drawing or sketch and discuss with galvanizer / HDGASA	P1	P1	
12	If necessary, hot dip galvanize a sample and establish acceptance / rejection criteria.	P1	P1	
13	Specify the correct temporary-marking pen for fabrication marking. (A 50/50 PVA paint to water mix, works well for temporary marking)	P1	P1	
14	Ensure that if permanent marking, such as welded lettering is used it will be appropriately hidden from final view.	P1		
15	Specify all flame cut edges to be thoroughly ground, ideally 2mm into the parent material.	P1	P1	
16	If deemed necessary, to minimize handling damage ensure correctly positioned lifting lugs are provided for the component or if not acceptable, soft lifting slings are used, by all parties, including the galvanizer, the transporter, the off loader and the erector, etc. The use of the former is possibly more appropriate.	P1	P1	
17	Specify welding that is fit for purpose; do not allow over welding.	P2		
18	Should stick welding be used, ensure that all weld slag is comprehensively removed by abrasive blasting or grinding prior to delivery to the galvanizer. (Excessive weld porosity can have a marked effect on the quality of the hot dip galvanized coating).	P1	P1	
19	If the build-up of zinc at a weld is unacceptable for aesthetical reasons, request that the correct welding wire or rod be used. Some welding materials are reactive wrt hot dip galvanizing and can result in a thicker coating on the deposited weld. Discuss with the HDGASA.	P1		
20	Simplify componentry – Simple structures – Better coating quality Complex structures – Harder to manipulate in the galvanizing bath, more control, cleaning and fettling necessary.	P1	P1	
21	Simplify complex structures by making use of bolting where possible or alternatively design for after galvanizing welding, by using a suitable masking material such as “Galvstop”, which can be easily cleaned, successfully welded and correctly repaired.	P1	P1	

No.	THE SPECIFIER AND DESIGNERS CRITERIA:	AG	GG	Y/N
22	Discuss packaging / dunnage requirements with the galvanizer during transport and ensure that ample site stacking facilities are provided. A hot dip galvanized coating is applied in a factory and then transported to site where frequently the components are inappropriately offloaded. Inappropriate offloading may lead to unnecessary mechanical damage of the coating. As the components are generally not wrapped, coating discolouration due to contaminants being deposited by wet trades, i.e. angle grinding of wet clay bricks in the presence of hot dip galvanized components, should be prevented.	P1	P2	
23	Discuss the appropriate repair method, if unavoidable repair is deemed to be necessary by the galvanizer. Silver spray paint on its own is not acceptable. The silver spray paint may be initially more aesthetically acceptable while the hot dip galvanized coating is shiny, but will ultimately stand out and be aesthetically unacceptable, when the hot dip galvanized coating begins to weather to a matt dull grey appearance. Furthermore, most silver spray paints do not provide the protection as a good zinc rich epoxy for repair purposes.	P1	P1	
24	Discuss the maximum size of coating repair allowable when alterations or adjustments are made on site, with the appropriate contractors. Refer to ISO 1461. Get HDGASA recommendation.	P1		
25	Discuss inspection requirements of the components prior to these leaving the galvanizer's premises.	P1	P1	
26	Ensure, if necessary that a certificate of conformance in accordance with the specification, has been obtained from the galvanizer. #4	P1	P1	
27	Allow sufficient time for the hot dip galvanizing process to take place, ideally 3 to 7 working days, unless other arrangements have been made. #3	P1	P1	
No.	THE GALVANIZERS' CRITERIA:	AG	NG	Y/N
1	At the tender stage, enquire whether the components are to be hot dip galvanized to an "architectural standard". If yes, ensure that all project team partners understand these criteria and have a copy of this check list.	P1		
2	If an architectural finish is required, obtain a sketch indicating significant surfaces or provide a working sample which may be hot dip galvanized, for discussion, negotiation and acceptance purposes.	P1		
3	Insist on the appropriate steel chemical analysis certificates for galvanizing control and record purposes.	P1	P1	
4	Ensure that significant surfaces if necessary have been discussed and agreed on.	P1	P1	
5	Ensure components can be dipped in a single immersion, unless the quality implications of double end dipping are discussed with the fabricator/customer/specifier.	P1	P1	
6	Ensure when offloading components at the galvanizer, that any transport damage is recorded and the client appropriately notified.	P1	P1	
7	Ensure that reasonable fill, draining and vent holes have been provided.	P1	P1	
8	Ensure that filling, draining and vent holes have been positioned correctly.	P1	P1	
9	When handling the component, make use of lifting lugs (if supplied) or alternatively use soft lifting slings after hot dip galvanizing.	P1	P1	
10	Ensure the use of optimum aluminium content in the zinc bath.	P1	P2	
11	Based on the chemical analysis of the steel, discuss immediate water quenching after galvanizing, if necessary to limit iron/ zinc alloy build-up with reactive steel. (This is only necessary if the appropriate steel has not been specified and steel used is reactive to molten zinc). The galvanizer should also be aware of the increased likelihood of distortion with certain components when quenching and discuss these with the project team.	P1	P1	
12	Ensure all agreed upon significant surfaces have been cleaned and free of imperfections after hot dip galvanizing, according to instructions.	P1	P1	
13	Ensure adequate fettling of the components using appropriate methods, particularly with reference to lumps, runs and excessive surface roughness, especially on significant surfaces, while taking care not to excessively clean the surface, leading to uncoated areas. Discuss flame cleaning vs mechanical cleaning, with the project team.	P1	P1	
14	<b>Zinc aerosol spray paint is not acceptable.</b> Ensure that the specifier is informed of the method of renovation of uncoated areas that might occur due to air entrapment during galvanizing or as a result of mechanical damage at the galvanizer.	P1	P1	
15	Passivating chemical in the quench water must be excluded if subsequent painting has been specified. See #2	P2	P2	
16	Ensure that inspection of the components is carried out before and after hot dip galvanizing, to the customers requirements. Issue a certificate of non-conformance before galvanizing or conformance with ISO1461, after hot dip galvanizing.	P1	P1	



# GENERAL AND CONTINUOUSLY HOT DIP GALVANIZED SIGNBOARD SUPPORT CHANNELS (2011)

S1



1

Metal Framing and Wiring Channels				
Typical Section	Material	Length	Finish	Usage
	2.5mm Thick Mild steel.	6.0m	Hot Dip Galvanized to ISO 1461	Metal framing, Cable ladder support systems, condenser support systems, pipe & air ducting support systems.
	2.5mm Thick Mild steel.	5.0m	ISO 3575 Coating Class Z275	



2

Typical Section	Material	Length	Finish	Usage
	1.6mm Thick Mild steel.	5.0m	ISO 3575 Coating Class Z275	Light framing, shelving and Wiring systems (Electrical wiring).
	1.0mm Thick Mild steel.	5.0m	ISO 3575 Coating Class Z275	Wiring systems (Electrical wiring).



3

Typical Section	Material	Length	Finish	Usage
	2.5mm Thick Mild steel.	6.0m	Hot Dip Galvanized to ISO 1461	Metal framing, Cable ladder support systems, condenser support systems, pipe & air ducting support systems.
	2.5mm Thick Mild steel.	5.0m	ISO 3575 Coating Class Z275	

Photos 1 - 3: The location, cross sectional shape and typical coating thickness of a 1.6mm thick continuous hot dip galvanized strut.

Photos 4 - 6: The lower three photos show the location and typical coating thickness of a 2.5mm thick general hot dip galvanized strut. As life of the coating is proportional to its thickness, it makes sense to use the thicker coating offered when the signage support is exposed to more aggressive environments.

Typical Section	Material	Length	Finish	Usage
	1.6mm Thick Mild steel.	5.0m	ISO 3575 Coating Class Z275	Light framing, shelving and Wiring systems (Electrical wiring).
	1.0mm Thick Mild steel.	5.0m	ISO 3575 Coating Class Z275	Wiring systems (Electrical wiring).



4



5



6

## UNDERSTANDING METALLIC ZINC COATINGS

### BEWARE OF STEEL WITH HIGH PHOSPHOROUS CONTENT (2012)

It should be reasonably common knowledge that to achieve a good quality hot dip galvanized coating thickness in terms of ISO 1461 of a minimum mean of about 85 microns on structural steel, the silicon content of the steel should be limited to the ideal requirements of the well known Sandelin curve (see figure 1) which basically tells us:

The two chemical constituents in steel that affect coating thickness and aesthetic appearance are silicon and phosphorous. When the silicon falls out of the two desirable ranges on the Sandelin Curve, an extremely thick and easily damaged mottled grey to silver and dark grey coat of zinc is the result. However, when the phosphorous content falls into the out-of-specification range, it affects the successful metallurgical bonding of the coating (i.e. the galvanizing will delaminate in large localised areas).

Ideal steels require a silicon content to fall between 0.02 to 0.04% (the so-called 'aluminium killed steel') and 0.15 to 0.25% ('silicon killed steel').

The maximum phosphorous content should be less than 0.02%. Steel that falls out of these ranges are called 'reactive' steel when it comes to galvanizing.

ISO 1461 includes an Annex A, which addresses the essential information to be provided by the purchaser to the hot dip galvanizer. Even though the Annex is situated at the back of the Standard, it does not reduce its importance when specifying hot dip galvanizing to ensure the quality product we have come to expect from reputable hot dip galvanizers. This includes information about the chemical composition of the steel.

Most general galvanizers will accept steel for hot dip galvanizing as long as the component has been reasonably designed and fabricated taking into account some simple design rules. However they cannot be aware of the potential reactivity of the steel in its black form with respect to molten zinc before hot dip galvanizing unless they have sight of accurate material certificates which spell out the chemical composition of the steel.

For heavy duty coatings on heavy steel sections, usually required for underground mining conditions, a bit of reactivity is a good thing so that a hot dip galvanized coating thickness of in excess of 150 microns can be achieved.

The galvanizer takes responsibility for hot dip galvanizing the steel but the choice of steel grade and chemical composition of the steel is the responsibility of the specifier, his fabricator and the steel

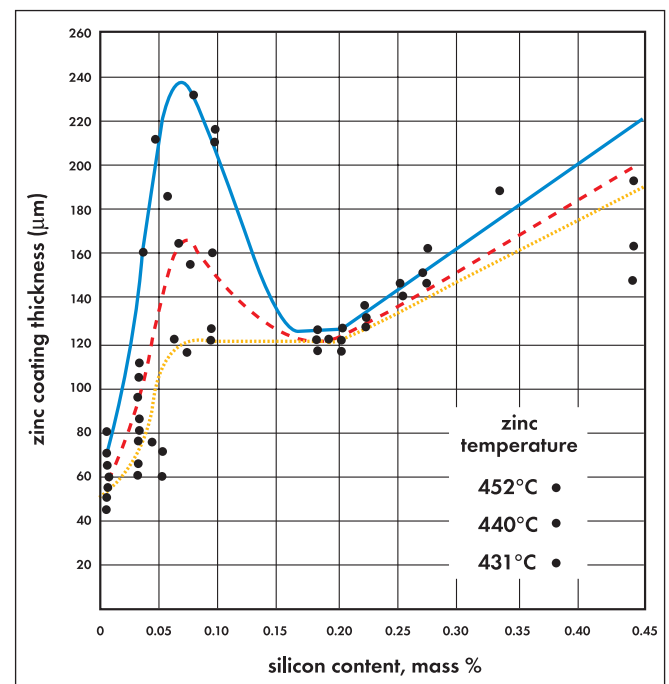


Figure 1: Bath temperature effect on the Traditional Sandelin Curve.

supplier, particularly when the latter has been informed that the steel is to be hot dip galvanized!

As a general rule, the fabricator should take responsibility for checking the chemical composition related to its suitability for hot dip galvanizing (as well as its conformance with design requirements) when purchasing the steel. The South African steel rolling mills will take care to supply, as long as it is ordered, steel that is suitable for hot dip galvanizing.

However, when it comes to the so-called commercial quality steels, no chemical composition certificates are available.

If the galvanizer is aware, that for a particular batch of steel, the chemical composition does fall into the 'problem steels' range he then can act accordingly. However, the methods he may use to limit coating build-up are generally insignificant in comparison to the coating buildup effect from extremely reactive steels. Should hot dip galvanizing of the steel be unsuccessful he may be able to offer his client a zinc thermal sprayed metal protective coating as an alternative.

**Photo 1:** Out of specification levels of phosphorous can cause severe cracking of the coating.

**Photos 2 - 5:** Cracking and local delamination of the coating can be caused by out of specification levels of phosphorous.



S2





## ABRASIVE BLAST CLEANING FOR DIFFERENT COATINGS (2013)

A compulsory pre-treatment for different coatings applied to a steel substrate.



Grit blasting, shot blasting and micro blasting are an essential prerequisite for the successful application of protective coatings.

In this article we will examine why it is necessary to blast and why it is a compulsory pre-treatment for these different coatings.

### PAINTING

Steel that is to be protected by a good protective coating system must be abrasive blast cleaned prior to painting to remove all contaminants, rust and mill scale. A quality paint requires a good clean surface with a suitable profile to provide adhesion to the paint as the life expectancy of the coating is directly proportional to the cleanliness of the surface and the thickness of the paint coating. Tests carried out in the United Kingdom have shown the life of a blasted paint coating system will outlast a wire brush system with the same paint system by 3 to 5 times in exterior environments.

Grit blasting should be carried out to a SA 2 1/2 or a SA 3 cleanliness which is a white metal finish with a surface profile which may vary from 25 to 75 microns depending on the paint manufacturers requirements and dft of the paint system. These systems can vary from 75 microns in rural conditions to 500 microns in aggressive salt spray environments.

### GRIT BLASTING AND METAL SPRAYING

Here the blasting profile (50 to 75 microns) is very important to ensure the necessary adhesion of the metal sprayed coating. In

addition the metal sprayed coating should be sealed by using a stainless steel wire brush as it tends to be slightly porous. Prior to using zinc metal spraying for damaged hot dip galvanized coatings, the damaged area should be locally abraded or roughened, ensuring adhesion.

### CASTINGS

Abrasive blasting is essential on iron castings prior to hot dip galvanizing.

### MICRO BLASTING PRIOR TO PAINTING ON A NEWLY HOT DIP GALVANIZED COATING

The choice of a micro grit for "sweep" blasting to provide an etch on a newly galvanized coating is all important as is the reduced blast pressure, angle of blast, nozzle type and sweeping distance of the blasting. Appropriate paint coatings over hot dip galvanizing are considered to be the Rolls Royce of corrosion control provided they are applied correctly. This is known as a Duplex paint system.

### BLASTING

While not necessary for all galvanizing, in certain instances there are several important benefits. On heavily pitted and rusted steel the only method to remove the corrosion product is by grit blasting the affected areas. Acids will only remove surface rust and will not penetrate the pits which are often caused by proximity to aggressive chloride conditions. Once blasted the clean steel can

be re-galvanized to provide the client with enormous cost saving rather than replacing the structure with new steel. Blasting is also suitable for removing old paint coatings and heavy and rolled in mill-scale but contaminants such as oil, grease and salts should be removed by a suitable degreasing solution prior to blasting.

### BLASTING REACTIVE STEELS WHICH CONTAIN REACTIVE LEVELS OF SILICON AND HIGH LEVELS OF PHOSPHORUS

Where these steels are hot dip galvanized and thick brittle coatings are experienced, it is important to provide the client with a coating that will withstand mechanical handling prior to erection without extensive damage that requires excessive repairing on site.

These thick brittle coatings may be accentuated by a long immersion time in the molten zinc which is sometimes unavoidable due to inappropriate venting of large tubular and complicated structures, such as road sign gantries. In addition to the metallurgical bond that occurs when galvanizing takes place, an abrasion blasted surface will provide a surface profile ensuring an additional mechanical bond. This is particularly important to key prospective thick galvanized coatings as a result of the steel type.

### ABRASIVE BLASTING TO PROVIDE A RELATIVE UNIFORM COLOUR

The scourge of the galvanizing industry is a coating which either becomes a very dark grey or due to the silicon and phosphorous levels becomes blotchy in appearance with large portions of shiny silver, dull grey and zebra type silver streaks.

It is consistently the most rejected coating by misinformed clients due to its unpleasing appearance but in fact is a good galvanized coating that will last for substantially longer periods of time.

By discussions with the client this coating can be improved by abrasive blasting prior to galvanizing which will remove a certain amount of the contaminants in the steel on the surface and will provide a uniform matt grey colour coating that is aesthetically pleasing in appearance.

As this adds a certain cost to the finished product, clients are normally reluctant to pay for this extra cost. However, where heavy steel structures are for export or are to be transported some distance it has the effect of removing the brittleness of the coating and presenting the client with an aesthetically pleasing product. Adding nickel or other approved alloys to the zinc kettle will also improve this appearance.

It is the duty of every hot dip galvanizer to continue to provide and promote a product that is aesthetically pleasing (when required) to equal the unmatched and unquestionable qualities of corrosion control that is provided by a hot dip galvanized coating.

S2



**Photo 1 (opposite page):** General view of the sign gantry.

**Photo 2:** The matt grey colour of the hot dip galvanizing as a result of the prior abrasive blasting of the substrate.

**Photos 3 - 4:** Close-ups showing the colour and coating thickness of 694 and 482µm respectively.

**Photo 5:** Colour of base plate arrangement.

**Photo 6:** Damage which has occurred to a thick brittle coating that was not blasted prior to hot dip galvanizing.

**Photo 7:** Coating thickness of 634µm on the base plate.



## MASKING: ALL ABOUT GALVASTOP (2014)

The ability to mask specific areas prior to galvanizing allows the galvanizing process to be more flexible and therefore, open to a wider range of applications.

### INTRODUCTION

Masking or stop off material are products that are applied to steel in specific areas prior to hot dip galvanizing to prevent zinc from reacting and adhering to the steel.

The hot dip galvanizing industries use masking for the following reasons, namely:

- Preference is given primarily to prevent the galvanizing process on large areas, rather than removing the zinc coating later. Additionally masking products are applied to threads where the precise fit is necessary and the additional coating thickness incurred by galvanizing would cause fitment issues.
- The ability to mask specific areas prior to galvanizing allows the galvanizing process to be more flexible and therefore, open to a wider range of applications.

There are a number of companies that offer this product to the galvanizing industry.

### MECHANISM

The paste is carefully applied to the designated areas, and successfully passes through the pickling process and then hardens with the heat of the galvanizing process and prevents zinc ingress. After the galvanizing process, this residue is easily removed by wire brushing.

### PROCESS SEQUENCE

- Surfaces must be cleaned prior to applying the mask such as "Galvastop".
- Once the component is dry, carefully apply "Galvastop" by brush or sponge.
- Make sure the desired stop off area is completely covered – avoid bare spots.
- "Galvastop" must dry before further processing; leave approximately 3 – 4 hours before processing of parts.

### PRODUCT PREPARATION

- Product comes ready to use.
- Stir and shake well and apply to surface.

### CONCLUSION

Masking of steel to be galvanized is never 100%, but by careful preparation, the effectiveness of the product can be increased for successful masking purposes.

### References

- (1) Galvanising Note: American Galvanising Association 2010. Processing and design notes.
- (2) Ask Dr Galv, <http://www.galvanizeit.org/images/uploads>.



**Photo 1:** High pressure water pipes have close fitting couplings which if galvanized may result in a coating too thick for fitment. "Galvastop" has been used to exclude a galvanized coating. The pipe ends are now zinc metal sprayed for corrosion control.



**Photo 2:** Male threads coated with "Galvastop".



**Photo 3:** This hole inside has been coated with "Galvastop" and after hot dip galvanizing has been cleaned out, showing a purposely uncoated area.



**Photo 4:** "Galvastop" has been removed after hot dip galvanizing in this female thread, showing purposely uncoated threads.



# WHAT IS CATHODIC PROTECTION AND WHAT IT ISN'T? (2012)

S2

In order to understand what cathodic protection (CP) is, one must first understand the very basics of the corrosion mechanism.

For corrosion to occur, three conditions must be present:

1. Two dissimilar metals
2. An electrolyte (water with any type of salt or salts dissolved in it)
3. A metal (conducting) path between the dissimilar metals

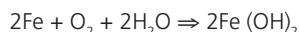
The two dissimilar metals may be completely different alloys, such as steel and zinc, but they are more often microscopic or macroscopic metallurgical differences on the surface of a single piece of steel. If the above conditions are present then at the more active metal surface (in this case we will consider freely corroding steel which is non uniform), the following reaction takes place at the more active sites: (two iron ions plus four free electrons)



The free electrons travel through the metal path to the less active sites where the following reaction takes place: (oxygen gas converted to oxygen ion – by combining with the four free electrons – which combines with water to form hydroxyl ions)



The recombination's of these ions at the active surface produces the following reactions, which results in the formation of the iron corrosion product ferrous hydroxide: (iron combining with oxygen and water to form ferrous hydroxide)



This reaction is more commonly described as 'current flow through the water from the anode (more active site) to the cathode (less active site)'. Cathodic protection prevents corrosion by converting all of the anodic (active) sites on the metal surface to cathodic (passive) sites by supplying electrical current (or free electrons) from an alternate source.

In the case of hot dip galvanizing (HDG), this occurs as the zinc sacrifices itself as it is more electronegative than the steel. CP may take place, as one has an anode (steel surface), a cathode (zinc surface), a metallic path between the zinc-iron inter-metallic layers which formed during the metallurgical reactions between steel and zinc during the galvanizing process, and an electrolyte (sea water, atmospheric water globules on the surface, etc.).

Cathodic protection (CP) works on submerged (e.g. water tanks) or buried (e.g. pipelines, piles, offshore rigs, etc.) structures, providing that the circuit resistance allows sufficient current to flow from the anode to the cathode through the electrolyte (soil, sea water, etc.).

## Does CP work on cars, stadium steel seats?

No. It would only work, if one were to submerge the car, stadiums, etc. in water (electrolyte). If CP worked on cars, it would be standard on all BMW, Mercedes, Toyota, Nissan, VW, Audi, etc., etc., but it is not.

## Can paints provide CP?

No. Please see *Zinc primers – an overview on page 20*.

## Does CP work in the 'marine splash zone' (MSZ) or any other splash zone?

No. As there is an intermittent supply of 'electrolyte' and intermittent flow of current. Due to the highly oxygenated 'water' and wet and dry conditions, extremely high corrosion rates are observed. Carefully designed systems with modified permanent 'electrolytes' do permit CP to take place in a MSZ, please see <http://www.structuraltechnologies.com/LifeJacket> but the 'environment' has been changed to allow CP to occur.

CP is like all other protection systems and has its limitations, so if you are in doubt, then after applying simple logic and the 'reasonable man test' one may need to contact a corrosion specialist.



1



2

**Photo 1:** The thinly galvanized coating (Z275) (used for security spikes in Kenilworth Cape Town after about 15 years of exposure) being a minimum of 13.5µm to a nominal 20µm per face (when new), both the edges and more so at the tip, the zinc coating providing CP will slowly recede away from the edge or tip revealing a localised rusted area, which as the zinc recedes, will gradually increase in size.

**Photo 2:** After 26 years of mild marine exposure, this site cut unrepaired hot dip galvanized steel grating still offers cathodic protection at the cut ends.

## ZINC PRIMERS: AN OVERVIEW (2005)

### METALLIC ZINC AS A PROTECTIVE PRIMER

It is generally accepted that particles of metallic zinc applied to a steel surface in a paint matrix in the form of a zinc primer provide protection to the steel by the process of cathodic protection. In the presence of moisture as the electrolyte, the steel forms the cathode and the zinc the anode in the resultant corrosion cell. The steel, being the cathode, does not corrode whilst the zinc, being the anode, corrodes preferentially and protects the steel. This protection continues until the zinc in the paint matrix is consumed or depleted.<sup>#1</sup>

### HOT DIP GALVANIZING VS ZINC RICH PAINT

It must be remembered that it is metallic zinc that affords cathodic protection to steel and the extent of protection offered is directly proportional to the coating thickness in terms of hot dip galvanizing and in terms of a zinc rich paint, the mass of zinc present in the dry film as well as the coating thickness. A further factor is the environment at hand.

Care should therefore be taken when selecting zinc based coating systems for chemical environments. Zinc, being an amphoteric metal, is attacked by both acids and alkalis. Zinc should only be used in the pH range 6 to 12.5.<sup>#2</sup>

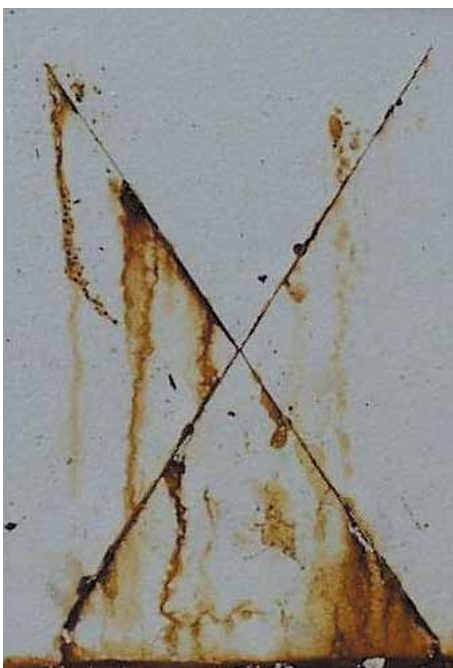
Zinc phosphate and zinc chromate containing paints do not provide cathodic protection as they are inhibitive rather than

sacrificial pigments and provide protection by a totally different mechanism.

When considering zinc rich paints, only those that contain sufficient quantities of metallic zinc dust will provide cathodic protection. There must obviously be sufficient zinc particles present to ensure that they are in electrical contact with each other in order to provide a common anode. Individual isolated zinc particles dispersed in the paint binder will not provide protection as they would essentially be insulated from the substrate and each other. On the other hand, if too much zinc dust is added to the paint there may not be sufficient binder available to glue these particles together, giving an unbound coating with poor adhesion and cohesion. In accordance with ISO 12944, all zinc rich paints should contain a minimum of 80% zinc in the dry film in order to function as sacrificial primers.

From the point of view of zinc content, **hot dip galvanizing is the ultimate zinc rich primer.**

A "Duplex Coating" is a term first introduced by Jan van Eijnsbergen of the Dutch Hot Dip Galvanizing Institute in the early fifties. It describes the protection of steel by over coating hot dip galvanizing with an organic coating system. The purpose is to provide additional corrosion resistance, easy visibility, camouflage, or when a pleasing aesthetic appearance is necessary.



1



2

**Photo 1:** Powder coated mild steel – 2 000 hours salt spray.<sup>#1</sup>

**Photo 2:** Powder coated continuous hot dip galvanized sheeting – Z275 – 2 000 hours salt spray.<sup>#1</sup>

<sup>#1</sup> Both coatings in photos 1 & 2 were scribed down to the steel substrate prior to exposure to the salt spray test.

Duplex coating systems provide synergy by virtue of the fact that the durability of the combined hot dip galvanized / organic coating system is greater than the sum of the separate durabilities of the hot dip galvanizing and a organic coating layer applied directly to the steel substrate.

The reasons for this synergistic effect are as follows.

When moisture, oxygen and pollutants diffuse through a paint coating onto steel, rust soon forms at the interface. Since rust (a mixture of various hydrated iron oxides with varying compositions) has a volume which is approximately twice to three times the volume of the steel from which it has been formed, the paint coating will lose contact with the substrate and, depending upon its adhesion and cohesion, will start to crack and/or flake off.

When hot dip galvanized steel is the base of a paint system, the occurrence of moisture, oxygen and pollutants at the zinc / paint interface causes the pure zinc (or eta layer) to corrode slowly. However, these zinc corrosion products (mainly zinc oxide and zinc hydroxide) have a volume which is only 15 - 20% more than the volume of zinc from which they have been formed. These zinc corrosion products will block off small pores, craters or cracks in the paint coating<sup>#3</sup>, thus conserving its protective properties over an extended period, provided that adequate adhesion of the paint coating was initially achieved.

The benefit of a metallic zinc primer such as hot dip galvanizing under an organic coating system is illustrated by the comparative photographs on the opposite page. The photograph on the left shows a powder coated mild steel panel that has been exposed in a salt spray cabinet for 2 000 hours. The rust staining weeping from the scribe cuts shows that the underlying steel is corroding where the salt spray has gained access to the substrate. The coating adjacent to the scribes is being lifted by the voluminous iron corrosion products. The photograph on the right shows a powder coated panel made from continuous hot dip galvanized sheeting – coating class Z275 (equates to about a 20µm coating thickness). In this instance the metallic zinc primer has provided cathodic protection to the underlying steel at the scribe cuts. The surrounding zinc is sacrificing itself to protect the steel, forming white zinc corrosion products. The solid volume of the zinc corrosion products is small and therefore the coating adjacent to the scribes has suffered little damage. After the same 2 000 hours period there is still sufficient zinc to prevent corrosion of the underlying steel. The sacrificial nature of zinc at the scribe points will in time deplete the surrounding zinc coating and as it recedes, leaving uncoated steel at the scribe point<sup>#4</sup>, localised corrosion will commence. Maintenance painting repairs would then be required before the steel substrate is damaged.

In extenuating circumstances such as, possible design restrictions, size of component, geographical location of the fabricator in comparison to the galvanizer, or where hot dip galvanizing is impractical or impossible etc., hot dip galvanizing may have to be substituted by either inorganic zinc or organic (epoxy) zinc.

It is beyond the scope of this article to cover the detailed pros and cons of hot dip galvanizing versus zinc rich paints but one of the main factors for consideration remains costs. A number of articles comparing the relative costs of hot dip galvanizing versus painting have been published.<sup>#5</sup>

The essential difference that must be appreciated is that hot dip galvanizing costs are calculated by mass of steel hot dip galvanized, whilst painting costs are based on area painted. Tables are available for most steel sections giving surface area by mass.

As a rule of thumb the following can be used:

Extra light steel	more than 40m <sup>2</sup> /ton
Light steel	30 to 40 m <sup>2</sup> /ton
Medium steel	20 to 30 m <sup>2</sup> /ton
Heavy steel	less than 20 m <sup>2</sup> /ton

In hot dip galvanizing, steel is subjected to a routine cleaning process, including, degreasing, acid pickling and fluxing, with intermediate water rinsing, thereby creating a thoroughly clean surface, essential for hot dip galvanizing to take place. The resultant coating thickness is dependent on several factors including, chemical composition of the steel, steel thickness and surface roughness, as well as a number of other less important factors. In steel of thickness equal and greater than 3mm but less than 6mm, the mean coating thickness is required to be at least 70µm and on steel thickness greater than 6mm, 85µm.

The painter will abrasive blast clean the steel and then spray apply a suitable 75 micron thick (inorganic or organic) zinc rich primer coat for a protective coating system at a cost based on the total area of steel he has painted.

Case histories have shown that for steel sections up to some 35m<sup>2</sup>/ton it is more cost effective to blast clean and paint whereas for steel sections with greater than 35m<sup>2</sup>/ton, it is more cost effective to hot dip galvanize. Obviously this cut off point varies with raw material and labour costs at any point in time. It will also be argued that the hot dip galvanized coating contains more zinc and will therefore last longer than the 75 micron of paint (with 80% zinc in the dry film).<sup>#6</sup> On the other hand the hot dip galvanizing will require thorough cleaning before the primer or intermediate coat can be applied.

The point is, however, that both methods of providing the required metallic zinc primer can be cost effective, depending upon circumstances. It is for this reason that in recent years both options have been given in protective coating specifications, leaving the final decision whether to hot dip galvanize or paint, up to market forces.

Unfortunately galvanizing has not fared well in these instances as consideration has to be given to the logistics of galvanizing rather than painting.

Many fabricators have a painting facility in their shops such that the fabricated steel moves through the wheelabrator and into the paint shop where it receives the primer, intermediate and sometimes the finishing coat before it is transported to site. If the steel is to be hot dip galvanized the fabricator has to fabricate, transport the steel to the galvanizer and return it before applying the subsequent paint coatings. In order to make hot dip galvanizing cost effective in this instance the galvanizer needs a painting facility in order to apply the top coats without incurring further transport costs. The concept of applying paint at the galvanizers premises has already been successfully implemented at a number of galvanizers throughout the country.<sup>#7</sup>



Clearly hot dip galvanized coatings and paint coatings complement each other in the protective coatings industry. However, there is still a perception in the market place that the galvanizers and paint manufacturers are in competition with each other.<sup>#8</sup>

### THE TECHNICAL MARKETING DIRECTOR COMMENTS TO THE ARTICLE ON ZINC PRIMERS

- #1 Due to the nature of paint having zinc dust in the coating matrix, on application the zinc will tend to immediately start sacrificing itself, leading to a relatively shortened period of sacrificial protection, and consequently corrosion protection.
- #2 Although zinc is amphoteric, i.e. will corrode at pH less than 6 and above 12.5, if sufficiently over coated with a comprehensive organic coating system, it will provide better protection than the same paint coating system applied over plain carbon steel.
- #3 All paint coatings in time become porous and this allows moisture to penetrate the coating.
- #4 In comparison to a coating thickness of about 20µm, produced by class Z275, continuous hot dip galvanizing of sheeting (ISO 3575), general hot dip galvanizing (ISO 1461) produces a thicker coating. 45µm – mean coating thickness, for steel less than 1.5mm thick to 85µm, mean coating thickness, for steel greater than 6mm. The thicker the available coating, the longer the period of sacrificial protection at damaged areas such as the scribe points detailed in the article, before the onset of localised corrosion.
- #5 Recent price comparisons indicate that hot dip galvanizing on its own is competitive when compared to an abrasive blast and a paint coating of about 75µm DFT of inorganic zinc rich paint, in steels from ultra light (70 to 120m<sup>2</sup>/ton) to heavy steel (25m<sup>2</sup>/ton). This comparison excludes the cost of independent substrate and coating inspection for the painted steelwork and additional transportation of the hot dip galvanized steel.
- #6 A hot dip galvanized coating comprises a series of Fe/Zn alloy layers making up between 50 and 85% of the coating. In most instances the Fe/Zn alloys will provide at least 30% greater corrosion control than a pure zinc coating. (Frank Porter).
- #7 In our opinion, the logistics of additional transport concerns not only the galvanizers but many steel fabricators, faced with stringent environmental regulations for applying paint, lack of skilled painting staff and general downsizing of expertise, forces many fabricators to outsource the painting stage. Furthermore, there are many hot dip galvanizers who have gained the necessary expertise to prepare and apply at least the primer coat, if not the entire coating system. Additionally, where this expertise is not available, some galvanizers can provide industrial painters with floor space, in which preparation and subsequent painting may take place.
- #8 While there is merit in using a duplex coating where it is required, such as in the instances referred to in the article at the start of this feature, there will in most instances be co-operation between the paint and hot dip galvanizing industries. However, when a single coating is specified that must be appropriate and cost effective, there will always be competition between the players of both industries.



The above photos show varying angles on the hot dip galvanized steel used architecturally in the National Library, Pretoria, South Africa (see article on page 52).

## PAINTING HOT DIP GALVANIZING OR DUPLEX COATING SYSTEMS

### EFFECTIVE CORROSION CONTROL (2013)

S3

In 2013 nearly one and a half million tons of hot dip galvanized steel products were produced for the local South African market either for domestic use or export in the form of sheet and wire, or pipe and fabricated steel structures that were dipped in general hot dip galvanizing plants. As the sheet and wire are relatively thin coatings of varying degrees of thickness our discussion will revolve around the approximately 500 000 tons that came out of the general hot dip galvanizing industry.

All these products show a remarkable corrosion free lifetime inland as zinc corrodes at a rate of about 1 to 2 microns annually (ISO 9223 / 14713) and most often exceeds the useful life of the structure for which they were designed. However it is important to know that the hot dip galvanized coating will fail over a period of time in certain aggressive environments and for this reason a suitable duplex system should be added. This is particularly relevant when thin continuous hot dip galvanized coatings (Z275 or less in accordance with ISO 3575 or ISO 4998) are used.

The average coating on structural steel from a general plant is in the region of 100 microns and will vary depending on steel profile thickness from a local coating thickness of about 55 to 250 microns on heavier sections. As silicon is added as a deoxidant for molten steel which when solidified is used in the manufacture of structural steel, generally the heavier profiles all tend to be reactive to molten zinc. This is especially applicable when longer immersion times are necessary due to excessive component size or inadequately sized and positioned fill and exit holes in hollow sections. It is very rare to find a minimum mean coating thickness of 85µm on thick structural profiles required by ISO 1461.

As we know hot dip galvanizing failures inland are nonexistent and the life of the coating will easily exceed 50 years. These lifetimes are common even in the average household where gates, railings, buckets, bins, light poles and garden accessories are hot dip galvanized. Failures of the coating only occur for a reason that can easily be determined by analysing the environment and are normally restricted to poor galvanizing practice containing large disguised (badly repaired excess coating damage areas), severe pollution, certain acidic waters and structures that are located in the tidal zone or too close to the sea. In these environments the coating must be reinforced with a suitable duplex coating system or in extreme cases be substituted with an alternative such as a high grade or Duplex stainless steel.

As inland coating failures do not exist without a reason galvanizers, much like their competitors the paint manufacturing companies should not hesitate to provide guarantees to their customers. This is of specific importance as these customers are substantial clients of the industry such as Eskom, Transnet and local municipalities, etc.

*Photo 1: Newly hot dip galvanized hand railing and light pole in an excellent condition (3 years) while in the background is the duplex coated mast (see successful duplex coatings option 2) coating system that is also in excellent condition after 12 years of exposure.*

*Photo 2: In the permanent splash zone the thin water based vinyl acrylic paint (80µm DFT) has failed and the heavy galvanized coating (250µm) has stood up well over the 21 years except on the base plate due to permanent wetting from the sea water.*



1



2





3



4

*Photo 3: The duplex coated mast showing the aggressive sea spray conditions in the background.*

*Photo 4: A hot dip galvanized watering can used in the Constantia area in Cape Town, South Africa purchased in 1963 (50 years old) indicating a coating thickness reading of 85µm. For the steel thickness of 2.0mm this is still far in excess of what's required in terms of the Standard!*

A warranty provides the specifier with the confidence he needs to promote the product as generally he or his firm are at risk for any failures.

It could be considered to be negligent not to specify a coating such as hot dip galvanizing or a suitably blasted and painted coating system on steel structures positioned in an aggressive exterior atmospheric environment. Wire brush preparation of the steel surface is not recommended for exterior applications due to the fact that mill scale is not comprehensively removed. Should the steelwork be left outside, the mill scale will tend to gradually flake off underside of the subsequent coating, leading to premature coating failure. In an aggressive marine environment a hot dip galvanized surface needs to be reinforced with a series of suitable paint coatings. There are varying degrees of marine conditions to consider.

#### **A. Extremely aggressive marine**

This most aggressive marine condition is in the splash zone up until about 20 metres from the sea. Here the steel installation may be permanently damp, receive little sunlight and be subjected to a continuous salt spray.

#### **B. Very aggressive marine**

Twenty to two hundred metres from the sea and be subjected to a continuous salt spray and sea mist.

#### **C. Aggressive marine**

200 metres to one (to 3 #) kilometres from the sea.

#### **D. Mild marine/suburban**

One kilometre (or 3#) to twenty kilometres from the sea.

#### **E. Rural inland**

Warm and dry inland.

A and B requires a duplex paint system with a minimum appropriate paint coating dry film thickness (DFT) of 200 to 250µm.

C requires a duplex paint system with a minimum paint coating DFT of 150µm.

D requires no overcoating.

E has an indefinite lifetime.

# – Depending on the combined effect of wave action, prevailing off shore winds, velocity of wind and flat topography this could be up to 3km.

#### **Successful duplex coatings for environment A and B; choice of 1, 2 or 3**

1. Epoxy primer, epoxy MIO intermediate coat, polyurethane topcoat to a total DFT of 200 to 250µm.
2. Water based styrene-acrylic copolymer plus two coats of plasticized styrene acrylic top coats to a total DFT of 350µm.
3. Epoxy tars on jetties where there is no sunlight to a total DFT of 350µm.

#### **Successful duplex coatings for environment C**

1. Epoxy primer and polyurethane topcoats to a total DFT of 100 to 150µm.

#### **Failures in environments A and B**

Vinyl acrylics, enamels and water based systems where the total DFT does not exceed 80µm.

While it can be seen from the accompanying photos that there are areas of rusting on structural steel in the splash zone, the hot dip galvanized coating has stood up remarkably well considering that the paint system failed within a very short period of time. Failures have been restricted to the water based systems where the total DFT of the paint coating did not exceed 80µm. I-Beam masts were installed twenty-one years ago and the boxed section masts were installed twelve years ago.

As unprotected mild steel corrodes at a rate of in excess of about 300µm per year in aggressive atmospheres, it is for this reason essential to apply an appropriate duplex coating system. These duplex coating systems have provided remarkable corrosion free lifetimes in aggressive marine installations.



## PAINTING HOT DIP GALVANIZED STEEL (2011)

S3

Painting hot dip galvanized steel is littered with failures over the years that have been created by a lack of preparation prior to applying the relevant paint system and failures due to very thin coats of paint applied in highly aggressive environments.

Having understood the need for carefully preparing the galvanized coating which must not be passivated prior to painting, either by sweep blasting at the right pressure and with the correct media, or by chemical cleaning which requires scrubbing the entire structure with a suitable chemical cleaning agent and then washing off and drying before paint application, we must now look to the next step.

It is then necessary to select the correct paint coatings and dry film thickness (DFT) after studying the positioning of the structure the accessibility and the aggressiveness of the environment. The lifetime and maintenance period intervals are also important considerations as thin coats of paint may require annual maintenance if they are very close to the sea. This may not always be possible, so duplex coatings systems or heavy-duty paint coatings should be applied at the onset.

The use of the correct applicator is also an important consideration. In this regard, a short-term guarantee provided jointly by the applicator and paint supplier to ensure against paint failure, and premature corrosion may be considered necessary. Paint adhesion failures normally occur in the first year after application. In South Africa most reliable suppliers will stand by their products including the hot dip galvanizing industry that may also have their own paint facilities.

### What is the cost of applying an epoxy primer and polyurethane topcoat on galvanized structural steelwork of varying thicknesses?

The table below details the cost of the coatings and is to be used as a guideline for specifiers and their clients. These costs can vary considerably from applicator to applicator.

### Why spend the extra money for a duplex system?

Inland in South Africa atmospheric failures of hot dip galvanizing are very rare and a batch hot dip galvanized coating can easily last 50/100 years. In the coastal regions, this is very different especially where there are continuous on shore winds and the items are subjected to permanent salt spray deposits. This is accentuated if the structure does not receive full sunlight and drying. This



Steel Profile Thickness	Per Ton		Per Ton		Per Ton		Total coating thickness
	m <sup>2</sup> per ton of Steel Cost	Hot Dip Galvanizing	Average H.D.G Coating Thickness	2 Coat Paint System Cost	2 Coat Paint Coating DFT	Total cost Duplex System	
3mm to 4mm	64	5500 (9000)	100	5120 (9600)	120	10620 (18600)	220
5mm to 6mm	42	5000 (8000)	125	3360 (6300)	120	8360 (14300)	245
7mm to 8mm	32	4500 (7000)	150	2560 (4800)	120	7060 (11800)	270
9mm to 10mm	26	4250 (6500)	175	2080 (3900)	120	6330 (10400)	295
11mm to 12mm	21	4000 (6000)	200	1680 (3150)	120	5680 (9150)	320
13mm to 20mm	13	3750 (5500)	225	1040 (1950)	120	4740 (7450)	345

#### Notes:

- Costs will vary for different applicators but are approximate on 100-ton lots of structural steel. (Figures in brackets are an approximation of the relevant prices in 2020).
- The paint system quoted is for an epoxy primer and polyurethane top coat for atmospheric conditions close to the sea and includes preparation before painting.
- This is a duplex system for a coastal environment but will require an extra paint coat (dft 100) depending on the proximity to the sea.
- The heavy galvanized coating thickness is achieved by hot dipping silicon killed steels and longer immersion times in the zinc. The ISO 1461 standard for general galvanizing is extremely conservative and only calls for a mean of 85 microns for steel profiles thicker than 6mm. This thinner coating is only achieved on aluminium killed steels which generally never exceed 4mm in thickness and the general galvanizer spends most of his time putting on double the zinc coating that is required due to reactive silicon killed steels. This heavy zinc coating is not a well advertised fact in the galvanizing industry.
- m<sup>2</sup> are based on the last profile thickness mentioned.

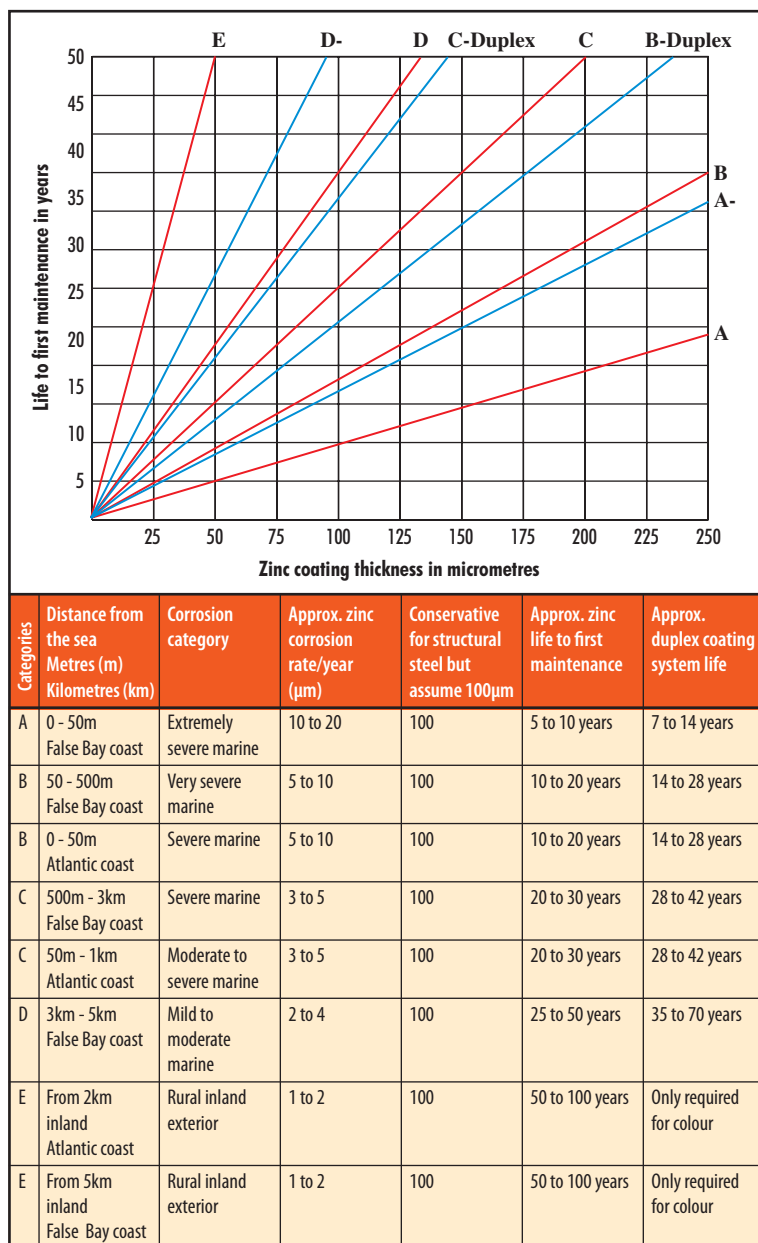


Table 1.

phenomena is called the “time of wetting” and adds considerably to the corrosion burden, as does severe onshore wind coupled with heavy wave action and a lack of rainfall to wash down the salt deposits. This means that in the Cape Peninsula the False Bay coastline is twice as corrosive as the Atlantic Ocean coastline due to the South Easter being the prevailing wind for about eight months of the year whilst on the Atlantic side the North Wester is accompanied by rainfall that has a wash down effect thereby reducing the salt deposits. Salt spray can be deposited a long way from Muizenberg with a strong south east wind.

In these instances next to the sea, appropriate duplex systems are essential and are a prerequisite to achieving a reasonable corrosion free life.

Thin paint coatings require annual maintenance and heavy-duty three coat paint systems with a DFT of about 250 $\mu\text{m}$  are essential to achieve a reasonable lifetime to first maintenance. The graph and Table 1 above indicates the lifetime of the hot dip galvanized coating on its own, which will be more than doubled

with a suitable paint coating system because if the zinc coating is protected then so is the ultimate life of the structure.

It is the duty of the specifier to provide his client with a coating system that allows his client the security and the knowledge that his permanent installation will not fail due to the ravages of corrosion which costs the country many billions annually. Always remember that hot dip galvanizing is the most reliable and effective primer coat as the coating forms a metallurgical bond with the steel in the form of a series of zinc/iron alloy layers. This coating is superior in every sense to any paint primer.

#### Notes: Refer to Table 1 above

- 1) All zinc corrosion rates are approximate and are a guideline only.
- 2) In all cases, the zinc coating thickness is relative to the lifetime of the coating.
- 3) Continuously hot dip galvanized sheet and purlins should not be used externally in aggressive coastal areas.
- 4) The above are the writers views only.



## DUPLEX COATING GOOD AFTER 14 YEARS (2014)

S3

The original task of the project team was to widen the bridge over Liesbeeck Parkway in Cape Town, South Africa and the adjacent Liesbeeck River, sufficient to include an additional traffic lane in both directions of the inbound carriage way of the N2.

### THE APPLICATION AND KEY FEATURES OF THE FINAL DESIGN

Key features of the final design were the following (see photos):

- Structural steel corbel and strut attached to existing reinforced concrete piers to accommodate additional live loading and also ensure acceptable road clearance and aesthetic characteristics. (Structural steel provided the optimum solution for the transfer of the high vertical and transverse forces to the existing substructure within the existing geometric constraints).
- Transverse post tensioning of the pier trestle beam by means of external dywidag bars.
- Positive anchoring of widened pier elements to the existing by using GEWI post tensioned anchors (rock anchors used in the mining industry) to ensure adequate shear friction transfer.
- Jacking by means of sacrificial flat-jacks fitted into pre-made pot bearing units. (Jacking pressure was achieved by a specially formulated and tested cementitious grout which hardened under vertical load after the required force was achieved).

### Durability

In view of the possibility of narrow concrete cross-sections due to the existing dimensional constraints the durability received particular attention and the following main measures were undertaken to ensure adequate durability:

- Using a blended OPC/FA mix. Not only did this provide enhanced concrete durability properties but also provided advantages related to improved concrete workability and surface finish texture.
- Hot dip galvanizing of all reinforcement and structural steel.

The following are the main considerations that resulted in the decision to specify galvanized steel:

- The location of the bridge in a moderate to severe exposure area.
- Extensive experience of the client with maintenance problems and costs of concrete structures with inadequate durability characteristics in similar areas.
- The method of construction with large contact areas between old and new concrete with critical reinforcement crossing the interface zone.
- The compatibility considerations of the old and new concrete properties and the effect of creep and shrinkage which could result in crack formation in the new concrete elements.

The design considerations and specification requirements were mainly based on the guidelines contained in the state of the art report, Coating Protection for Reinforcement, published in 1995 by Thomas Telford Services Limited. (This is the formal publication of the 1992 Comité Euro-International Du Beton Bulletin 112).

*Photo 1: The Liesbeeck Parkway intersection looking towards Table Mountain showing the duplex coated steel corbels.*

*Photos 2 - 3: The duplex coated steel corbel which while slightly discolored from rain water remains successfully intact.*







4



5

The following are some of the noteworthy items in this publication regarding the use of galvanized reinforcement, which was taken into consideration in the design process, as reported from case studies for mainly bridge decks:

- Proper galvanizing techniques have no significant effect on the mechanical properties of the steel reinforcement.
- Zinc coating provides local cathodic protection to the steel as long as the coating has not been consumed.
- Corrosion of galvanized steel is less intense and less extensive for a substantial period of time than that of black steel.
- Galvanized steel tolerates higher chloride concentrations than black steel before the corrosion starts.
- Greater compatibility is achieved with lower alkali cements (in this instance the use of FA as an extender provided the added benefit of reducing the active-alkali content in the mix).
- Accidentally reduced cover is less dangerous than with black steel.
- The development of the bond between steel and concrete is dependent on both the age and the environment and usually takes longer for galvanized steel. (This was taken into consideration with the form-work stripping requirements). The final value, which may in some instances be higher than with ungalvanized bars, is dependent on the chromate content of the cement.
- The use of galvanized reinforcement should not be considered as an alternative to the provisions of adequate cover and/or dense impermeable concrete and must be seen as a complimentary measure.

#### Aesthetic considerations

This aspect received particular attention during the design for the widening of the substructure and the client, who provided extensive input during the design process, stipulated stringent guidelines.

In view of the fact that the final widening consisted of an unusual structural steel strut it was considered especially important not to alter the main character of the existing reinforced concrete structure and that the widening should not have a “stuck-on” temporary appearance.

This objective was achieved by the following and it is believed that the widening has actually improved the bridge appearance:

- Design of structural steel element geometry to be compatible

*Photo 4: Positive anchoring of widened pier elements to the existing by using GEWI post tensioned anchors.*

*Photo 5: Preparation of the existing reinforced concrete pier to accommodate the hot dip galvanized structural steel corbel and strut.*

with the existing concrete profile with minimal additional protrusions.

- The use of cover-plates to hide unavoidable structural steel like elements.
- The painting of the steel cover-plates with the same cementitious based protective coating, which was specified for the substructure concrete. (An extensive testing procedure was required to achieve suitable bond characteristics).

#### THE ENVIRONMENTAL CONDITIONS

The conditions at Liesbeeck Gardens Interchange fall into a mild to moderately corrosive environment where the corrosion rate of zinc (on its own) is likely to be at worst about 2 to 3µm per year.

#### OUR FINDINGS

While a close up examination of the duplex coated corbel and strut was not possible due to its height, the duplex coated elements (apart from some discolouration from water runoff) are in a good condition. (See photos).



*Another view on the hot dip galvanized steel used architecturally in the National Library, Pretoria, South Africa (see article on page 52).*

## METALLIC ZINC TECHNICALITIES

# THE DIFFERENCE BETWEEN HYDROGEN AND STRAIN-AGE EMBRITTLEMENT (2014)

S4

Although it happens infrequently, embrittlement of steel during the hot dip galvanizing process is possible.

The most known type of embrittlement is hydrogen embrittlement, but this type of embrittlement is very rare during the galvanizing process. If a steel member becomes embrittled during galvanizing, odds are it is due to strain-age embrittlement, not hydrogen embrittlement. To differentiate hydrogen embrittlement from strain-age embrittlement, it is best to start at the definition of the word embrittlement.

The definition as the term is defined in *ASTM A143/A143M Standard Practice for Safe-guarding against Embrittlement of Hot Dip Galvanized Structural Steel Products and Procedure for Detecting Embrittlement*; embrittlement is the loss or partial loss of ductility in steel that fails by fracture without appreciable deformation. Another way to think about embrittlement is steel cracking without any bending or flexing to indicate the steel is yielding.

### STRAIN-AGE EMBRITTLEMENT

The most common type of embrittlement encountered in the hot dip galvanizing process is strain-age embrittlement. Strain-ageing is a process where steel becomes very brittle in areas of high stress when exposed to elevated temperatures. At room temperature, strain-ageing happens very slowly, but at elevated temperatures, like those used in the galvanizing process, strain-ageing can happen very quickly. When the steel has incurred enough stress due to strain-ageing, it can become embrittled. For strain-ageing to occur, two components are necessary.

The first component is stresses must be induced into the steel prior to the galvanizing process. This normally occurs through cold working the steel. Cold working can include bending, rolling, punching, or shearing the steel. If the stresses from these cold working practices are not relieved prior to galvanizing, they become points of high residual stress during the galvanizing process and can lead to strain-age embrittlement. Strain-ageing can also be caused by impurities in the steel, such as those found in lower quality steels used for reinforcing bar. If a part cracks due to strain-age embrittlement, the cracking occurs immediately after galvanizing, but is also often seen at the job site, as in the case of reinforcing bar. Often times simple handling is enough stress to cause a strain-age embrittled member to crack.

Cracking of the steel shortly after galvanizing is a critical distinction between strain-age embrittlement and hydrogen embrittlement. There are several ways to reduce the occurrence of strain-age

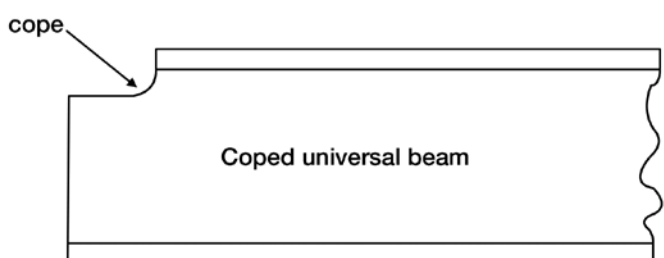
embrittlement, but all methods focus on one aspect – reducing the stresses induced into the steel prior to galvanizing. Instead of cold working, which induces stresses into steel, the steel can be hot worked at temperatures between 590°C and 700°C. After cold work the steel, relieving the stresses induced from cold working can be accomplished by heating the steel to 650°C to 700°C for heavy cold working and up to no more than 650°C for less severe cold working. When bending steel, it is best to allow for a bend diameter at least three times the section thickness. When punching is necessary on thicker steels (19mm or greater in thickness), the holes should be reamed at least 1.5mm around the edge of the hole. When flame cutting, such as on structural beams, the minimum radius of the copes or snipes should be 25mm or greater. Grinding the areas around the cope is recommended to remove small micro-cracks in the steel from the flame cutting process.

### WHAT IS A COPE?

*Diagram 1* shows a cope detail on a universal beam. Copes are oxy cut, usually in two operations. The first cut removed the top flange and a section of the web. The second operation cuts the cope radius and removes the remaining section of the web.

### HYDROGEN EMBRITTLEMENT

Hydrogen embrittlement occurs when steel cracks due to hydrogen trapped between the grains of the steel. Although steel commonly absorbs hydrogen during the hot dip galvanizing process, it is usually expelled due to the temperature of the zinc in the galvanizing kettle. In some cases, however, the grain size of the steel is too small to allow release of atomic hydrogen. This can later cause cracking due to increased stress at the location of the hydrogen between the grains. Grains of steels with a tensile strength below 1 000MPa (150 000 psi) are usually big enough to allow escape of hydrogen, but for steels having a tensile strength



*A cope detail on a universal beam.*

## S4

greater than 1 000MPa, there is a potential for hydrogen to remain trapped between grains leading to hydrogen embrittlement. Hydrogen embrittlement is not observed until the part is under load, unlike strain-age embrittlement which is observed shortly after galvanizing. In other words, whereas strain-age embrittlement can be observed shortly after galvanizing, hydrogen embrittlement is not seen until the steel has been under load for some extended period of time. Hydrogen embrittlement can be avoided in several ways.

The most obvious way is to ensure the designer has chosen steel with a tensile strength less than 1 000MPa. As stated earlier, these types of steels have grains large enough to allow escape of any trapped hydrogen. When it is necessary to galvanize high strength steel, a modified galvanizing process can be used to minimize the chances of hydrogen embrittlement. Rather than pickling the steel for the normal length of time, this modified process includes mechanically cleaning the steel, such as by blast cleaning, and then flash pickling for less than 30 seconds. Flash pickling is necessary to remove any residues from the blasting operation. This reduces the amount of hydrogen the steel is exposed to and thus reduces the chances of hydrogen becoming trapped in the small grains of high strength steel.

### RESPONSIBILITY FOR AVOIDING EMBRITTLEMENT

ASTM A143/A143M spells out who is responsible for avoiding embrittlement. The responsibility lies on the designer, fabricator, and the galvanizer, but each party has different responsibilities. Choosing steel appropriate for the practices normally encountered in the galvanizing process and designing the product to avoid embrittlement are the responsibilities of the designer. The fabricator is responsible for using suitable fabrication procedures to avoid embrittlement, such as following minimum bend recommendations and reaming holes on thicker steel (as discussed above). And finally, the galvanizer is responsible for employing proper pickling and galvanizing procedures during the galvanizing operation.

Communication between the designer, fabricator, and galvanizer is the key.

Communication throughout the design, fabrication, and galvanizing processes ensures best practices are used throughout and thus minimises the possibility of strain-age or hydrogen embrittlement.



*The above photos show varying views on the MTN Headquarters, Johannesburg, South Africa, where hot dip galvanized steel was used architecturally (see article on page 51).*



# PLACING HYDROGEN EMBRITTLEMENT OF FASTENERS IN PERSPECTIVE (2012)

S4

## WHAT IS PROBLEMATIC IN IDENTIFYING THE PRESENCE OF HYDROGEN EMBRITTLEMENT (HE)?

Failures from possible hydrogen embrittlement in steel are notoriously difficult to prove post failure for the following reasons<sup>(1)</sup>:

- 1a. Measuring the total *hydrogen concentration* in the steel to prove the presence of HE is often meaningless as hydrogen trapping occurs at carbides, grain boundaries etc, and it is really the so-called *diffusible hydrogen* that needs to be measured, i.e. that hydrogen that can move to a crack tip and enhance its propagation;
- 1b. Even if the diffusible hydrogen content is measured, the “danger level” of such hydrogen is not a fixed value as its effect varies with the strength of the steel. For a high strength steel, levels as low as 1 or 2 ppm may already be effective in initiating HE while for a low strength steel many tens of ppms may still be acceptable;
- 1c. Once hydrogen atoms have “done their damage” they can even move out of the steel, yet the damage remains there (as “flaking” or “fish eyes”) and may later culminate as a long delayed failure;
- 1d. A SEM fractograph of the original fracture face is also not necessarily conclusive as a seemingly ductile dimple fracture is often present after HE. The observations from fractographs of a HE steel that often (but not always) shows intergranular fracture are also not necessarily characteristic of HE as a number of other metallurgical mechanisms also lead to intergranular fractures.

## THE CURRENTLY ACCEPTED MODEL FOR UNDERSTANDING HYDROGEN EMBRITTLEMENT OF STEELS

The current most accepted mechanism of HE failures is the so-called HELP model<sup>(1)</sup>, i.e. Hydrogen Enhanced Local Plasticity, in which the hydrogen atoms diffuse towards the high stress concentration area at the tip of a crack where they actually enhance the plasticity during crack advancement but thereby quickly exhaust the ductility of the steel in that area, forcing the crack to move a step forwards to “fresh” material where the process repeats itself. This brings about that the stop-start of the crack tip leaves so-called “tear ridges” on the cleavage planes on a slow fractured surface in contrast to clear cleavage planes for the same steel but fractured in

a fast impact where the crack tip “runs away” from the diffusing hydrogen atoms.

## THE DELAY OF FAILURE BY HYDROGEN EMBRITTLEMENT

Delayed failures in HE steel components often occur sometime after processing the component although the delay times are usually measured in hours or days and seldom are longer as diffusion of hydrogen (the smallest of all atoms) in ferritic steel is relatively fast and movement of the hydrogen atoms to the crack tip is relatively fast, even at room temperature.

## SOURCE OF HYDROGEN FOR HYDROGEN EMBRITTLEMENT

If HE is suspected one needs to consider from where the hydrogen may have come? If there is no credible source of hydrogen then HE is not likely to be present. Hydrogen may arise from moisture on scrap steel or master alloys fed during melting of the steel or during electroplating or pickling of a final product. It is for this very reason that vacuum degassing is generally employed in the melting and casting of High Strength Low Alloy (HSLA) steels and electroplating and pickling of the same steels is avoided for critical components.

## LOSS OF HYDROGEN DURING HEAT TREATMENT

Ferritic steel actually has a very low solubility for hydrogen and any hydrogen contained within the steel will tend to diffuse out of the component if allowed to. This forms the basis for the so-called *diffusion anneal* of steel components that are suspected to be embrittled by hydrogen.

The design of such a diffusion anneal is a standard calculation<sup>1</sup> which takes into account the distance  $L$  from the centre to the surface of the component where the hydrogen will escape, the time  $t$  at temperature  $T$  and the diffusion rate  $D$  for hydrogen at the temperature of the anneal. The latter parameter needs to take into account that “trapping” of hydrogen atoms takes place at carbides, grain boundaries, dislocations etc. that results in a “lower than usual” diffusion rate and use is, therefore, made of experimentally determined “effective” diffusion rates.

*Table 1 (below): Calculated retention factors of any initial hydrogen in the steel during a typical solution anneal, quenching and tempering cycle.*

Bolt size	Solution treatment: 880°C for 1 hour		Tempering treatment: 425°C for 45 min		Overall Hydrogen retention factor: % from the original
	$D\gamma/H$ cm <sup>2</sup> /s	Retention factor %	$D\alpha/H$ cm <sup>2</sup> /s	Retention factor %	
M30	1.3x10 <sup>-5</sup>	90	1x10 <sup>-4</sup>	35	32
M24	1.3x10 <sup>-5</sup>	73	1x10 <sup>-4</sup>	28	20
M20	1.3x10 <sup>-5</sup>	47	1x10 <sup>-4</sup>	13	6

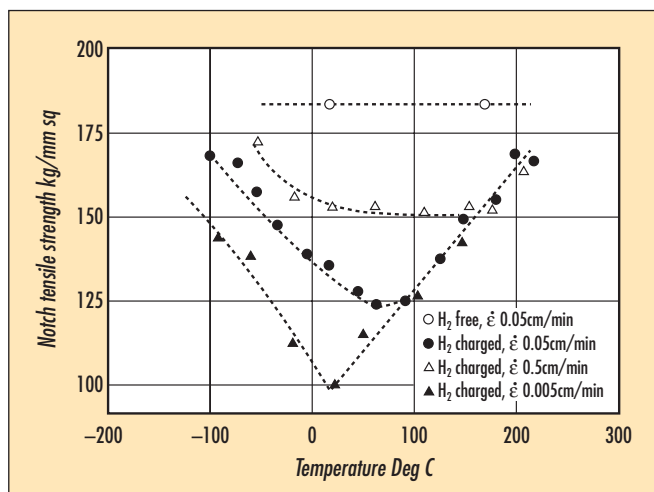


Figure 1.

Fasteners seldom suffer HE from an initial hydrogen introduced in the melting and casting process as the typical solution anneal, quenching and tempering for high strength bolts effectively act as a "diffusion anneal". Calculations for M30, M24 and M20 bolts during the solution treatment (the steel is austenitic then) and the subsequent tempering process (the steel is ferritic then) have shown the following (see Table 1) typical hydrogen retention percentages.

The overall hydrogen retention factor means, for M20 bolts as an example, that if the hydrogen content in the steel was say 2 ppm before the heat treatment, that only  $0.06 \times 2$  ppm will remain after the heat treatment, i.e. only 0.12 ppm will remain. For M24 and M30 bolts the retention factors are naturally somewhat higher from the longer diffusion paths from the centre of the bolt to the surface.

It is for the above reason that short term pickling of fasteners is even allowed in some standards provided that the pickling time is less than the galvanizing time at temperature where some hydrogen pickup from the pickling is removed again during galvanizing.

Where high strength fasteners, however, appear to show effects of HE, the source of hydrogen generally is not from the original melting and casting process but most likely arises from the environment in which the fastener operates or from surface treatment processes of the fasteners such as pickling and/or electroplating. In such a case, HE-induced fracture will, therefore, not be initiated from the centre or core of the fastener but rather at

Figure 1: The notched tensile strength of steel AISI 4340 as a function of test temperature for three strain rates of testing<sup>(8)</sup>.

Figure 2: Macro-photographs of the failure by HE initiated at a "fish eye" of a 360 mm shaft manufactured from a low alloy Cr-Ni-Mo-V quenched and tempered steel<sup>(9)</sup>.

Figures 3 - 4: SEM fractographs of both cleavage and dimple fracture areas from the same freshly impact broken sample of a quenched and tempered low alloy Cr-Ni-Mo-V steel that was known to contain Hydrogen in excessive quantities. The white arrows show a few of the large number of secondary microcracks<sup>(9)</sup>.

Figures 5 - 6: Slow SSR tested fractographs of the same 360mm shaft as in Figures 3 - 4 above. Note the "patches" of cleavage fracture areas amidst dimple fractured areas in the center of both figures with both of them showing clear "tear ridges" <sup>(10)</sup> seen as the fine lines on the cleavage planes<sup>(8)</sup>.

Figure 7: ASTM G129: Effect of SSR testing on the Reduction in Area for a HE specimen<sup>(2)</sup>.

its outer surface, most likely within the stress concentrated area of the threads.

## TESTING FOR HYDROGEN EMBRITTLEMENT

A number of standards exist to test for HE in steel<sup>(2 to 7)</sup> with slow bending or slow strain rate testing and stepped loading tests relatively common. Both of these classes of tests rely on the principle that hydrogen atoms, given enough time, will preferentially move to the high stress concentration at the tip of an advancing crack and thereby affect the ductility of the steel in that area, allowing the crack to advance one more step. These tests, however, also have some limitations:

### Step loading

In the step loaded test a critical stress / crack combination will be reached at some point during the regular increase in the stress level (typically on a daily basis), leading to HE-induced fast fracture. The weakness with this type of test is that it cannot distinguish between a pre-existing crack that will also become critical at a certain critical stress in the absence of hydrogen according to classical Fracture Mechanics and a crack induced by HE. This type of test is, therefore, well suited to indicate the presence of HE in those cases where no pre-existing cracks can be guaranteed but will fall short if any pre-existing cracks were present.

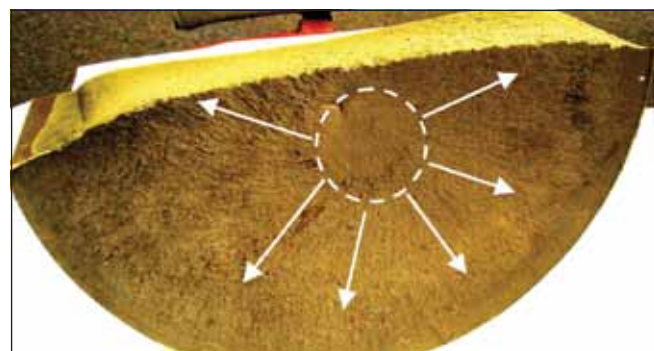


Figure 2.

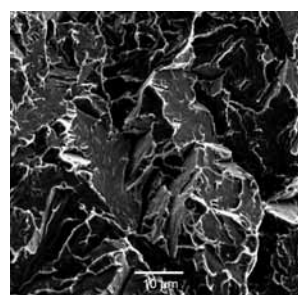


Figure 3.

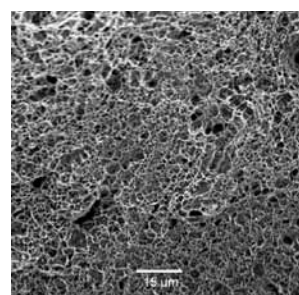


Figure 4.

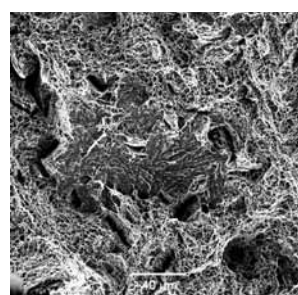


Figure 5.

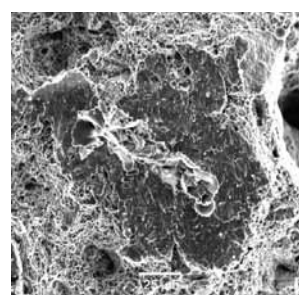


Figure 6.

### Slow strain rate tests

The SSR test for HE is based on the widely accepted HELP mechanism, i.e. strain a tensile test specimen in which HE is suspected, at a very slow strain rate (typically  $10^{-5}$  to  $10^{-6}$  s $^{-1}$ ) until fracture. The very slow crack propagation rate allows the hydrogen atoms to diffuse to the crack tip where they enhance the local plasticity but also quickly exhaust the local ductility, thereby extending the crack tip to a new area to which the hydrogen atoms will diffuse once more, thereby repeating the process. This brings about that the stop-start of the crack tip leaves so-called "tear ridges" on the cleavage planes on a slow fractured surface in contrast to clear cleavage planes for the same steel but fractured in a fast impact.

Temperature also plays an important role in the hydrogen embrittlement of steels with embrittlement most severe near room temperature and less severe at lower and higher temperatures. This temperature effect is shown in the *Figure 1* for an AISI 4340 steel (Fe – 0.4%C – 0.8%Cr – 1.8%Ni – 0.25%Mo). It is for this reason that the SSR test is also conveniently done at room temperature.

Note the significantly lowered notch tensile strength for the quenched and tempered low alloy steel AISI 4340 if tested at a cross head speed of only 0.005cm/min compared to less severely affected notch tensile strengths at higher strain rates, both with hydrogen charged specimens.

### Signatures for a hydrogen embrittlement fracture

A number of indirect signatures exist for identifying fractures from HE present in the steel:

- 2a. The fracture usually starts at a so-called "fish eye" which is mostly deep within or even near to the centre of the component where the hydrogen concentration will be the highest after any heat treatment. Fracture is, therefore, unlikely to start at or near to the surface where little or no hydrogen will be present after heat treatment.
- 2b. HE may show either dimple or cleavage fractographs but very often shows secondary cracks leading from the primary fracture face inwards.
- 2c. The fractographs from a Slow Strain Rate (SSR) test compared to a fast fractured one, show two signatures, i.e. a mixture of dimple and cleavage fractures and "tear ridges" on the cleavage planes.  
Compare the "clean" cleavage planes in *Figures 3 - 4* of a fast fractured specimen with the cleavage planes full of "tear ridges" of a SSR tested one in *Figures 5 - 6*, both from the same 360mm Cr – Ni – Mo – V shaft.
- 2d. Finally, SSR testing will also reveal a low Z (Reduction in Area) if compared to a normal tensile tested sample, as shown in *Figure 7* taken from the Standard for slow strain rate testing for HE susceptibility: ASTM G129<sup>(2)</sup>.

### SUMMARY

From all of the above background, it is evident that care should be taken not to arrive at any firm conclusion on the possible presence of HE based on only one or even two observations "that fit the picture" while ignoring the rest but that a "global" perspective needs to be taken, typically by a decision tree as proposed below for hydrogen present in the steel from its melting and casting:

- 3a. *Is there an identified possible source of hydrogen for contaminating the steel?* If yes, then consider HE;
- 3b. *Was there a "fish eye" present in the fracture face where the original fracture in the "field" was initiated and did the fracture*

*start near to the centre of the component?* (This is particularly so for delayed failures running into months and not necessarily so for typical delay times of only a few hours) If yes. Then suspect HE;

- 3c. *Is there a marked reduction in the SSR's Z-value (Reduction in Area)?* If yes, HE is suspected;
- 3d. *Does the SSR tested fracture face contain a mixture of dimple and cleavage fracture?* If yes, then strongly suspect HE;
- 3e. *Do the cleavage planes of the SSR tested specimen contain evidence of so-called "tear ridges" whereas the fast fractured ones have "clean" cleavage planes?* If yes, HE is proven.

For the case where the source of hydrogen is from the operating environment or from surface processing (pickling and/or electroplating) and not from the melting and casting of the steel, the above decision tree is still applicable with the exception of Step 3b while steps 3d and 3e should be ideally located at or near to the surface of the fastener where the hydrogen may be present.

### References

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8. BA Graville, RG Baker and F Watkinson, *British Welding Journal*: 14 (1967) p 337.
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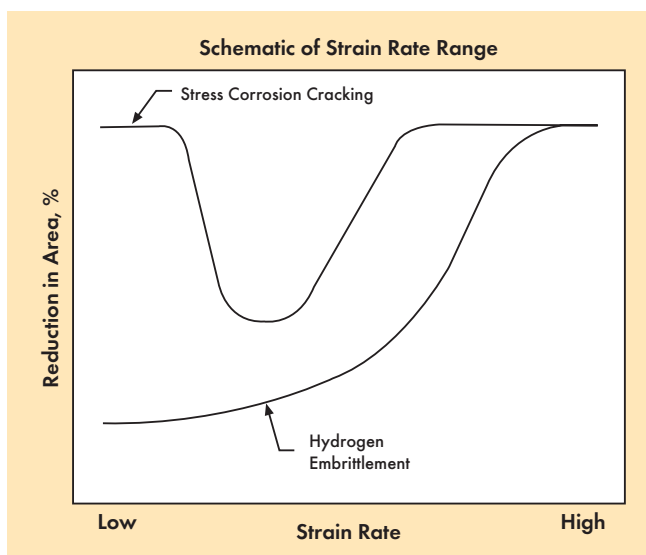


Figure 7.



## ALTERNATIVE APPLICATION OF METALLIC ZINC COATINGS

S5

### MEDUPI POWER STATION CHIMNEYS: THERMAL ZINC METAL SPRAYING OF PLATE GIRDERS (2011)

#### BACKGROUND

The Medupi Power Station has two 213m high chimneys with three flues. The flues are manufactured from both mild and stainless steel. The majority of the mild steel in this project is hot dip galvanized, except for three of the girders.

The three girders with dimensions of 17m x 3.1m are required for the support of the Medupi North and South chimney platforms at 205m. In this instance however the dimensions of the girders ruled out the use of hot dip galvanizing due to the combination of the length and width, making it either too long or too wide to fit in a kettle for a double dip. Another factor which also ruled out hot dip galvanizing was the possibility of distortion.

Although Robor (now Monoweld) Galvanizers are renowned for their ability to handle very complicated and large double dips a joint decision with Grinaker-Lta was reached that the best alternative to hot dip galvanizing would be to thermal zinc metal spray the girders.

Thermal Zinc Metal Spray is the best alternative to hot dip galvanizing due to the fact that the zinc applied during thermal

zinc metal spraying is of the same chemical composition as the zinc used in the hot dip galvanizing process. The only difference is that adhesion to the steel surface is mechanical, whereas during hot dip galvanizing a metallurgical bond is formed.

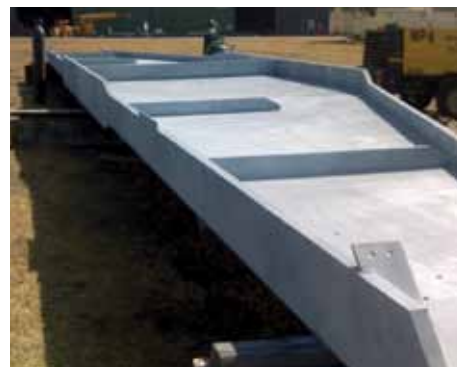
#### LOGISTICS AND OTHER REQUIREMENTS

Robor (Monoweld) Galvanizers drafted a method statement detailing the safety, environmental and quality requirements which was accepted by Grinaker-Lta. Robor (Monoweld) transported the equipment, consumables and personnel to the Grinaker-Lta fabrication site at Vanderbijlpark. The compressed air needed was supplied by a mobile compressor courtesy of Grinaker-Lta fabrication workshops.

The metal spray process required the shot blasting of the girders and was carried out in the facility run by Bulldog Projects situated in close proximity. The size of the products necessitated shot blasting of one side of the girders at a time which resulted in the frequent use of heavy transport vehicles between the blasting and spray areas. This was necessary to avoid flash rusting of the freshly blasted areas. The spray process was carried out under cover but in a well ventilated area.



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*Photo 1: Thermal metal spraying in the workshop.*

*Photo 2: The appearance of the finished zinc metal sprayed coating.*

*Photo 3: Frequent quality and coating thickness testing was required.*

*Photo 4: Typical coating thickness achieved.*

Part no. 101 530 02					
Individual readings	Area 1	Area 2	Area 3	Area 4	Mean coating thickness
1	339	238	137	129	
2	260	279	140	177	
3	273	222	153	201	
4	275	269	131	154	
5	378	230	137	178	
Local mean coating	305	247.6	139.6	167.8	215
Part no. 101 530 02 CCC					
Individual readings	Area 1	Area 2	Area 3	Area 4	Mean coating thickness
1	256	191	298	187	
2	257	193	236	225	
3	236	251	184	257	
4	242	250	180	229	
5	234	270	134	243	
Local mean coating	245	231	206.4	228.2	227.65
Part no. 101 530 01					
Individual readings	Area 1	Area 2	Area 3	Area 4	Mean coating thickness
1	205	318	343	240	
2	252	265	260	290	
3	227	317	231	353	
4	242	339	264	315	
5	265	287	365	266	
Local mean coating	238.2	305.2	292.6	292.8	282.2

Table 1.

Once the one side was completed, the girder would be turned over and transported back to blasting area where the whole process would be repeated.

### IN-PROCESS QUALITY CHECKS

It quickly became evident that frequent quality checks were needed to identify areas which required additional layers of metal spray. The operators from Robor (Monoweld) were issued with calibrated coating thickness gauges which they used for their own inspections. In addition, frequent checks were also carried out by a member of the Robor (Monoweld) management team who also checked on the safety compliance issues.

### FINAL INSPECTION

The final inspection was carried out using the requirements as set out in the ISO 1461 standard. A total of four reference areas, as opposed to the required three, were selected along the length of each girder. Five coating thickness readings were taken in each reference area. The results were used to calculate the local and mean coating thicknesses. The results are shown in *Table 1*.

### IN SUMMARY

The project was successfully completed taking into account the dimensions of the products and the logistical issues. The finished products were accepted by all parties and it was generally accepted that this project, being a first of its kind, was handled professionally by all involved.



**Photos 1 - 2:** The intricate angles by which zinc metal spraying was applied to these triangular prism shaped structures, which were too large to hot dip galvanize.

**Photo 3:** The partly over coated zinc metal sprayed coating using a two coat paint system for these intricately shaped triangular prism structures.

**Photo 4:** The complete roof structure that was zinc metal sprayed and then painted for the roof of the Blue Downs Swimming Pool, Cape Town, South Africa.

## HOT DIP GALVANIZING IN MINING APPLICATIONS

S6

### THE USE OF HOT DIP GALVANIZING IN MINING IN SOUTH AFRICA (2014)

The role of the HDGASA in the direct or indirect promotion and use of hot dip galvanizing in various mining applications, including gold, platinum, iron ore and coal and future motivation of its use in the Petro Chemical Industry, in South Africa.

#### ABSTRACT

This paper introduces deep level mining and its corrosivity in South Africa. It reflects on the history of mining in South Africa over the last 50 years and then introduces a number of case histories including Platinum Concentrator Plants, Collieries and an Iron Ore Beneficiation Plant. The prospect of using hot dip galvanizing in future Petro Chemical Plants is also motivated.

The paper introduces the Hot Dip Galvanizers Association Southern Africa (HDGASA) and the direct or indirect role that the organisation has played in the development and acceptance of hot dip galvanizing and duplex coating systems in the mining industry.

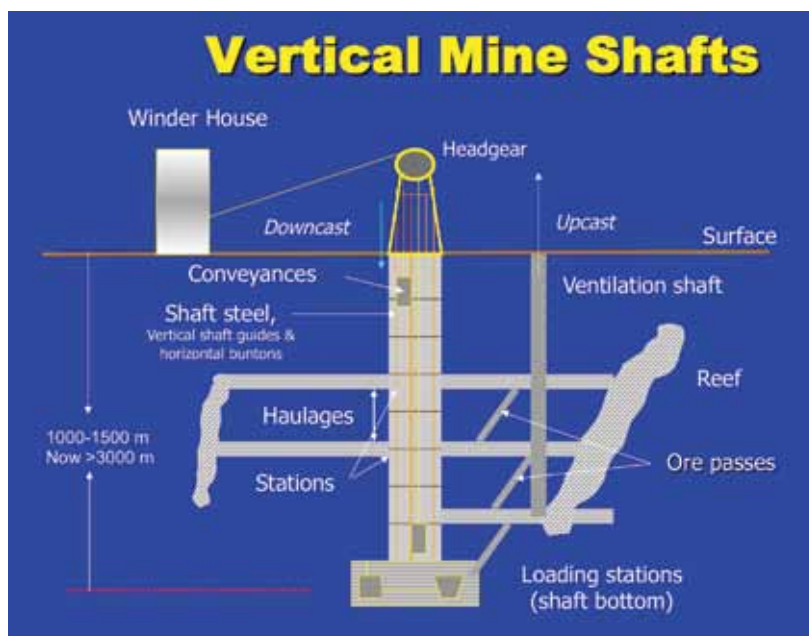
While the Association's drive has included most mining companies, Anglo American, AngloGold Ashanti, Anglo Coal, Amplats and Kumba Iron Ore particularly, have specified and extensively made use of the coatings with extremely successful results.

Deep level mining includes Gold and Platinum, etc. while open cast mining includes Coal, Iron Ore, etc.

The paper concludes with references on the use of hot dip galvanizing from Anglo Platinum, Anglo Coal and Kelloggs Brown and Root (KBR), from Houston, Texas.

#### OVERVIEW

- Introduction.
- Historical information of Mining in SA and hot dip galvanizing and duplex coating systems.
- The Hot Dip Galvanizers Association Southern Africa and its members.
- Some case histories including two Platinum Smelters, several Collieries and an Iron Ore Beneficiation Plant.
- Evidence of hot dip galvanizing's performance in a coastal Petro Chemical Plant and its possible future use.
- References from Amplats (Anglo Platinum Management Services), Anglo Coal and Kelloggs Brown and Root (KBR) on the use and benefits of hot dip galvanizing in Petro Chemical Plants.
- Conclusion.



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**Photo 1:** A cross section through a vertical mine shaft of depths greater than 3 000m.

**Photo 2:** A typical deep level mine headgear.

**Photos 3 – 4:** Typical environmental conditions in a shaft, which become more corrosive the deeper ones descends.

**Photos 5 – 6:** The shaft provides continual access for men, materials, machinery and ore, maintenance free performance of upwards of 25 years and is required to minimise routine downtime allowances. Photos 5 and 6 show hot dip galvanized shaft guides (left) and buntons and connections (right). Note the additional paint coating at crevices and over the fasteners.

S6

## INTRODUCTION

South African gold and platinum mines generally utilise single to multiple stage vertical shafts, extending to depths of between 500m and 4 000m below ground (*photos 1 & 2*). In shallow mining, inclined shafts are more typical extending to lengths of 1 000m and depths of between 200 to 600m below ground. Irrespective of the type of shaft used, environmental conditions encountered are usually highly corrosive and become even more so the deeper one proceeds (*photos 3 & 4*). These conditions are due to the presence of corrosive fissure waters, high levels of humidity, corrosive fumes and gases, as well as corrosive and abrasive ores. In addition, thriving corrosion cells develop due to the accumulation of debris at catch points and crevices including internal surfaces of various hollow steel components.

A major design requirement applicable to all mine shafts (which provides continual access for men, materials, machinery and ore) and all tertiary support steelwork, irrespective of environmental conditions or type of corrosion control system employed, is the need for a safe extended service life, maintenance free performance of 25 to 30 years with minimum routine down time allowances (*photos 5 & 6*).

## HISTORICAL OVERVIEW

The first mine to hot dip galvanize shaft steel was President Brand in the Free State in about 1957. This was a duplex system consisting of hot dip galvanizing and coal tar epoxy paint which proved singularly successful. Apart from this, the use of hot dip galvanizing was mainly confined to high pressure pump columns and medium to small bore piping.

In about 1972, an active approach was made to promote hot dip galvanizing in the gold mining industry particularly for use in applications below the surface.

The first success was Kinross No. 2 shaft where the lower half of the shaft was duplex coated.

This was soon followed by other mines with an encouraging breakthrough into the Anglo American Gold mining industry where shaft steel components were galvanized for amongst others President Brand, President Steyn, Freestate Geduld, Elandsrand and Vaal Reefs No. 8 shaft.

Johannesburg Consolidated Investments (JCI) soon after became converts with the new shafts at the Randfontein Estates complex and Joel Mine.

The next phase was to introduce hot dip galvanizing to the Platinum Mines where considerable resistance and scepticism was encountered. Rustenburg Plats were the first converts (Amandabult No. 2 shaft and Spud Shaft are two examples). Impala Platinum and a host of other mining applications, including Platinum Concentrator Plants, Collieries, Iron Ore Beneficiation Plants, then followed.

The performance of the selected coating system in a number of these deep mining applications has, unfortunately due to lack of time and personnel from the Association's perspective, not been closely monitored. However, Moab Khotsoang a gold mine south east and about 120km from Johannesburg was equipped with about 6 700 tons of hot dip galvanized steel down a shaft of over 3km deep and has been monitored relatively well over the last 20 years since inception, with good results. These results have been documented in two papers – see References and Acknowledgements.

## HOT DIP GALVANIZERS ASSOCIATION SOUTHERN AFRICA AND ITS MEMBERS

### Reasons for the Association's existence

The Association's primary mission is to develop and expand the demand for hot dip galvanizing and duplex systems as viable and economical corrosion control systems. Our main objective is to SELL the concept of hot dip galvanizing directly to end users and



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All crevices and fasteners were comprehensively over coated to enhance the corrosion protection.

S6



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Photos 7 - 8: The galvanizer plays a vital role of good quality coatings and good service.

Figure 9: Map showing the location of the Case Histories in South Africa.

Photos 10 – 13 (left to right): After 5 years of service at Bafokeng-Rasimone PCP – The appearance of the 3 coat system, while the residual coating thickness on the hot dip galvanized bolt is 128µm; a damaged hot dip galvanized coating; coating thickness on a hot dip galvanized water pipe (59µm) (tube hot dip galvanized to EN 10240) and coating thickness at the damaged area (61µm).

Photos 14 – 15: Early photos of the 6 500 tons of superstructure hot dip galvanized steel at Bafokeng-Rasimone Platinum Concentrator Plant.



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decision makers to the benefit of members, end-users and all other stakeholders.

### Interviews, presentations, plant tours and technical courses

Initial interviews with individuals within a company will generally result in a follow up technical presentation and possibly a plant tour to other technical staff of that company. Frequent follow up visits to these companies generally instill confidence and trust.

Presentations can be extremely valuable if directed at the correct audience e.g. decision makers and specifiers. The success of a presentation is normally gauged by the time spent with questions and discussion, not necessarily only the formal presentation.

Follow up training courses in this regard are also extremely valuable.

### Technical expertise

The technical staff of the Association must have an in-depth knowledge of corrosion technology and how to reduce its impact. They must be technically qualified to be able to discuss competitors' products, but not knock the opposition. They must possess an intimate knowledge of hot dip galvanizing and its corrosion control properties, both strengths and weaknesses. To recommend hot dip galvanizing where it is inappropriate is a recipe for disaster.

### Membership

Membership of the HDGASA includes general or batch type, centrifuge, tube, continuous sheet and wire hot dip galvanizers, Associate members who buy and sell to the industry as well as Affiliate Company, Professional, Individual and International members who have a vested interest in the industry as a whole.

The Association plays the role of unbiased back up to members in situations of dispute, where possible.

All members of the Association undertake to provide customers with a committed, reliable and professional encounter and subscribe to the Code of Ethics of the Association. The Code of Ethics Statement encompasses good business practice among members and their customers.

The Association publishes promotional literature such as the Steel Protection Guide, Practical Guidelines for the Inspection and Repair of Hot Dip Galvanized Coatings, Design Wall Chart and the quarterly "Hot Dip Galvanizing Today" a self-supporting magazine sent to specifiers, users and members of the Association. The Association also administers an informative web site [www.hdgasa.org.za](http://www.hdgasa.org.za).

### The role of the galvanizer

With the utmost respect, it is necessary to emphasise the vital importance of good service and good coating quality. Failure to achieve this by a single galvanizer with a single consignment of steel can nullify months and even years of intensive promotional effort by the Association. In developing markets such as South Africa there are numerous sceptics who remain to be convinced of the merits of hot dip galvanizing (*photos 7 & 8*).

## CASE HISTORIES

### Bafokeng-Rasimone (Platinum Concentrator Plant)

The use of hot dip galvanizing for structural steel and equipment in metallurgical plants is far less common than its use in deep and inclined mining shafts, due mainly to concerns regarding its long-term performance in the perceived 'chemical' environment of a metallurgical plant. Metallurgical plants in the mining industry are diverse in nature, including, for example, gold CIP plants that use hydrochloric acid, copper and platinum group metals (PGM) smelters and gas handling plants with rich sulphur dioxide gas environments, sulphuric acid plants, and base and precious metal refineries that use either sulphuric or hydrochloric acid. In these types of plants, the choice of hot dip galvanizing would not be deemed appropriate on account of the expected rapid attack of the zinc coating in acidic conditions. The environments of many other types of metallurgical plants could, however, be regarded as being benign as, apart from some acidic and alkaline reagents, generally in small quantities, their processing streams are at near to neutral pH values. PGM concentrators are typical examples of these types of plants. One of the problems in the development of markets for hot dip galvanizing has been that owners and specifiers have tended to classify all types of metallurgical plants as having the same sort of chemical environment and have thereby unrealistically elevated the risk of using galvanizing in many of these applications.

During investigations to characterise the parameters for using hot dip galvanizing in underground conditions, Anglo Platinum also investigated the feasibility of using galvanizing for platinum concentrator plants. Hot dip galvanized steel was gradually introduced as a material of construction for cable racking, flooring, stair treads and hand rails for new, maintenance and replacement projects, with their performance being closely monitored. Alternative corrosion protection options like epoxy and vinyl paint coatings on steel; epoxy powder coatings and the corrosion resistant alloy 3CR12 were also studied. In all of these investigations it was apparent that hot dip galvanized steel was the superior option in terms of cost-effectiveness over the life cycle of the plant. The measured and evaluated success of hot dip galvanizing in these investigations provided the required degree of confidence for the specification of this method of corrosion protection for numerous new projects being undertaken by Anglo Platinum as part of their expansion drive, the first of which was the construction of the Bafokeng-Rasimone Platinum Mine situated 25km North of Rustenburg in North West Province, in 1997.

The following paragraphs outline the performance of the hot dip galvanizing used at Bafokeng-Rasimone over a five-year service period.

### Overall performance

In general terms, the performance of the installed hot dip galvanized steel in both the underground and plant environments, has been exceptionally good. Apart from complete protection of the steel, the rate of deterioration of the zinc coating has been extremely low. Thickness measurements have been unable to detect any removal of zinc and the steel is virtually in the same condition as when it was installed. While the design life of the hot dip galvanizing was set at 25 years, it is apparent that apart from any unforeseen circumstance arising in the future, the future life of the hot dip galvanized steel is well in excess of the design life.





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**Photos 16 – 19:** A number of views of Marula Platinum Smelter and the hot dip galvanized structural steel, including conveyor steelwork from an inclined shaft to varying process plants at the mine.



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### The reagent area

Because of the concerns and possible doubts, as well as a lack of data, regarding the long term performance of hot dip galvanized steel in the reagents area on account of the presence of relatively small quantities of various alkaline and acidic reagents, the specification for steel in this area excluded the use of galvanizing and selected instead the use of a conventional organic paint system (a three-coat vinyl co-polymer system over a SA 2½ surface preparation grade was used), (photos 10 - 13), the performance of the paint system has been marginal and will require replacement or maintenance, at best about every second year. Although hot dip galvanizing was not used in this area, certain small items, like water pipes and hand rails were galvanized and these serve to provide some performance data on galvanizing in this area. It is interesting to note that these small items of galvanizing have performed extremely well and indicate that at the BRM plant, the use of hot dip galvanizing would have been a better option than the painting system that was used. Since metallurgical reagents are often changed or modified, as process parameters change, it would be more prudent to use a duplex coating system in these

**Photos 20 - 21:** The severity of the environment at the Twistdraai Colliery coal washing plant.

**Photos 22 - 23:** The total coating thickness of the duplex coating system at 336µm and 378µm respectively.



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areas. It must also be noted that different platinum concentrators often make use of a different suite of reagents and accordingly, for a specific plant, trials should first be conducted to confirm the suitability of hot dip galvanized steel.

A similar evaluation of the hot dip galvanizing was undertaken after 10 years and the results were almost identical to the earlier inspection (photos 14 & 15).

### Marula Platinum Smelter

#### Brief background

Marula Platinum Limited (Marula) is 73% owned by Implats and is one of the first operations to have been developed on the relatively under-exploited eastern limb of the Bushveld Complex in South Africa. It is located in the Limpopo Province, some 50 kilometres north of Burgersfort.

The establishment and development of the mine, requiring considerable investment from Implats in both infrastructure and environmental protection measures, commenced in October 2002.

Current mining activities target the UG2 Reef only which is accessed via two declines, Clapham and Driekop, which are situated 1.3 kilometres apart. The declines were sunk on-reef from the outcrop at a minor dip of 9.5 degrees, each with three portal entries.

The metallurgical plant which was commissioned in February 2004, consists of a concentrator and a dense media separation plant (DMS) (photos 16 - 19).

### Twistdraai Colliery

#### The company

The Twistdraai mine and washing plant is part of Sasol Mining's Secunda Collieries complex. Lying in the Highveld coalfield, east of Johannesburg, the mine was opened in 1980 to produce coal for Sasol's Secunda synthesis plant, and since 1995 has been a three-shaft complex producing low-ash steam coal for the export market as well as a middlings product for Sasol feed.

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**Photo 24 – 25:** The Douglas Colliery (photo 24) and the V3 conveyor exposed to the environment for more than 20 years (photo 25).

**Photos 26 – 27:** Some typical coating thickness readings (298 and 234µm respectively).



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**Photos 28 – 30:** Three views of the Douglas Middelburg Optimisation (DMO) expansion project, including the primary crushing station (photo 28), 26kms of conveyors (photo 29) and the Schade Circular Stackers and Portal Stackers Reclaimer (photo 30), completed 2010.

**Photo 31:** A view of the Primary Crushing Station (ROM tip), Rotary Breaker and Plant conveyors at Klipspruit Colliery completed 2009.



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Photos 32 - 34: Views of the conveyors of Isibonella Colliery.

Photo 35: The transfer tower.

Photo 36: The transfer tower and hopper.



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Photo 37: Goedehoop Colliery after 17 years of exposure.

Photo 38: The transfer tower.

Photo 39: The coal washing plant.

Photo 40: Cross scribed duplex coating.

Photos 41 - 42: Total coating thickness 337 $\mu$ m and the hot dip galvanized coating thickness 123 $\mu$ m. Note the paint had to be removed to measure this.



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### **The application**

A perception exists that suggests that one cannot apply hot dip galvanizing within a colliery. Hot dip galvanizing has over the years been extensively used for conveyors, both overland and even underground. In the most severe corrosive conditions such as a coal washing plant, hot dip galvanizing plus a suitable top paint system has been applied with excellent results.

### **Environmental conditions**

Corrosive conditions within the Twistdraai coal washing plant would be classified as a C5 environment in terms of ISO 9223. In other words, one of the more extreme corrosive conditions listed in the ISO specification. *Photos 20 and 21* can best illustrate the corrosive conditions encountered at the washing plant.

### **The site**

This case study reviews the performance of a duplex system at Sasol's Secunda Twistdraai coal washing plant. Coal is delivered from the mine to the coal washing plant, where after processing it is dispatched to end users.

### **Our findings**

During the site inspection, some 53 different overall coating thickness readings were taken on the total coating thickness with the following results: Maximum 888µm, Mean coating thickness 388µm, Minimum 277µm.

In general terms the structural steel together with the duplex system was found to be in excellent condition. It was reported that the coating system has been in operation for approximately 4 years. In addition an annual inspection is conducted aimed at monitoring the coating performance.

### **Conclusion**

A duplex coating system uses the strengths of both hot dip galvanizing and selected paint coatings to compile and enhance "synergistic new performance" coating, which is cost effective where "value analysis" and long-term maintenance costs are taken into consideration. The system is designed to provide extended service life in severe corrosive environments. Surface preparation is a critical factor to the success of the coating's performance and as such, must not be overlooked in terms of the specification, as well as at the time of the application (*photos 22 and 23*).

## **Douglas Colliery**

### **The company**

Douglas Colliery (*photo 24*) is situated near Van Wyks Drift in Mpumalanga and is now privately owned.

### **The application**

As overland conveyors form the lifeblood of the supply of material used in many process plants, their general lack of future coating maintenance due to the dusty conditions at hand and unlikely adequate surface preparation for maintenance painting, coupled to their often extraordinary length, suggests that a material or coating that can offer extensive years of service free life, be used.

The V3, V4 and V5 overland conveyors at Douglas Colliery, are such a system (*photo 25*). First reported in the Foreword of our inaugural booklet, "Steel Protection by Hot Dip Galvanizing and Duplex Systems", the original of which was produced in January 1997, these conveyors at inspection were estimated to be in excess of 20 years old. Although the hot dip galvanized coating is still

performing admirably, the coatings on both the idler frames, which are painted and the fasteners, which are zinc electroplated, are in the process of failing.

### **Environmental conditions**

From a general atmospheric corrosion perspective the conditions at hand are most probably a C2 category – ISO 9223 (Interior – Occasional Condensation; Exterior – Exposed Rural Inland), suggesting that the corrosion rate of zinc is about 0.1 to 0.7µm per year. In addition to the general atmospheric conditions, coal dust and particularly coal ash, coupled with moisture will be corrosive to zinc and therefore the coating may be prone to a more severe attack by way of corrosion.

Conditions at hand at this site indicate that the corrosion of zinc is slow and that the hot dip galvanized coating is likely to carry on performing in a manner that has become the norm, expected from most specifiers, in their use of hot dip galvanized steel.

### **Our findings**

Having visited several parts of the V3, V4 and V5 conveyor steelwork we found the hot dip galvanized coating on the horizontal and vertical members to be in excellent condition, with coating thickness readings varying between 117 to 279µm with a mean coating thickness of 140µm. The coating thickness readings are still well in excess of that required by the ISO 1461 standard, for this thickness of steel. All together 108 coating thickness readings were taken on both the horizontal and vertical angle support steelwork.

### **Conclusion**

The hot dip galvanized coating on the overland conveyor steelwork has over the 20 year period, performed exceptionally well and if required, based on the residual coating thickness, will provide a further 40 to 60 years of maintenance free life. If necessary, the painted idler frames, which are showing signs of corrosion, may be selectively removed, abrasive blasted to remove the residual paint coating and then hot dip galvanized, providing a durable, predictable coating of extended maintenance free life. All fasteners if necessary should soon be replaced with hot dip galvanized equivalents (*see photos 26 and 27*).

## **Douglas Middleburg Optimisation (DMO)**

A BHP Billiton company this turnkey project included 26kms of conveyors, a primary crushing station, Schade Circular Stacker Reclaimer and Portal Stacker Reclaimer, Civils, C&I and substations. Built in 2010 all steelwork was hot dip galvanized (*photos 28 - 30*).

## **Klipspruit Colliery**

A BHP Billiton company, this turnkey project included Primary Crushing Station (ROM tip), Rotary Breaker and 6 Plant conveyors. Built in 2009 all steelwork was hot dip galvanized to ISO 1461 (*photo 31*).

## **Isibonella Colliery**

### **Location**

Isibonella Colliery is located approximately 120km due east of Johannesburg, near Secunda, in Mpumalanga.

### **Brief history**

Anglo Coal and Sasol Mining entered into a contractual agreement in October 2003 to jointly develop the Kriel South Reserve Area. Under the agreement Anglo Coal committed itself to establishing Isibonella Colliery, an opencast operation, to supply



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*Photos 43 –46: The Sishen expansion project including some 22 000 tons of hot dip galvanizing in the form of process and conveyor steelwork.*

Sasol's Synthetic Fuel (SSF) plant in Secunda. In November 2003 construction work began and the first coal was supplied to SSF in July 2005.

Isibonella Colliery is designed to supply SSF approximately 5 million ton / year over a 20-year period (see *photos 32 - 36*).

### **Goedehoop Colliery**

#### ***The company***

Goedehoop is an Anglo Coal company situated in the Witbank area in Mpumalanga (*photo 37*).

#### ***The application***

Goedehoop Colliery has been in existence since the early eighties. In about 1995 the mine embarked on several extensions, one of them being to the transfer tower (*photo 38*), the coal washout facility (*photo 39*), and conveyor material supply system.

It was then suggested to mine management personnel that because of previous paint coating failures that a duplex coating system be used to protect the steel. The suggested system comprised a single coat high build epoxy coating applied to sweep blasted hot dip galvanized steel in accordance with the Hot Dip Galvanizers Association's Code of Practice HDGASA-01:1990 for surface preparation and application of organic coatings.

#### ***The environmental conditions***

Coal washing facilities are relatively aggressive environments, due to the combination of coal dust and water.

#### ***Our findings***

Although in existence for a number of years the old wash out plant was found to have several coating failures. Coatings in these conditions are extremely difficult to maintain unless the entire operation is shut down.

The duplex coating system on the steelwork in the new area is in exceptional condition, so much so that the organic coating had

to be purposely damaged in order to assess the adhesion of the organic coating and overall condition of the hot dip galvanized coating underneath.

### ***Conclusion***

The assessment was done after 10 years of service the duplex coating system is in exceptional condition and had to be purposely damaged, in order to assess and measure the hot dip galvanized coating thickness (*photos 40 - 42*). In comparison the paint coating on the carbon steel hand rails of the coal washout facility had failed.

### **Sishen Iron Ore Beneficiation Plant**

#### ***The company***

Kumba iron ore a successor of Kumba Resources is the fourth largest iron ore producer in the world and owns 74% of Sishen Iron Ore Company.

#### ***The location***

Sishen Iron Ore Company is situated inland in the Northern Cape.

#### ***The plant expansion***

The plant expansion included some 22 000 tons of hot dip galvanized steel in various forms including extensive conveyors. After installation iron oxide dust alters the silvery grey hot dip galvanized coating to a reddish brown colour which seems to form a natural duplex coating (*photos 43 - 46*).

### **Petro SA**

#### ***The company***

The Petroleum Oil and Gas Corporation of South Africa (PetroSA) is a wholly owned subsidiary of CEF and its main activities include the exploration and production of crude oil and natural gas off the southeast coast of South Africa.

Petro SA refinery was commissioned as "Moss gas" in 1987. This is one of the world's largest gas to liquids (GTL) refineries, and has always been a leader in the challenge of commercialising the GTL processes.

Petro SA was formed in July 2000 out of a merger of the business of Moss gas and Soekor to effectively develop and exploit the crude oil and gaseous hydrocarbon resources of South Africa.

#### Location

Petro SA is situated about 2.5 to 3km from the coast and about 13km to the west of Mossel Bay's central business district.

#### Application

During a site inspection to determine the condition of certain paint systems that were in discussion, a number of hot dip galvanized cable ladders and trays were inspected and found to be in excellent condition. These cable ladders and trays were purportedly installed at plant inception. As the resulting coating thicknesses could not be photographed as proof of their performance, for safety and security reasons, it was decided to evaluate the hot dip galvanized lighting masts on the outer perimeter of the plant and if they were in an acceptable condition, compile a report for circulation as there is a possibility that a new oil refinery Project Mthombo would be built at Coega Harbour in a similar position relative to Moss gas on the coast.

The perimeter lighting masts at Petro SA in Mossel Bay have been exposed to the environment since the inception of the plant in 1987, making them about 25 years old. Due to some misunderstandings on the possibility of Liquid Metal Embrittlement in structural steel when hot dip galvanizing is used for petro chemical plants, the report was ultimately emailed to Richard Rood P.E. – Coatings, Insulation and Fireproofing, KBR Engineering, Houston, Texas, for his comments (photos 47 - 50).

#### Response from KBR regarding our query on Liquid Metal Embrittlement

**From: Richard Rood PE – KBR Engineering**

**Subject: Performance of hot dip galvanizing at Petro SA**

Although LME can occur with certain alloys under certain conditions, LME has not been a problem with structural steel. KBR's standard practice on nearly all petrochemical projects over the past 60 years has been to hot dip galvanize all structural steel; including all platform steel, handrails, ladders, cages, grating, etc. The only exceptions we recommend painting over hot dip galvanizing of structural steel are:

1a. High strength bolting which is mechanically galvanized to avoid hydrogen embrittlement,

1b. Large welded steel structures (e.g., modular steel which can't fit in galvanizing baths),

1c. Steel fabricated and erected in countries that do not have galvanizing facilities, except we do require that all platform steel, handrails, ladders, cages, grating, etc. be hot dip galvanized.

1d. Special applications which require thermal spray aluminum or zinc-aluminum (85/15) with sealers.

Disadvantages of (paint) coatings are:

2a. Maintenance of the items listed above are extremely difficult if not impossible.

2b. Paint coatings are easily damaged during shipping, handling and erection, and require more field touch-up.

2c. Paint coatings have a considerably shorter life expectancy than hot dip galvanizing.

2d. Paint coatings are more costly, increases TIC, and maintenance painting costs.

2e. Paint coatings are dependent on weather conditions and causes shop problems which affect EPC schedules.

Galvanized structural steel has many advantages over painted steel, such as;

3a. Galvanizing provides long term corrosion control (20 to 30 years) that cannot be provided by traditional paint coating systems (5 to 10 years).

3b. Galvanizing forms a Zn-Fe alloy with the steel. This alloy is extremely tough and not prone to mechanical damage. If it becomes damaged corrosion protection is still provided by the surrounding galvanizing.

3c. Galvanizing is more economical than protective paint coatings, reduces plant TIC as well as maintenance painting costs.

3d. Galvanizing greatly aids projects constructability which has the following benefits:

- Shorten the overall EPC schedule
- Reduces field work and rework
- Reduces the projects TIC costs
- Value added is improved
- Safety is enhanced due to minimized field rework, especially at elevated locations



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**Photos 47 - 48:** The perimeter masts at Petro SA near Mossel Bay that have been installed since plant inception (25 years).

**Photos 49 - 50:** Coating thickness on the holding down nut 211µm and on the mast 159µm respectively.



Protection of structural steel by painting is difficult due to:

- 4a. Sharp edges and corners on structural shapes lead to early coating failures and corrosion problems.
- 4b. Interior surfaces of angles, channels and I-beams are difficult to coat properly and lead to early coating failures and corrosion problems.
- 4c. Coatings do not provide corrosion protection in crevices, faying surfaces, and bolted connections.
- 4d. Coated welded attachments and upper surfaces of pipe support beams pose corrosion problems.

**Reference from Amplats (Anglo Platinum Management Services) taken from Master Specification No ADC 001**

*"Although successful in many areas, eg. surface plants, protective paint coatings are of limited use in shafts. The coatings are easily damaged during erection and service and they cannot be effectively maintained in the corrosive shaft environment. Access within a shaft for maintenance is also extremely difficult. Since paint coatings offer very little by way of effective corrosion protection, the steel undergoes rapid corrosion which is generally of a pitting nature, and perforation of the steel. Hot dip galvanizing provides a hard abrasion and corrosion resistant surface which, in addition, provides protection to the base steel at points of damage. The nature of the corrosion on galvanized surfaces is also uniform and the risk of pitting corrosion is reduced.*

*In order to cater for the very corrosive conditions in upcast shafts and in the lower regions of downcast shafts, use is made of duplex coatings which comprise of a hard durable paint coating system over hot dip galvanized surfaces.*

*In the conditions that prevail at the shaft bottom loading facilities (very severe corrosion and abrasion) the use of 3CR12 may be considered instead of hot dip galvanizing or duplex coatings.*

*In very abrasive situations, eg. loading chutes, abrasion resistant steel such as Roqplast are more effective.*

*Both 3CR12 and abrasion resistant steels would not be expected to last for the full service life of the shaft and would require replacement at fairly frequent intervals.*

*For temporary shaft situations, eg. sinking and mid-shaft loadings, the corrosive conditions would be present for a shorter period of time, eg. 2 to 4 years compared to 25 to 30 years for permanent shaft fittings."*

**Reference from Anglo Coal**

*Thinus Schmidt, Principal Mechanical Engineer of Anglo Coal quoted the following: "Hot dip galvanizing is our preferred corrosion control system for all structural steel used at Anglo American Thermal Coal for surface and underground applications. We've had a few instances in the past where we had to grant concessions to contractors to supply painted structural steel because no slot could be secured at galvanizers at the period when South Africa went through a construction boom.*

*We are currently well advanced with the detail design of the first phase of a major project which has a design life of 60 years. We*

*have subsequently specified a heavy duty hot dip galvanized coating for all structural steel. Based on our investigation, we expect that the coating will be sufficient for the entire design life."*

**CONCLUSION**

The successful specifying and application of hot dip galvanizing and duplex coating systems with any mining specifier is dependent on:

- Experienced association staff in collaboration with all interested members, committed to providing quality coatings in accordance with set specifications.
- Initial introduction and ongoing education of mining specifiers in their understanding of the coatings appropriate use for the conditions at hand.
- Education of mining specifiers and technical personnel on the design required for components that are to be successfully hot dip galvanized or duplex coated.
- Education of the steelwork contractors on the fabrication standard for hot dip galvanizing.
- Where environmental conditions are initially considered inappropriate for its use, appropriate testing of applicable samples that are hot dip galvanized or duplex coated, should be exposed, monitored and reported.
- Added value services, such as hot dip galvanized fasteners, appropriate repair materials and other fixing devices should be made readily available.
- Involvement of appointed galvanizer/s in large projects on the project team.
- Based on proven past performance the following corrosion control in mining will generally prove successful:
  - Deep level mine steelwork – HDG.
  - At worst, lower 10 – 15% Duplex Coated.
  - PGM Smelters, Metallurgical & Gas Plants – Duplex Coated.
  - Coal Washing Plants Duplex Coated.
  - Generally all Conveyors and Transfer Towers – HDG (unless coastal).
  - Other than acidic areas in Petro Chemical Plants, HDG is acceptable (unless coastal).

Finally, overall success in the mining industry will result from unrelenting and frequent representation to the specifiers, unbiased and open minded specifiers, who through the positive results they experience in curtailing long term costs and safe working conditions to their staff, will happily repeat specifying of hot dip galvanizing and duplex coating systems and freely supply the references that are included in this paper!

**REFERENCED PAPERS**

*"Hot dip galvanized steel as an appropriate and realistic material of construction for mine shafts." Authors: Bob Andrew; Walter Barnett and Bob Wilmot and "Hot Dip Galvanized Steel used in Deep Level South African Mines." Author: Bob Wilmot – Ex-Executive Director HDGASA.*

## SUCCESSFUL APPLICATIONS OF HOT DIP GALVANIZING AND DUPLEX COATINGS

S7

### CONSTRUCTION OF THE SOUTH AFRICAN POLICE SERVICE RADIO CONTROL CENTRE, PORT ELIZABETH, SOUTH AFRICA (2012)

To improve on response times the South African Police Service has undertaken to expand its operations to provide a drastically improved and more efficient call out rate to the country.

SAPS 10111 existing facilities at Mount Road, Port Elizabeth, is inadequate in terms of size and does not allow for expansion due to the nature of the existing structure. A new high-tech facility is necessary to deal with large sensitive electronic equipment with all its related supporting functions and requirements.

The building is positioned on a generous 2.4ha site in Korsten, Port Elizabeth, surrounded by secondary arterial roads to the South and open space to the North. The site, being one of the highest points in the area, provides great opportunities with respect to panoramic views across the Bay.

The building's footprint is orientated along an East West axis aligning itself to the North as opposed to the sites North East boundaries. This juxta-position intentionally reinforces the building's form as a pavilion with its massing defined by the levels of the site.

Access is from the North East directly along the buildings central axis, allowing views through the building to the West. The central Call Centre/Radio Control is perceived as the hub of the facility and designed as an independent entity inside the space of the building's structure, defined by a single mono-pitched roof. All

supporting accommodation feed off this central space taking advantage of the views.

The clients brief to provide an uninterrupted space for call takers required an intricate steel structure to both span and support a service platform above over an area of 800m<sup>2</sup>.

Within the Call Centre space two primary steel girder beams are visible with supporting steel bearers being concealed within the ceiling void. The concrete framed structures that flank this central entity delicately interface with this core using carefully detailed steel walkways, again with an industrial touch. The central office

*Photo 1: Eastern gable end completion.*

*Photo 2: View showing western Gable end including entrance canopy.*

*Photo 3: Gate house and hot dip galvanized steel canopy.*



accommodation within the two framed structures is designed as composite members using steel I-beams and flat concrete slabs. This allowed the offices below to be uninterrupted in terms of support structure and allows flexibility in terms of office compartmentalization which can be changed to suite the end users requirements.

The building will be submitted to GBCSA (Green Building Council of South Africa) for a four star accreditation. One point can be achieved where 50% of the buildings steel structure is designed for disassembly. This is to encourage and recognize designs that minimize the embodied energy and resources associated with demolition. The use of steel as the main defining structure was therefore envisaged with particular attention paid to detailing between the different elements of the building. This structure was then in turn galvanized to achieve a harmonious 'industrial' aesthetic throughout the building. This continuity enables one to perceive the entire structural element in its 'raw' state and reduces any maintenance issues throughout the buildings lifespan,

a specific requirement of NDPW (National Department of Public Works) who as a standard also require all steel to be hot dip galvanized.

The building was completed in August 2012.

### PROJECT TEAM

**Client:** National Department of Public Works

**End user:** South African Police Service (SAPS)

**Architect and principal agent:** The Matrix...cc Urban Designers and Architects

**Structural and civil engineers:** BVI Consulting Engineers

**Quantity surveyors:** Rousseau Probert Elliot

**Electrical and mechanical engineers:** Palace Technologies

**Building contractor:** Pro-Khaya Construction

**Electrical and mechanical contractor:** Besamandla (Eastern Cape).



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*Photo 4: Early view of the hot dip galvanized support steelwork for the call centre mezzanine.*

*Photo 5: The call centre ceiling installation showing the exposed hot dip galvanized steelwork.*

*Photo 6: Completion of the hot dip galvanized steelwork at the western gable end.*

*Photo 7: The view on the hot dip galvanized steel gable end installation.*

*Photo 8: The smoke extraction installation showing interior hot dip galvanized steelwork.*

*Photo 9: View on the south face showing the solar shading detail.*

*Photo 10: The hot dip galvanized steel lift installation.*



# HOUSE TAYLOR, BALLITO BAY, KWAZULU NATAL, SOUTH AFRICA: A COMMITMENT TO HOT DIP GALVANIZED STEEL (2012)

S7

## FOR THE RECORD

The Green House on the hill in Ballito has become one of the most talked about buildings in local history. The reason is plain to see. In an attempt to build a house that is environmentally sensitive and cutting edge, owner and designer, architect Charles Taylor, has embraced technology that will hopefully revolutionise the way many future homes will be built in this region.

The extensive use of hot dip galvanized steel allows for a modulated frame to take layers of wood, glass and greenery which form the enclosures to create a house that is dramatically different from the norm.

The enormous commitment to hot dip galvanized steelwork can freely be seen in this view of the house and pool deck.

The one acre site was previously the first water reservoir for Ballito from the 1960's and stands majestically on the crest of the highest point in lower Ballito with sweeping vistas over the rooftops of distant mountains behind it, and spectacular ocean views in front.

The ultra-modern design elements incorporate the latest in green technology. 'Passive' cooling, ventilation and lighting are always designed as a first principle, integrating latest technology in an adaptive position to allow for future systems.

## FOR THE ARCHITECT

My wife and I have always loved conservatories and green houses, and wanted to incorporate the feeling of being in a certain volume with steel structure, greenery and sky dominant.

The building design represents a response to site in terms of views, outdoor spaces, existing tree positions, and wind and sun

orientation. The structure has been designed with flexibility and adaptability in mind.

Structural steel is a great medium – it is ancient yet modern, recyclable, shimmers in the light, provides an ordered and square structure that can handle long spans, and is very easy to integrate with other materials.

Edges of forms have been slightly curved to soften the aesthetic and pick up on the way the eye links the edges of the structure to the sky and clouds, the rolling hills beyond and the ocean.

All living spaces and bedrooms are arranged to ensure every room has a minimum of 3 sides orientated to obtain natural light and ventilation. Large service duct areas enable adding or changing the mechanical or electrical systems of the house.

## FOR THE ENGINEER

Charles Linda Ness of NJV Consulting to help him design his beautiful house on the hill. There was no doubt about the use of structural steelwork as the backbone, complete with ribs, for the double storey dwelling – the Architectural Revit models incorporated a strong visual element of exposed steelwork.

An extensive reinforced podium presented a springing point for the steel frame. A concrete sheet retains the bank set into the hill at rear, extends forward as a ground floor supported on RC columns

*Photo 1: The enormous commitment to hot dip galvanized steelwork can freely be seen in this view of the house and pool deck.*

*Photo 2: The hot dip galvanized steel frame forms a rigid support onto which the flooring, glazing and floor decking is hung.*



into the basement, and finally folds into a 25m length pool along the front edge.

Since speed of construction was important to Charles, the engineering strategy was to quickly define the steel / concrete interface, and get going with the concrete – using the wet-works construction time to design and detail the steelwork.

In our view, one of the most satisfying steelwork design processes is one which affords collaboration with architect and fabricator from the outset, and we were fortunate here. Working closely with Warren and Charles from concept structural development stage, the decision to modulate, how and with what were smooth decisions.

'Light weight', precast ECHO slab elements were used to create the floor elements, supported on steel beams which wrap upward in cycles of vertical ribs to support external balconies and vertical shading screens. The steelwork frame is horizontally braced by a series of vertical concrete walls and masonry ducts, which are carefully mechanically tied at strategic points both to steel and ECHO floor planes.

#### STRUCTURAL TRIGGER POINTS:

- 'The long way around is the short way home' – Charles house is minimalist, steel needed to be modular and flush. The suite of steel sizes was selected and validated using a full house structural model in OASYS.
- No cross-bracing or visible zigzags!
- As the steel was to be hot dip galvanized, and aesthetic, all connections needed to be shopped, and all interfaces considered – there could be no welding or touch-up on site. Thanks to Terry Smith from the HDGASA for his valuable advice from time to time.
- On the front elevation a sweeping first floor covers an unusually high ground floor living space, complete with missing corner columns. We think the photos speak for this structural trigger point!

As there was little lead time for fabrication, Rebcon opted to go direct to shop detailing from engineering sketches and a series of detail meetings. This is no easy feat and the subsequent outcome is in no small part as a result of Rebcon's professional and outstanding commitment to their product.

#### FOR THE FABRICATOR

From the outset Charles was intent on using steel with a hot dip galvanized finish, without any further corrosion protection to be applied. The site is positioned in an extremely aggressive corrosive environment, being on top of the ridge in Ballito, hence the structure needed to be detailed in a manner to obviate site welded joints.

Positioning of blowholes / drainage holes was carefully selected at detailing stage to ensure that the Hot Dip Galvanized finish resulted in a good architectural finish with minimal inclusions or ash marks.

A modular grid that agreed with standard material stock lengths was adopted by CTA to ensure that there was minimal waste (offcuts) from stock length material. A common section size, being mainly 152 x 152UC sections was chosen by LNA to maintain symmetry on use of section sizes. The "hooped" sections were



*Photo 3: A view of the elaborate but essential steel column head.*



*Photo 4: The hot dip galvanized framing clearly defines the extremities of the timber floor decking and the glazing components.*

fabricated ex plate to achieve the same section profile of the 152 x 152UC, to align with CTA's requirements for the rounded corners.

Rebcon procured and installed the Echo precast floor slabs, taking responsibility for the detailing of geometry of same, at steel shop detailing stage. Due to the complexity of access to site, the installation of the steel structure and Echo precast slabs was carefully sequenced to work from furthest point out to site entrance.

The project was designed by CTA in phases, the main structure being phase 1 and 2 and the ancillary components being add on's. The benefit of the use of steel allowed CTA flexibility in design of ancillary components

#### FOR THE ENVIRONMENT

Cool air from a basement is pulled through a buried gabion rock mattress into one low energy fan in the centre of the building which circulates the "cooled" air throughout the building. The temperature of the earth at this depth is constantly around 15 - 17 degrees. Although the humidity is not dealt with it suffices for most of the year and takes the edge off the heat. This experimental idea originated from a friend and local engineer Bill Yeo.

The extensive glazing in the house will also play an important role in temperature control. The glazing system is a combination of HBS products that allow for single or double glazing within the same module.

Because the swimming pool water will be sanitised without the use of chemicals, chlorine or salt thanks to a remarkable E-Clear Pool Treatment system, it can be backwashed onto the garden and reticulated through conventional pipes because it will not create the corrosion associated with salt or chlorine.

The Green House will generate its own electricity. A silent vertical turbine wind generator provides 5kw of power on this appropriately windy site. The system will generate enough power to run the entire household including a single phase lift. It will also push electricity back in the local grid so the electricity meter will run backwards.

# MTN HEADQUARTERS BUILDINGS, JOHANNESBURG, SOUTH AFRICA: PHASE 1 AND 2 (2005)

S7

## DESCRIPTION

MTN requested the use of a hot dip galvanized coating in an architectural manner in order to protect all the external steelwork of their head-quarters, achieve a dull matt grey steelwork finish and more importantly to minimise future maintenance.

## LOCATION

Fairlands, Johannesburg

## TONNES OF STEEL

Approximately 600 tonnes

## TYPE OF STEEL

Hot dip galvanized building facades, floor gratings, sunscreens, staircases, perimeter fence and shade cloth supports.

## PROJECT PARTNERS

**Owner:** MTN

**Property developer:** RMB Properties

**Developer:** Fikile Stocks

**Architect:** Boogertmann & Partners

**Specifier:** Africon (now Aurecon) Johannesburg & Pretoria

**Contractors:** Tass Engineering, Magnet Engineering, Nancy Engineering and Omni Struct

**Hot dip galvanizers:** Armco Galvanizers, Barloworld Galvanizers and Supergalv

## PROJECT INCEPTION DATE

2004 to 2005

## PROJECT VALUE

R270 million



## INFORMATION

- The quality of the hot dip galvanized coating had to be above the standard required by the ISO 1461 hot dip galvanizing standard. It was for this reason that an architectural checklist for the designers and the respective galvanizers was compiled and issued to the respective contractors.

- When Phase I of the MTN head office was built, the architect required that a handrail configuration be hot dip galvanized for erection at the site mock-up. This mock-up was to provide the client with a look and feel of the components before the final decision of material or coating choice was made for the project. The sample was hot dip galvanized without any prior instruction from the contractor to the galvanizer as to the function of the article.

On seeing the erected sample, which was of poor aesthetic appeal, the architect contacted the HDGASA for assistance. This led to an alternative material being specified for the hand railing for Phase I, with the HDGASA requesting involvement in the planning of Phase II. The involvement in Phase II of the HDGASA led to the compilation of the "Architectural Checklist" and a restrictive repair procedure being drawn up for implementation at the start of the project.

- Although the use of hot dip galvanizing for architectural purposes is small by comparison to the mainstream use of the coating in Gauteng, the introduction of the checklist promotes effective communication between all parties, thereby increasing the use of hot dip galvanizing in architectural applications.
- Due to the long term maintenance-free aspects of hot dip galvanizing, the client will not have to maintain the hot dip galvanized components for the foreseeable future.
- Training by way of frequent site meetings to most members of the project team, followed up by staff meetings at the respective companies, ensured that all possible measures were implemented to reduce errors both in the short term as well as medium and long term for other projects.
- The Phase I and II of the MTN headquarters have made extensive use of hot dip galvanizing, namely for building facades, floor gratings, sunscreens, numerous staircases, perimeter fence and shade cloth support structures.
- Various hot dip galvanizers were used due to the size of the project as well as size of items that had to be hot dip galvanized.
- MTN has in the past been a supporter of the hot dip galvanizing industry by way of its masts throughout South Africa and north of the border.
- A further alliance has been forged with various project team members, including the Architect, Structural Consultant, the Main Contractor and all the Sub-Contractors.
- It is anticipated that the check list system will be further understood and enhanced on subsequent phases of the project.

See other photos on page 30.





## DESCRIPTION

The new National Library incorporates a four-storey building, including a raised public piazza leading to the entrance, hot dip galvanized steel and glass covered walkways and ramps as well as double-volume reading rooms with views onto the streets.

## LOCATION

Pretoria, Gauteng, South Africa

## PROJECT PARTNERS

**Client:** Department of Public Works

**Architects:** Jeremie Malan Architects in association with ImpenduloDesign Architects and Gandhi Maseko Lingelighle

**Project manager:** Jeremie Malan Architects

**Main contractor:** Rainbow Construction in a JV with WBHO

**Steelwork contractor:** Maristeel

**Quantity surveyors:** Taljaard Meyer Storm, Lindile Mteza & Associates and Quantity Surveyors Africa

Pretoria's Central Business District on Government Boulevard and combines all the different requirements of The National Library which was previously spread over five buildings in the city.

- It is a unique, fully-funded government project to foster and revitalise education, arts and culture within South Africa.
- On 1 November 1999, a decision was made to integrate the Cape Town Library and the Pretoria State Library into a single National Library of South Africa. The Pretoria Campus (The National Bibliographical Library) and the Cape Town Campus (The Preservation Library) would make up this national library.
- The building seats 1 500 users, making its capacity 10 times that of the former library and will be able to house 3.5 million books within the next twenty years.
- The new National Library has been split into two sections; the studying section and a research section, which includes a foreign official publication section. This will allow foreign officials to access

# NATIONAL LIBRARY, PRETORIA, SOUTH AFRICA (2009)

information directly from their official government publications, thereby helping to promote the library all over Africa, as an information hub of Africa.

- A new campaign was launched in 2001 to position the library as an icon for the people. This was part of an initiative called 'Masifunde Sonkwe' that aims to promote and maintain a reading culture within South Africa. This reading culture will ensure that the South African heritage and values are encouraged through all cultures and languages.
- The materials used are face brick, concrete, steel and glass, which are easy to maintain, thereby keeping these costs low. The simplicity of the materials means that the building will not age quickly.
- Existing trees on and around the property were protected and preserved, with heavy penalties imposed for any trees damaged.
- All façade steelwork is hot dip galvanized. The architect believes that part of the success of this project was due to the early involvement by the Hot Dip Galvanizers Association SA, as well as frequent meetings throughout the process.
- A further contribution to its success was that of detailed drawings by the architect, consulting engineer and shop drawings by the fabricator.
- Hot dip galvanizing was selected by the architect due to its low maintenance, sustainable long life and aesthetic appeal. Jeremie Malan describes the aesthetics in this project as the naturalness of the materials used; dark face brick versus the light colour façade. Furthermore, there is a contrast between the dark solid face brick versus the light weight hot dip galvanized façades, which are inviting and visually approachable.
- The materials were not selected because of their perfection in terms of colour – in fact, face brick, granite and hot dip galvanizing all vary in colour!
- The selected colours on this project represent the 'sand' colours of South Africa; dark by the brickwork and granite, light to reflect the sky and the glimmer reflected by hot dip galvanizing.
- This project used the Architectural Checklist for Hot Dip Galvanizing, which was developed by the Association. This checklist was developed for the MTN Building and a visit to the MTN Head Office was a reassurance and source of favourable information prior to the finalisation of the specification.
- The correct chemical analysis of the steel with regard to silicon and phosphorus content was discussed with all parties, including Highveld Steel, and approved and added to all the consultant's drawings. However, there were instances when steel was purchased from other suppliers. The lack of availability of the specific steel was raised as a concern, discussed and resolved at a meeting attended by all parties.
- The location of this project, being in the centre of Pretoria, with extremely limited off-loading and lay-down areas presented some real problems from a logistical point of view. Selection of the crucially required steelwork, both through the fabricator and hot dip galvanizer, had some thought provoking moments!

See other photos on pages 22 and 28.

## HOUSE ROOI ELS, CAPE PROVINCE, SOUTH AFRICA: A COMMITMENT TO DUPLEX COATING SYSTEMS (2010)

S7

*Designed on the back of a serviette over a plate of calamari in Hermanus, this vacation beach house is carefully crafted to create an extraordinary living experience! Primary design drivers revolve around minimum intrusion on the fynbos and dunes that carpet the site. By suspending the house on the dune slope allows the fynbos to be practically continuous under its footprint. Capitalising on its unique context with panoramic views from Cape Point through to Gordon's Bay, the house is conceived as a steel framed glass box with a hull shaped roof to facilitate distant elevated views to the surrounding mountains. All the external walls are sliding folding glass doors and are concealed by slatted timber shutters which open hydraulically to become a veranda. All interior walls dividing living and sleeping spaces slide away during daytime hours to create a single large space which flows out on all four edges to broad cantilevered decks. The effect created is thus an umbrella, connecting iso-tropically to the amazing environment that cradles the house.*

The challenge behind constructing the house that is currently under erection at the point of Rooi Els in the Western Cape was not just the barrier to entry on the environmental responsibility front. It was also a question of the barrier to the environment: *how do you adequately protect an open steel structure in such a proximity to some of the worst corrosive conditions in the Cape?*

Environmentally, Brandbild have made huge strides in protecting and rehabilitating dune vegetation outside of the site boundaries. Using non-woven fabric constructed with coconut husk, pinned to the constantly shifting sands, they have squeezed into a site literally no bigger than the footprint of the overhanging floor perimeters. In tribute fynbos grows liberally on the site establishment fences.

The location of the structure quickly focused the design team on smoothing the corrosion resistance ride for the steelwork. With a back-to-back corrosion protection guarantee for the Client in mind, a team was brought together where the fabricator, galvanizer and paint manufacturer offered a 15 year guarantee on a duplex coating system.

This has undoubtedly created a continued awareness for the quality issues surrounding the preparation and implementation of the system at every stage, without the traditional concerns at the



interface between one trade and the next. The unusual guarantee satisfied a somewhat perturbed NHBRC, who referenced that 316 stainless steel was perhaps the only metal suitable for the site.

With the corrosion protection system defined and the team on board, attention was diverted to devising a suitable family of joints, splices and connections within the frame. The Architectural aesthetic for the steel skeleton is 'seamless', so maximising the shop fabricated 'chunks' of frame was paramount to minimise site bolting and welding. This was limited to the size of the galvanizing baths at Cape Galvanising, and transport facilities to the point of Rooi Els.

The structural design was challenging in the large clear span leaps and cantilevered overhangs demanded by the Architecture. Careful attention was paid to the deflection criteria over and around glazed sliding-folding perimeter walls, under particularly onerous wind loading conditions. A full analysis model was initiated by Linda Ness of NJV Consulting, using OASYS, both for design, design

*Above: A conceptual elevation of the house on the site.*

*Photos 1 - 2: The balance of the intricate detailing and initial shop detailing were taken to completion by Apocalypse fabricators on their factory floor.*

*Photo 3: The carefully preplanned 'chunks' to be masked, hot dip galvanized, primed and coated at the premises of Cape Galvanising.*





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interface, and towards a full understanding of the behaviour of the steelwork structure.

The structural detailing was taken to a stage just short of intricate completion by PSN using 3D environment modelling, Xsteel, in close deliberation with LNA. After collaboration with the fabricator, structural details were refined in design, revised on the 3D model and bled into a visual approval process by Elphick Proome Architects who were aware of the structural development at all stages, so to retain the original philosophies of the design. Finally the basic fabrication shop details were issued to the fabrication factory.

The balance of the intricate detailing was carried out by Apocalypse fabricators who infused the inevitable complexity of minimalist architecture, open honest steel structure, and all the services in-between. In this way the initial shop details were taken to

completion in the factory (see *photos 1 - 2*). Not least of these complexities was the development of a unique mechanical shutter system (see *photo 4*) that necessitates a series of complex fabrications to accommodate the moving parts. As an unusual measure: pre-drilled holes for attachment of other features on the structure such as the roof, blinds, glass, and other attachments have generated just over 1 600kg of swarf!

The Apocalypse factory floor, an area smaller than the footprint of the final skeleton, in Gordon's Bay, became a full scale prefabrication facility. Sequential lengths of the structure, both floor perimeter and roof, were fabricated and preassembled in the factory before being carved off into the carefully preplanned 'chunks' to be masked, hot dip galvanized, primed and coated at the premises of Cape Galvanising (see *photo 3*). Steel was bulk delivered onto the site for erection in two separate phases: floor perimeter and roof (see *photos 5 - 10*). All site welding is carried out on section ends that were masked prior to hot dip galvanizing and zinc metal sprayed on site prior to a final brush on paint coating system application.

The floor structure is a composite of a reinforced concrete flat slab, framed by a steel channel, and supported on a regular grillage of steel columns bolted to reinforced stub columns using isolated 316 stainless steel HD bolts (the only stainless steel utilised on the primary structures). The perimeter channel emits a regular skirt sequence of propped and cantilevered tubular frames that support the perimeter timber slatted verandah. Tubes were used specifically in the outdoor environment to minimise the corners and heels associated with accelerated corrosion of angular hot rolled sections. And also to maximise natural wash-down during rains.

The steel columns extend uninterrupted up to the ceiling plane where they are framed by a 'toblerone' vierendeel truss that rings the house and ultimately forms a glazed clerestory. Off this truss ring, springs another series of cantilevered frames which emulate the verandah below and form a framework for the mechanical shutters, and a narrow skirt of cladded roof in which all of the

COATING SYSTEM		Data Sheet		Film Thickness (microns)		Minimum interval between coats at 20°C
No of Coats	Coating			Wet Film	Dry Film	
1	Sigmacover 280	7417		175	100	8 hours
1	Sigmacover 435	7465		160	100	8 hours
1	Sigmafast 210	7541		180	100	8 hours
3	TOTAL DRY FILM THICKNESS				300µm	

Table 1.

COATING SYSTEM		Data Sheet		Film Thickness (microns)		Minimum interval between coats at 20°C
No of Coats	Coating			Wet Film	Dry Film	
1	Sigmafast 210	7541		70	40	8 hours
3	TOTAL DRY FILM THICKNESS				300µm	

Table 2.



services are hidden. The fabricated curved rafters and cold rolled lipped channel purlins form the ribs and grillage for a slim-line biscuit of smooth timber roof cladding, and timber ceiling.

While the project has still to be completed, it is an easy statement that no one aspect of such a project overshadows any other, and that all the designers and builders demanded full attention of the others. Corrosion protection of the primary structural mediums of reinforced concrete and steelwork were considered right from inception.

At the time of writing, 95% of the steelwork is erected, no fabrication adjustments have been required to the factory pre-fit and only two dozen or so holes drilled on site, which is testament to the attention. This in turn means the conservation of the protection system remains optimal, ahead of final wash down and the application of the site coat.

### STEELWORK CORROSION PROTECTION SYSTEM

As the atmospheric conditions are fully marine (typically C5), we believed that a comprehensive coating system was necessary in order to achieve a high degree of corrosion control and ultimately satisfied customers. The coating system comprised the following:

- All structural steelwork other than the tubing was abrasively blasted prior to hot dip galvanizing. The reason for this was although abrasive blasting is not necessary prior to hot dip galvanizing, we felt that there are occasions when the fillets of structural I-beams and channels show an unsatisfactory roughness, which if not removed often result in a rough hot dip galvanized coating along this area. The roughness would be more than amplified when hot dip galvanized and over coated with paint.
- Hot dip galvanize to ISO 1461.
- The hot dip galvanized coating was then mechanically cleaned to remove obvious surface roughness, bumps and lumps to an acceptable degree of "smoothness" (This is relative when compared to the gas or air knife wiped surface of continuously hot dip galvanized sheeting). The coating was then chemically cleaned using scotch brite pads and an appropriate GIC (Galvanized Iron Cleaner).
- The cleaned hot dip galvanizing was then factory painted, as shown in *Table 1*.

### Application in the factory was done by airless spray

To eliminate bolted joints (for aesthetical purposes) all the joints were site welded to ensure a degree of structural smoothness. The

applicable sections were treated using a mask, 'Galvstop' to ensure the localised exclusion of the hot dip galvanized coating. (This is essential when welding for structural purposes). The subsequent paint system was then also cut back appropriately, so that each coating, including the hot dip galvanizing could be appropriately re-instated after site welding took place.

Once all the site coating repairs have been completed, the entire structure will be painted, for uniformity by brush or roller as follows:

### Surface preparation

Rinse surface with potable water to remove salts. Degreaser must be used if surface has been contaminated with mineral or vegetable oil or grease

### Coating System

See *Table 2*.

### Application on site must be done by brush or roller

#### *Special requirements from the paint manufacturer*

All surface preparation and application shall be in accordance with the relevant product data bulletin, this specification and the general painting specification of Sigma Coatings.

It is the responsibility of the applicator to ensure that he can achieve the required DFT of any and all the required coats in a single operation. If multi-coats are required due to method of application or other, they shall be applied per the instructions of Sigma Coatings and all additional labour shall be for the sole account of the applicator.

If the surface becomes contaminated between the coats, the surface shall be washed thoroughly to remove all contamination prior to application of further coats.

The applicator is responsible to have an operational and auditable Quality Control and Assurance program in place.

The applicator shall have full time and identifiable supervision on site at all times.

Total overall coating thickness including the hot dip galvanizing once finished will be about 450µm.

### A COMPREHENSIVE COATING SYSTEM!



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## ACKNOWLEDGEMENTS

The following companies and persons are acknowledged for their respective contributions:

- Page 13 *General and continuously galvanized signboard support channels (2011): Strutfast (Pty) Ltd., Johannesburg.*
- Page 16 *Abrasive blast cleaning for different coatings (2013): Iain Dodds (Ex Cape Galvanising), Cape Town.*
- Page 19 *What is cathodic protection and what it isn't? (2012): Gerald Haynes of CTC, Johannesburg.*
- Page 20 *Zinc primers: an overview (2005): Dr Colin Alvey (Ex Corrosion Advisory Technical Services, Randburg, Johannesburg).*
- Page 23 *Effective corrosion control (2013): Iain Dodds (Ex Cape Galvanising), Cape Town, in conjunction with Jan van Eijnsbergen & Chandler & Bayliss.*
- Page 25 *Painting galvanized steel (2011): Iain Dodds (Ex Cape Galvanising), Cape Town.*
- Page 27 *Duplex coating good after 14 years (2014): Aecom Bellville, Cape Town.*
- Page 29 *The difference between hydrogen and strain-age embrittlement (2014): American Galvanizers Association, Technical Department. Authored by Bernardo A. Duran III.*
- Page 31 *Placing hydrogen embrittlement of fasteners in perspective (2012): Prof Waldo Stumpf, Department Materials Science and Metallurgical Engineering, University of Pretoria.*
- Page 34 *Medupi Power Station Chimneys: thermal zinc metal spraying of plate girders (2011): Robor (now Monoweld) Galvanizers*
- Page 36 *The use of hot dip galvanizing in mining in Southern Africa (2014): Terry Smith Ex Technical Marketing Director, Hot Dip Galvanizers Association Southern Africa.*  
*With acknowledgement of: Bob Wilmot, Ex Executive Director HDGASA; Walter Barnett, Past Executive Director HDGASA (Deceased); Bob Andrew, Consulting Value Engineer and Honorary Life Member of HDGASA; Koos Viljoen, Petro SA and Richard Rood of KBR; Thinus Schmidt of Anglo Coal; Anglo American, Anglogold Ashanti and Amplats (Anglo Platinum Management Services).*
- Page 47 *Construction of the South African Police Service control centre (2012): Neal Fisher of The Matrix Urban Designers and Architects.*
- Page 49 *House Taylor, Ballito Bay, KwaZulu Natal: A commitment to hot dip galvanized steel (2012): Charles Taylor of Charles Taylor Architects as well as Linda Ness of NJV Consulting.*
- Page 51 *MTN Headquarters Buildings: Phase 1 and 2 (2005): Aurecon and MTN*
- Page 53 *House Rooi Els: A commitment to duplex coating systems (2010): Elphick Proome Architects; Linda Ness of NJV Consulting; Contractor – Branbild (Pty) Ltd; Fabricator – Apocalypse cc; Galvanizers & Paint Applicators – Cape Galvanizing (Pty) Ltd; Paint Manufacturer – Sigma Coatings.*







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