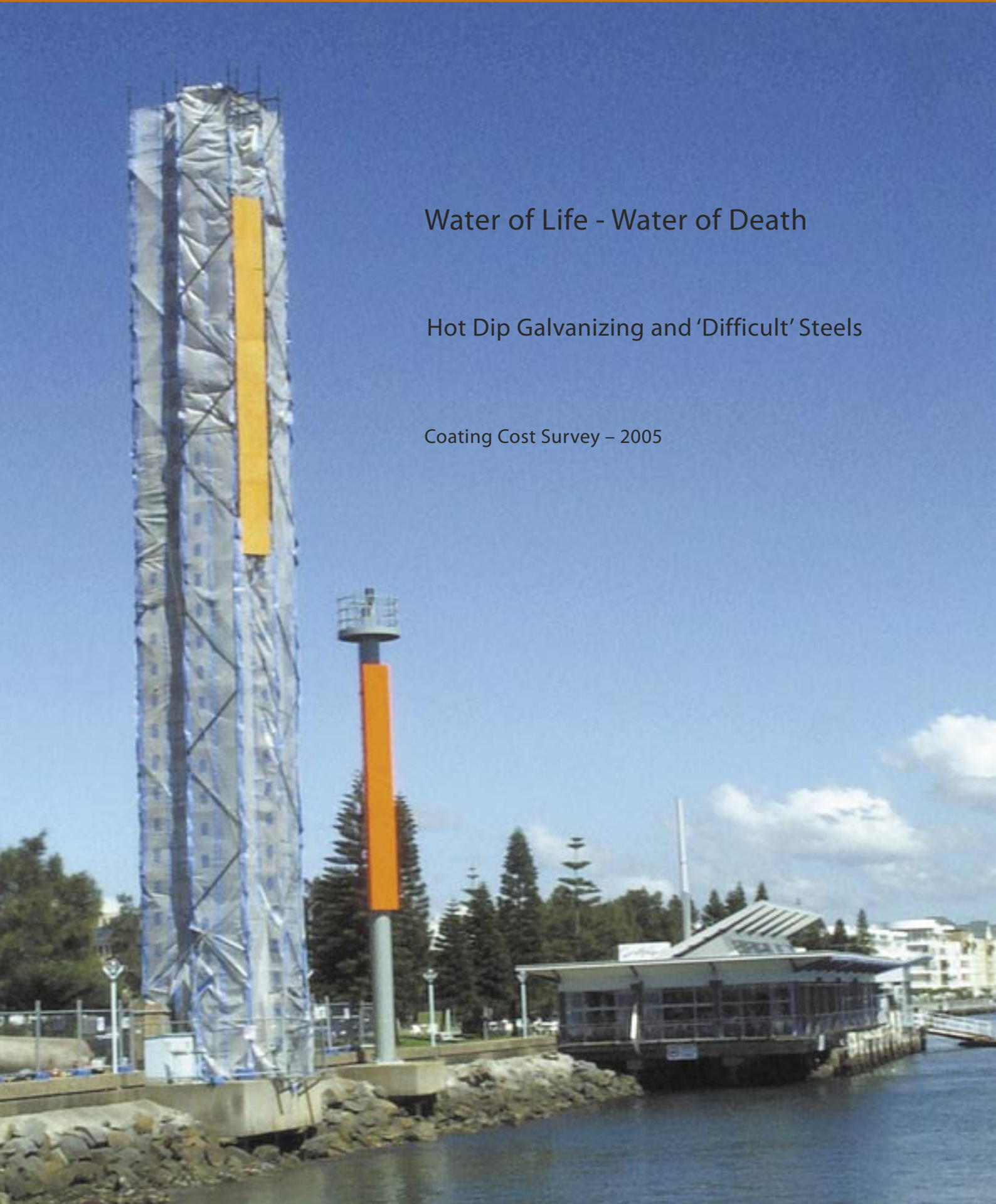


Water of Life - Water of Death

Hot Dip Galvanizing and 'Difficult' Steels

Coating Cost Survey – 2005





It's time we galvanized your opinion of steel poles.

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CORROSION MANAGEMENT

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

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COVER:

The repainting of one of the main navigation towers on Newcastle Harbor (NSW) required full containment with positive air extraction because of its public space location in Newcastle's popular Harbor Foreshore area. The project was undertaken by KGB Protective Coating, who specialises in environmentally sensitive painting projects.
Contact: 02 4969 4533
Mob: 0400 694 533.

PUBLISHER:
Industrial Galvanizers Corporation Pty Ltd

EDITOR:
John Robinson
312 Pacific Highway
Hexam NSW 2322
Ph: +61 2 4967 9088
Fax: +61 2 4964 8341
Email: jrobinson@indgalv.com.au
www.indgalv.com.au/cmmagazine

DESIGN:
MAP Marketing
Villa Franca, 2 Scott St
Newcastle NSW 2300
Ph: +61 2 4929 7766
Fax: +61 2 4929 7827
Email: maria@mapmarketing.com.au
www.mapmarketing.com.au

ADVERTISING:
MAP Marketing
Villa Franca, 2 Scott St
Newcastle NSW 2300
Ph: +61 2 4929 7766
Fax: +61 2 4929 7827
Email: maria@mapmarketing.com.au
www.mapmarketing.com.au

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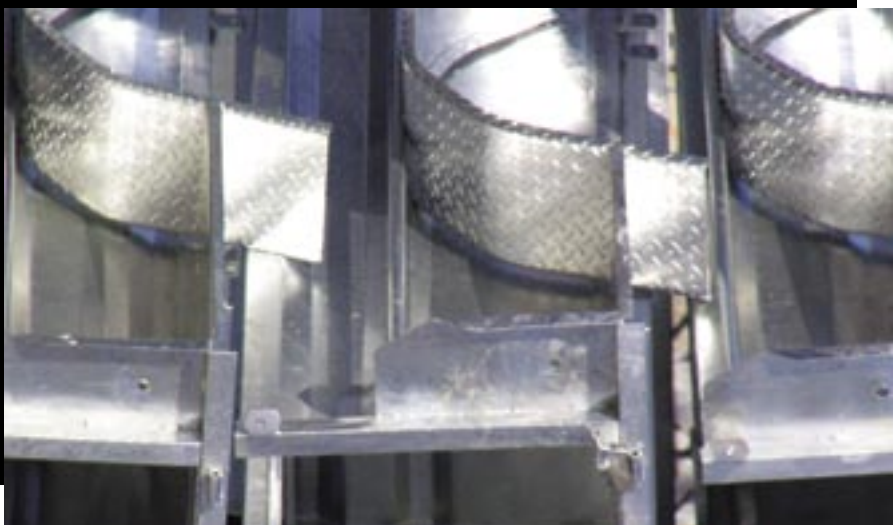


These refurbished bridge rails have been Sa Class 2 abrasive blasted prior to hot dip galvanizing.

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MANUFACTURING

INGAL CIVIL PRODUCTS – www.ingalcivil.com.au

- Head Office – Ingal Civil Products
Ph: 02 9710 5555 Fax: 02 9542 3667

- Brisbane
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- Head Office
Ph: 03 8551 2456 Fax: 03 8551 2454
- New South Wales
Ph: 02 9997 8555 Fax: 02 9997 7546
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- Western Australia
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- Queensland
Ph: 07 3323 2555 Fax: 07 3344 5422
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Ph: 02 6247 4555 Fax: 02 6247 4777
- Tasmania
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John Robinson - Editor

E D I T O R I A L

Corrosion Management staff periodically survey protective coating costs and this has again been done in 2005. While there are some regional variations, there are national trends that are reasonably consistent.

Like many other industrial services, the cost of protective coatings has been impacted by the robust level of construction in the mining and energy industries, the shortage of skilled labour, and increased input costs driven by rising commodity prices. This is an added incentive for specifiers to 'do it right the first time' and ensure that the protective coating systems used last as long as possible.

A steel coating technology that was used extensively in Australia in the 1970s and early 80s was metallising, or metal spraying. Zinc or aluminium, or a combination of both, is used to spray molten metal onto cleaned steel surfaces. Many pipelines and large structures were protected in this way.

The advent of large galvanizing baths, and the use of inorganic zinc rich paints as primers almost eliminated the use of metal spraying in Australia as a protective coating technology. It remains a very effective long-term coating technology and is more widely used in Europe and New Zealand.

In this issue of Corrosion Management, we review the latest development in metal spraying as a method of protecting steelwork from corrosion.

Water is the vital ingredient for all living things, and is also the major participant in most metal corrosion, either as H₂O or as the vehicle that allows the electrons associated with other compounds in the water to obey the universal laws of entropy that work to return metals to the earth.

While the presence of water makes corrosion of metal inevitable, an understanding of the chemistry of water and how this impacts on the performance of metals and their coatings, allows the durability of these materials to be better managed.

This issue of Corrosion Management investigates the impact of water and its constituents on the durability of steel, as well as its behavior in contact with protective coatings, and zinc coatings in particular.

Alternative methods of dealing with corrosion are always of interest, and sometimes, well-established technologies will still provide outstanding performance in difficult environments. Wrapping tapes are one such example. Developments in wrapping tape systems now allows

wrapping tape solutions to be applied to a wider range of structures with the option of more aesthetic end-results, compared with the petrolatum systems used originally. The current state of the art is covered in this issue.

This is the final issue of Corrosion Management for 2005. The magazine has now in its 14th year and will continue to deliver practical information on the performance of coatings and materials to our readers.

One observation that we have made, particularly in the 21st Century, is that there is a less tolerant attitude amongst clients and asset owners to coating failures, and litigation is now the first resort rather than the last, if durability problems arise that are deemed to be caused by incorrect specification or application.

More focus on durability issues at undergraduate level in the relevant disciplines, and a focus on durability issues at professional development level by the professional institutes will hopefully allow those involved in the design and construction of steel structures to stay out of court.

Water of Life – Water of Death



Marine exposure – salmon farm pens in southern Tasmania. High corrosion rate of the galvanized steel in the splash zone on these structures limits coating life to less than 10 years in this type of water.

**Corrosion Management would like to acknowledge the considerable assistance given by Dr David Nicholas, Principal Materials Engineer for Hunter Water Corporation's consulting division, Hunter Water Australia, in the preparation of this article. Additional advice and assistance related to microbiological corrosion issues has been provided by Dr Robert Jeffrey, Director of Pacific Environmental Testing Services, and Reza Javaherdashti Senior Corrosion Engineer Extrin Corrosion Consultants.*

INTRODUCTION

The importance of water to all living things on the planet hardly needs to be expanded here. However, when it comes to corrosion, water is one of the principle participants, particularly with respect to the corrosion of metals.

Corrosion Management staff has frequent requests from readers seeking information on how materials will perform in contact with water. This can range from rainwater through ground water or process water to sea water, in its various forms.

Like all materials, the constituents of the water will determine its effect on the materials with which it comes in contact, but the effect of one type of water on a material like steel may differ from water with the same chemistry in contact with zinc-based coatings.

The use of various indices to assess the corrosion rate of metals and materials in water systems is probably one of the most misunderstood and misinterpreted issues in the corrosion control industry. The following should help to make some of the issues at least a bit clearer. Note, however, that some of the corrosion mechanisms themselves are complex and incompletely understood and that 'corrosivity' itself varies from material to material.

WATER CLASSIFICATION

1. Drinking Waters

By drinking (or potable) waters we generally mean those reticulated 'town' supplies which provide the majority of Australians with their water supply. The following should be considered when assessing the 'corrosivity' of various water supplies:

- In general, softer waters are more corrosive than harder, scaling supplies, but in Australia the latter are less common. For waters that meet the Australian Drinking Water Guidelines (ADWG), most would corrode bare steel at about the same rate.
 - Materials such as galvanized steel, copper, brass, stainless steel and concrete all have quite different corrosion or degradation mechanisms and a universal application of 'corrosivity' can be quite misleading. Virtually all the common materials corrode through a localised rather than general corrosion mechanism, i.e. there is a tendency to pit.
 - The use of the various saturation indices' such as Langlier Saturation Index (LSI) and the Calcium Carbonate Precipitation Potential (CCPP) can be particularly misleading. These are not corrosion indices and are incapable of predicting metallic corrosion rates, although they do have some use as water treatment targets to ensure a reasonably stabilised, buffered supply that does not unduly affect cement mortar linings on steel and cast iron pipes.
 - Although low pH (acidic conditions) would seem to be a 'worst case' for corrosion, high pH can be just as troublesome for some materials such as copper and brass and even galvanized steel. For copper, this may be related to complex issues with Microbiologically Induced Corrosion (MIC). High pH often reduces the effectiveness of disinfection that may promote MIC. For some materials such as galvanized or aluminium structures, high pH can increase the corrosivity quite significantly.
- High levels of disinfectants such as chlorine or chloramines may negatively impact on the performance of some materials, including some elastomers and plastics. Chloramines can be particularly aggressive to some elastomers. The normal levels of disinfectant associated with reticulation supplies generally have minimal impact on common pipe and plumbing materials.
 - Chlorides, in the range normally found in ADWG waters, have relatively little effect on corrosion rates of most materials. The exception is stainless steel where crevice corrosion can and does lead to major corrosion issues if the design, grade and fabrication techniques are not properly considered.
 - Note that in Australia there is very little unlined cast iron or steel water mains. Factory cement mortar linings were available in the mid 1920's and this is in stark contrast to Europe and the USA where reticulation systems still contain large amounts of unlined pipe, which has led the USA to add corrosion inhibitors and other corrosion control measures. Inhibitors for other forms of corrosion control are not used here due to the fact many of these are phosphate-based which have a negative environmental impact on the wastewater side of the water cycle.
 - A water treatment that is widely used in soft, unbuffered supplies is lime/ carbon dioxide dosing. This effectively raises the alkalinity and promotes a more stable, buffered supply that resists wide fluctuation in pH and helps to provide stable operating conditions.
 - Rainwater tanks can give significant corrosion problems particularly with copper and copper based alloys. Some rainwater can have pH levels as low as 4.5 and can be particularly corrosive in a range of plumbing items such as hot water systems.

2. Mine and Ground Waters

- Mine waters have significantly higher Total Dissolved Solids (TDS) when compared to drinking water, usually including large amounts of chloride and sulfate. These amounts can vary widely but, at their extreme, mine waters can have chlorides exceeding 10,000mg/L and a pH of 4. They can be extremely corrosive and need to be assessed on a case-by-case basis.
- Again, the LSI and CCPP are often used to try and assess mine waters corrosivity. This is also used for ground waters, reflecting the desire to use alternative water supplies to augment the surface supplies. Computer programs (eg 'Staysoft', AWWA) developed for calculation of the saturation indices do not work for highly saline mine waters and should not be used as the results will be largely meaningless.

- If required, a quantitative or semi-quantitative corrosivity of mine waters can be assessed using electrochemical techniques such as Linear Polarisation Resistance (LPR). These methods are material-specific but the technique can be successfully applied to individual mine waters.
- For ground waters (including some drinking water supplies) the important and often neglected issue is that of dissolved gases, particularly carbon dioxide which results in the lowering of pH. Free, or aggressive, carbon dioxide can accelerate corrosion of copper, zinc and concrete to a significant degree and can cause relatively quick failure in water supply systems.

3. Sea Waters

- To some degree, seawater is better understood than other forms of water. This is largely because it is always assumed to be corrosive and therefore attention needs to be made to proper materials selection. This is a good example where corrosive water can be misleadingly classified as non corrosive if the LSI and CCPP were only considered i.e. seawater has a positive LSI and a high CCPP.
- Nevertheless, there are localised differences in seawater. Fresh, flowing, unpolluted seawater is less corrosive to some grades of stainless steel than stagnant, polluted supplies where MIC can be a significant corrodent. Well-made concrete, however, usually performs well as does copper and some timbers.



The white areas are steel that has been 'pickled' by acidic microbiological excretions in a cooling water tank. MIC has corroded over 1 mm of steel in less than 2 years.

GALVANIZED STEEL AND WATER

Australia has one of the highest levels of consumption of galvanized steel per head of population in the industrialised world. The use of galvanized sheeting started here in the 1850's and remains one of the most widely used construction materials for roofing and cladding.

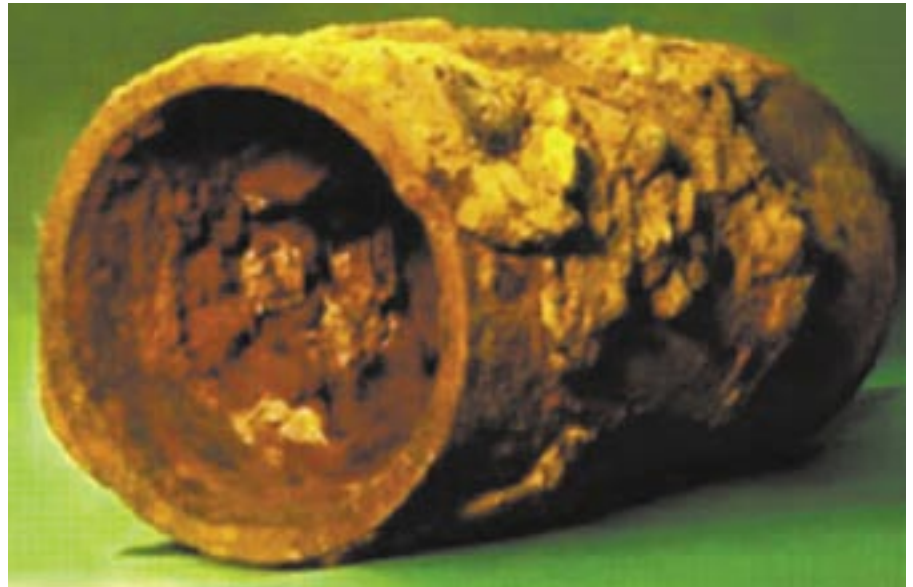
It was used almost universally for roofing and rainwater tanks for a century or more in regional Australia, and its performance has been well documented.

While not readily understood, pure water is highly corrosive to zinc coatings. Zinc needs an oxide film to provide it with its very good atmospheric durability. This oxide film is a complex zinc carbonate, generated through the action of the zinc with atmospheric carbon dioxide or appropriate carbonate salts.

Pure water contains no dissolved salts and it reacts with zinc to form zinc hydroxide – a white, bulky and unstable oxide film. In the ongoing presence of pure water, the reaction will continue until all the zinc is consumed.

This was identified in galvanized rainwater tanks, where premature failure had occurred. This was traced to new tanks being filled quickly with storm water, which was essentially a large volume of relatively pure water. Tanks filled slowly from intermittent rainfall accumulated more dissolved salts through contact with atmospheric dirt and dust, and thus proved far less aggressive in galvanized water tank applications.

At the other extreme, sea water, with its high chloride levels, is also aggressive to zinc coatings, particularly in splash zones. While the corrosion rate is much lower than that of bare steel in sea water, corrosion rates in the order of 15-20 microns per year are typically experienced. This may result in unacceptably short coating life (5-10 years) with even heavily galvanized sections. It is worth noting that while



Typical microbiological corrosion in a water pipe.

sea waters are relatively aggressive, they do not behave in the same way as a sodium chloride solution of the same dissolved salt concentration.

The presence of magnesium and calcium ions in seawater has some inhibiting effect and fully immersed sections will typically provide double the coating life compared to zinc coatings exposed to the tidal or splash zone.

Hard waters do not give rise to high rates of corrosion in zinc coatings, and in most cases have a beneficial effect due to the carbonate scaling that occurs on the zinc surface.

EFFECT OF SPECIFIC CONSTITUENTS

Water, by its very nature, is an excellent solvent, and dissolves a large number of elements, compounds and gases that give natural waters their characteristics. Groundwater, rainwater and seawater will all have variable chemistry related to the environment in which it evolves.

The oxygen content of water is an important factor. It will vary widely, according to its source. Most surface waters will have a relatively high oxygen content. Ambient temperatures (around 25°C), water will dissolve around 10 mg/litre of oxygen.

Anions, and chlorides in particular, are most corrosive to zinc in water. The softer the water (the lower in carbonate), the greater the corrosive effect of chlorides. Significant corrosion can occur at chloride levels of 80 mg/l, while little corrosion may occur in hard water with 9 times as much chloride present.

Sulfates will increase the rate of corrosion of zinc but at a much lower level than chlorides. Nitrates do not generally occur at significant levels in natural waters, and levels exceeding 160 mg/l are required to have a significant effect of zinc durability.

Hydrogen sulfide is more likely to occur in groundwater arising from acid sulfate soils. While aggressive to zinc, copper and iron have higher levels of sensitivity to hydrogen sulfide.

WATER RATING INDICIES

Various indices are used to rate water for its tendency to scale or to assess its corrosivity largely with respect to its application in cooling water systems. In general, waters that are prone to scaling are less corrosive than those that are not. Some commonly used indices are listed below.

Langelier Saturation Index

The Langelier Saturation Index (LSI) is an equilibrium model derived from the theoretical concept of saturation, and provides an indication of the degree of saturation of water with respect to calcium carbonate. The LSI is based on the concept of using pH as a main variable. The LSI is thus based on the pH change required to bring water to equilibrium.

The LSI is probably the most widely used indicator of cooling water scale potential. If the LSI is negative, there will be no potential to scale and the water will dissolve CaCO₃. If the LSI is positive, scale can form and CaCO₃

precipitation can occur. If LSI is close to zero, scaling potential is borderline and changes in water temperature or evaporation could alter the index.

For space and simplicity reasons, the formula for calculating LSI has been omitted. It can be found, along with examples on the Corrosion Doctors web site at www.corrosion-doctors.org/NaturalWaters/Langelier.htm

Ryznar Stability Index (RSI)

The Ryznar Stability Index (RSI) correlates an empirical data set derived from municipal water systems to the water chemistry. The RSI can be calculated from the following equation:

$$RSI = 2 (\text{pH}_s) - \text{pH}$$

Where:

- pH is the measured pH of the water and;
- pH_s is the pH at saturation in calcite or calcium carbonate.

If:

- RSI is 6 or lower then scale tendency increases as the RSI decreases.
- RSI is 7 then calcium bicarbonate formation does not produce a protective corrosion inhibiting film.
- RSI is 8 or higher, corrosion of steel (and zinc) becomes an increasing problem.

Larson-Skold Index

The Larson-Skold Index rates the corrosivity of water to mild steel. The Larson-Skold Index is based on evaluation of in-situ corrosion of mild steel lines transporting Great Lakes (North America) water. The Larson-Skold Index is the ratio of equivalents per million (epm) of sulfate (SO₄²⁻) and chloride (Cl⁻) to the epm of alkalinity in the form of bicarbonate plus carbonate.



These corrosion nodules have formed on a galvanized cooling water tank and are typical of microbiological corrosion. The water treatment additives in this system have contributed to the accelerated MIC activity.

The Larson-Skold Index has been correlated to observed corrosion rates and to the type of attack of Great Lakes waters, which are typical of a significant preponderance of other waters around the globe. Water with low or extreme alkalinity will usually be outside the LSI model.

The Larson-Skold Index is considered a reliable measure of appropriateness of corrosion inhibiting programs that rely on natural alkalinity and film forming capabilities of water used for cooling purposes.

Larson-Skold Indices of the following levels can be interpreted as:

- Larson-Skold Index 0.8 Chlorides and sulfates will probably not interfere with natural film formation.
- Larson-Skold Index 0.8 – 1.2 Chlorides and sulfates will probably interfere with natural film formation and higher corrosion rates can be anticipated.
- Larson-Skold Index 1.2 + High corrosion rates can be expected.

MICROBIOLOGICALLY INDUCED CORROSION

Microbiologically Induced Corrosion (MIC) is a significant problem in many applications where metals are in contact with water. There are many types of bacteria that can colonise metal surfaces if water conditions are favourable. The more aggressive species of bacteria are anaerobic and prosper in oxygen deficient conditions.

Stagnant water in fire service pipework or tanks can create favorable conditions for the MIC. In some cases, bacteria that develop in aerobic conditions can create biofilm that then provide a habitat under the films that favour the anaerobic species.

The steps in biofilm formation are:

1. Conditioning film accumulates on submerged surface.
2. Planktonic bacteria from the bulk water form colonies on the surface and attach themselves to the surface by excreting exopolymer.



Hard water such as the process water used in North Goonyella coal treatment plant causes scaling on galvanized coatings, which have still retained their original thickness (over 100 microns) after 12 years of operation.

3. Different species of sessile bacteria replicate on the metal surface.
4. Microcolonies of different species continue to grow and eventually establish close relationship with each other on the surface. The biofilm increases in thickness and the electrochemical conditions beneath the biofilm begin to vary in comparison with the bulk of the environment.
5. Portions of the biofilm slough away from the surface.
6. The exposed areas of the surface are recolonised by planktonic bacteria.

Gradual formation of biofilms can change chemical concentrations at the surface of metal substrate significantly because the physical presence of biofilm exerts a passive effect in the form of restriction on oxygen diffusion to the metal surface and the development of differential aeration or chemical concentration cells. Active metabolism of the micro-organisms, on

the other hand, consumes oxygen and produces organic and inorganic acids as metabolic by-products. This micro-organism-assisted transformation of inorganic chemicals into corrosive by-products such as sulfides under oxygen-free conditions can lead to highly aggressive corrosion attack on iron-containing metals.

The impact of MIC on critical components has led to much more work being done in recent times to enhance the understanding of the conditions in which MIC can prosper.

CONCLUSION

The role of water in metal corrosion is well established, and an understanding of water chemistry and the effect of the constituents that activate corrosion when in contact with materials of construction; particularly iron and steel and galvanized coatings, allows the durability of these materials to be better managed.

Metal Spraying – High Performance Protection for Steel

INTRODUCTION

The spraying of molten metal onto steel to protect it from corrosion was first done in the 1930s to protect steel bridges in the USA and the UK. Zinc metal spraying in Australia was widely used in the 1960s and 1970s in particular on major infrastructure projects.

Transfield was a leader in this field with a large metal spraying facility at its Seven Hills, NSW site, used to process large steel power transmission structures and pipelines. Some specialised coating companies offer metal spraying services to Australian industry in most major centres.

The commissioning of large structural galvanizing plants from the late 1970s, saw the use of zinc metal spraying decline in Australia, because of the lower cost and similar performance of hot dip galvanized coatings.

In other countries, the technology is more widely used, and remains a very effective method of protecting steel structures from corrosion, where maximum durability is required in difficult environments.

An advantage of metal spray systems is that very heavy zinc or alloy coating can be applied to large complex fabrications that cannot be effectively coated by other methods. Metal spraying has proved very successful in items such as submerged trash racks and flow control gates in water storages, where regular access for maintenance is not possible.



Flamespray MK 73 gun uses a gas flame to melt the metal feed wire.

THE PROCESS

Metallising is done by liquefying zinc wire or dust in a gas flame or electric arc and propelling it with compressed air onto an abrasive blasted steel surface. The metal droplets adhere to the surface and each other to form the coating.

The bond between the coating and the steel is essentially mechanical and requires a surface profile of 75-100 microns to an AS 1627 Class Sa3 (the highest – white metal) level of cleanliness.

Aluminium and zinc-aluminium alloy (85% zinc – 15% aluminium) can also be used, particularly for marine exposures.

For zinc metallised coatings, the coating has a white appearance due to the zinc oxides formed during the melting process. Metal sprayed coating also have a rough, abrasive feel cause by the discreet droplets of metal forming the surface of the coating.

Access issues are similar to those associated with industrial paint coatings. Internal surfaces and narrow gaps between elements of fabrications may not be accessible for metal spraying.

Aluminium Wire

Sprayed aluminium is preferred for use in industrial environments, especially where there are high concentrations of sulfur dioxide and other pollutants. Arc sprayed aluminium has a relatively high bond strength even over marginally prepared surfaces.

- Aluminium pH range is 4 to 11.
- At elevated temperatures up to about 1100° F (590° C); for example, on the fire side of fossil fuel boiler tubes.
- Applications include steel pilings above and below the mud and water lines; in marine atmospheres, offshore oil platforms, ship chain lockers, fish holding tanks; U.S. Navy applications are too numerous to mention.

Zinc Wire

Zinc provides greater galvanic protection than aluminium. Its greater electrochemical potential with respect to steel protects gaps in the coating better than pure aluminium. It is marginally easier to spray pure zinc than pure aluminium by flame or arc spray systems.

- Zinc pH range is 6 to 12.
- Zinc should not be used in immersion service at temperatures above 140° F (60° C).
- Applications include steel bridges, the inside of potable water tanks, power transmission and communication towers, buried iron pipe. Zinc is used in combination with galvanizing to avoid double dipping, and for general repair of galvanized steel.
- A relatively new use for thermal sprayed zinc is for cathodic protection of rebar set in concrete. There are two systems which use the sprayed zinc; one relies on an impressed electrical current, and the other is passive or

galvanic. This is a special application and requires a certain level of expertise.

Zinc Aluminium Wire (85/15)

Zinc - 15% aluminium wire combines the benefits of pure zinc with the benefits of pure aluminium in the metallised coating.

It is very often used as a substitute for pure zinc because it is somewhat more chloride and sulfur dioxide resistant than pure zinc, while retaining the greater electro-chemical activity of pure zinc.

APPLICATIONS

A metallised coating system is designed for a particular application and service environment. Commonly, a metal coating of 150 to 200 microns will provide very long service life. The metal coating thickness may vary so that a coating of 250 microns of zinc may be specified for the inside of a potable water tank, while a coating of 375 microns of aluminium may be specified for certain high temperature applications, such as valves and boiler tubes.

In the case of structural steel, with a ten-year inspection cycle and minor periodic maintenance by re-sealing, a sprayed metal coating can provide an indefinitely long service life well in excess of 30 years. When maintenance is finally required, it may not be necessary to completely remove an intact metallised coating by abrasive blasting.

Metallising may also be compared with hot dip galvanizing. The two metallic coatings are similar in some respects, but metallising has some important differences. Pure aluminium and zinc-aluminium alloys may be sprayed, as well as zinc.

These coatings protect steel better than pure zinc in marine and industrial environments. Aluminium and the zinc-aluminium alloy, 85% zinc with 15% aluminium, are not available by hot dip galvanizing.

When metallising, the surface being coated remains at a low temperature, with local temperature never exceeding about 250-300° F. Because metallising is a "cold process" when compared with hot dip galvanizing, relatively thin steel sections can be metallised without risk of distortion.

Metallised coatings are mechanically bonded to the steel, while galvanized coatings have a metallurgical bond with much greater adhesion. Metallised coatings, while very tough, should be treated with more care in transport and handling that is normally required with hot dip galvanized coatings.

Metal spray coatings can also be applied to non-metallic surfaces and have been applied to wood to for specialised communication applications, and to reinforced concrete on bridges and marine structures to act as an external anode to cathodically protect the reinforcing bar from corrosion.

Application options

There are three types of sprayed metal coating systems. These options are bare metallic coating, sprayed-metal-plus-sealer or sprayed-metal-plus-sealer-plus-topcoat.

The bare metallic coating acts like any standard zinc coating, although the metal sprayed coating is relatively porous, and in its early life, may appear to corrode at a high rate because of the roughness and high surface area of the coating.

The sealed-sprayed metallic coating is often the most economical and is the preferred system of the three metallised coating options. The sealing blocks the pores of the coating and generally enhances its long-term durability.

There are two schools of thought on the use of sealers with sprayed-metal coatings. The first is to apply the sealer after metallising and allow it to act as a passivation barrier for the zinc until the zinc has time to develop its stable oxide films.

No subsequent maintenance is scheduled. Eventually the sealer fails, and once the sealer is gone, the metallic coating corrodes slowly over time protecting the steel like any conventional galvanized coating. The sealer extends the life of the coating for the relatively low cost to apply the sealer. This acts in a similar way to the chromate passivation coating applied to newly galvanized steel.

The second school of thought is to periodically apply more sealer as the sealer weathers, preserving the underlying metallic coating indefinitely.

The addition of one or more paint topcoats is usually a matter of aesthetics. The top coated system also has the shortest maintenance interval, since the paint will require more frequent maintenance than either of the other options. Painting directly over an unsealed sprayed-metal coating is not recommended and properly specified coating systems should be used over metal sprayed coatings.

Sealing

Experience with sealing of metallising in Canada, the UK and by the U.S. Navy found that sealing is necessary to resist chloride attack in marine environments. Decades of experience in the UK has found that sealing is necessary but painting over sprayed-metal is not. All metallised coatings used by the U.S. Navy are sealed.

Cost

Metallised coatings are at the premium end of the cost curve. In Australia, the specialised nature of the application and the lack of dedicated facilities to handle large projects makes metallising a relatively costly option, compared to hot dip galvanizing for high performance industrial painting systems.

The need to blast the steel to a Sa Grade 3 level is a significant cost – typically considerably exceeding \$15.00/m² on structural steel. The rate



Zinc metal spraying of large structural sections is a cost effective method of applying a metallic zinc coating to steelwork too large to galvanize.

at which the metallised coating can be applied is determined by the power input to the spray equipment and the skill of the operator.

Deposition rates for zinc metallised coatings can range from 30 kg/hour to 50 kg/hour, although automated systems using more advanced spray unit designs may exceed this. An operator applying 30 kg/hour, considering some overspray losses, will coat approximately 20-25 m² of steel surface to a coating thickness of 150 microns at a material cost of about \$3.00 - \$4.00/m². Average Australian zinc metal spraying costs are in the order of \$40-50/m².

An advantage of metallising over industrial paint systems is that it is weather independent, and is generally a single-coat system that is 'ready to use' immediately after it is applied. The aesthetic options are limited, however.

STATE OF THE ART

In researching this article, considerable assistance has been provided by UK company, Metallisation Ltd - one of the major international suppliers of metal spray equipment.

Metallisation has developed highly efficient electric arc-based metal spraying equipment designed to maximise productivity. An example is the Arcspray 170 system, designed to complement Metallisation's existing Arcspray systems. This new system will offer users shorter spray times, minimum downtime and reduced material costs.

A benefit of the Arcspray 170 is a 10 metre push/pull system for 1/8" (3.17mm) and 3/16" (4.76mm) anti-corrosion wires, which provides the longest reach 3/16" system for hard to access areas. This saves time having to move material when spraying large items. As all the wire is used with a push/pull system, it is more efficient as fewer reel changes are required when dispensing from small reels.

The new system is being designed for anti-corrosion applications, particularly large structural corrosion protection applications, such as off-shore platforms, ships, pipes, vessels and bridges. The marked increase in spray rate provided by the Arcspray 170 enables items to be sprayed more quickly. Larger diameter wires and improved deposit rate, through the use of larger wires, improve material usage efficiency.



Metal spraying technology can be used with a wide range of metals for other than corrosion prevention. This application is building up a worn area on a shaft with wear resistant material.

In the Metallisation Arcspray process, the raw material, a pair of metal wires, is melted by an electric arc. The molten material is atomised by a cone of compressed air and propelled towards the work piece. This spray solidifies when it hits the surface of the work piece to form a dense coating. In addition to corrosion protection applications, sprayed coatings may also be used to build up worn parts, provide wear resistance, or enhance electrical and thermal conductivity.

Metallisation also supplies metallisation spray equipment that uses a gas flame rather than electric arc to melt the feed material, marketed under its Flamespray banner.

In this Flamespray process, the raw material, which is in the form of a single wire, cord or powder, is melted in an oxygen fuelled gas flame. The molten material is atomised by a cone of compressed air and propelled towards the work piece.

A CASE STUDY – CORROSION UNDER INSULATION

A recent project for Metallisation customer, Coastguard, in the UK, using Metallisation's MK73 Flamespray pistols, was at the Esso refinery at

Fawley, owned by ExxonMobil, that is the largest in the UK and one of the most complex in Europe. Situated on Southampton Water, it is a modern marine terminal that handles around 2,000 ship movements and 22 million tonnes of crude oil and other products every year.

Coastguard was recently selected by ExxonMobil Chemical to apply thermal sprayed aluminium (TSA) in order to combat Corrosion Under Insulation (CUI) problems. Typically equipment is coated with TSA during normal routine maintenance turnarounds when the process units are shut down. However, Coastguard applied TSA onto live equipment in order to eliminate any loss of production.

The process to repair and refurbish live equipment followed the same stringent working procedures used during routine maintenance turnarounds but with enhanced safety precautions to mitigate any risk from working on live equipment.

Approximately 200-250 microns of TSA was applied with the Metallisation MK73 system after removal of the external weatherproofing jacket and insulation, full visual and ultrasonic thickness inspection and surface preparation to a minimum of SIS SA

2.5. A coat of Leigh's paint sealer, L574 zinc phosphate, was applied to extend the life of the TSA prior to re-insulation and re-jacketing.

The application of TSA offers great benefits where CUI occurs. Because of the severe consequences of a failure in high pressure pipes and vessels, the maintenance costs are very high, as the insulation must be removed regularly in order to perform inspection. The protection offered by TSA coatings greatly reduces the number of inspections required and life cycle costs are significantly reduced.

(Further information on Metallisation Ltd's products contact +44 (0)1384 252 464 or visit the web site at www.metallisation.com)

Coating Cost Survey – 2005



Chemical pretreatment facilitates surface preparation for complex shapes, with costs almost an order of magnitude lower than mechanical pretreatment processes.

INTRODUCTION

Corrosion Management has periodically undertaken a coating cost survey of industrial coatings to give its readers updated information on the typical cost for protecting steel structures and products from corrosion.

Like many other industrial services, material input costs and the favorable supply versus demand situation for services and skilled labour has had a significant impact on industrial coating costs.

While costs may vary regionally and locally, every attempt has been made to provide realistic average costs for commonly used industrial coatings, with the following information gathered from paint suppliers,

applicators and galvanizers from major centres around Australia.

COATING COSTS FOR NEW STEELWORK

The cost of coating new steelwork is made up of a number of factors. These are:

1. The type of steel – size, shape, section.
2. The quantity of steel.
3. The location of the project with respect to the coating provider, the fabricator and the site.
4. The regional cost of labour.
5. The material cost (paint components/zinc/chemicals).

6. The cost of surface preparation (abrasive blasting/chemical/mechanical).

7. The cost of application – number of coats, plant capability, processing time.

8. Logistic costs – inspection, loading, transport, erection.

9. Post erection costs – remediation of handling damage, on-site completion.

For applied coatings (paint, metallising) the surface area of the steelwork and the complexity of the fabrication will be the most significant factors influencing the cost. Logically, thin steel sections with high surface area per tonne will absorb more labour and materials than heavy structural sections.

For example, a 3 mm thick steel section has a surface area per tonne of over 80 m², while a 10 mm section has a surface area of 25 m² per tonne.

For process-applied coatings (hot dip and continuous galvanizing, powder coating), material costs and fixed costs are important, making the profitability of these processes very volume sensitive.

Many of the materials incorporated in coatings are traded as commodities with supply and demand affecting prices above and beyond normal inflationary variations. The following indicative prices are for generic materials used in coating in mid-2005, in commercial quantities

Zinc	\$2.00/kg
Zinc dust	\$2.50/kg
Red oxide zinc phosphate	\$8.50/litre
Epoxy primer	\$8.50 - \$9.00/litre
High build epoxy	\$11.00/litre
Urethane – standard grade	\$10.00/litre
Urethane GP3 grade	\$15 - 20+/litre
Polysiloxane	\$30+/litre
Acrylic – water based	\$8.00/litre
Acrylic – catalysed	\$12 - 15/litre

NOTE: There are many proprietary coatings available that may cost in excess of \$100/litre. The use of these is generally confined to specialised industrial applications where high temperatures, severe corrosion or abrasion conditions prevail.

Paint coatings

The true material cost of paint coatings is determined by how much of what is in the can ends up on the steel surface. This is determined by the volume solids in the paint, the applied thickness of the coating and the coating efficiency (over-spray losses).



Abrasive blasting costs have increased at a greater rate than other material costs for industrial coatings.

Low volume solids will result in higher losses due to solvent evaporation. Simple solid structures (beams, tanks) will experience higher coating efficiencies that open structures (pipe work and trusses).

One litre of paint, applied to a wet film thickness of 100 microns will theoretically cover 10 m² of surface. In practice, the same paint applied to a dry film thickness of 100 microns, to medium structural steel by airless spray will cover approximately 5m².

All paint suppliers have product safety data sheets for each of their paints. These documents list technical specifications for the paint, including volume solids, recommendations for wet and dry film thickness requirements and theoretical coverage.

In addition to the paint cost, most solvent-based spray applied coatings require the addition of thinners, typically around 30% by volume) which becomes a component of the paint material cost.

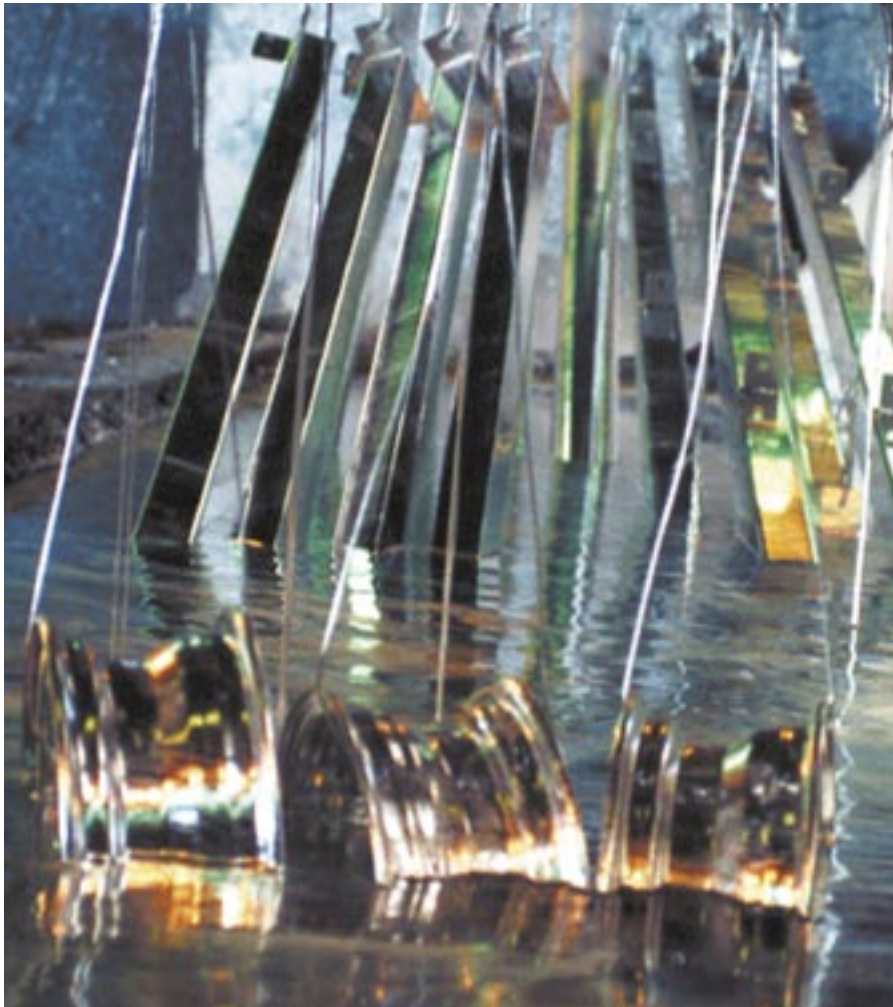
An important point to note is that the paint cost is a relatively small proportion of the applied system cost. Based on a typical practical coverage rate of \$5.00/m², the cost differential between a basic industrial epoxy or urethane and a high performance urethane or polysiloxane is in the order of \$3.00-\$4.00/m².

The most significant single cost in paint coatings is surface preparation. Abrasive blasting is almost mandatory to ensure acceptable performance for industrial paint systems.

Fabricated steelwork is usually abrasive blasted with chilled iron shot, in a chamber that allows recovery and recycling of the blasting media. Abrasive blasting standards are defined in Australian Standard AS 1627.4. Class 2 ½ Blast is most commonly specified for industrial coating, with Class 3 (the highest level) being a requirement for specialised coatings such as zinc metal spray.

Abrasive blasting costs vary regionally, but generally fall in the \$12.00 - \$14.00/m² range. Large automated blasting facilities using wheelabrator equipment to process columns, beams and plates can significantly reduce this cost.

Where galvanized coatings are to be painted, Class 1 or whip blasting is generally specified. This involves using less aggressive media such as garnet or illmentite, at typical cost ranging from \$8.50 - \$12.00/m², depending on the complexity of the fabrication.



Hot dip galvanizing costs are related more to the shape and mass of the item rather than its surface area. The efficiency (how many kilograms) with which individual components can fit on a galvanizing jig is a major cost determining factor.

Chemical preparation (pickling, phosphating) is rarely used as a method of preparing fabricated steel for painting, and is confined to process applied coatings such as powder coating and galvanizing.

Powder coating costs are usually charges on a 'window area' basis rather than surface area, as the area the item takes up on the powder coating line is the main factor in its cost of processing. For standard grades of polyester powder, powder coating costs are typically \$10.00 - \$14.00/m², although large quantities of uniform manufactured product that can be loaded to high line efficiencies can be powder coated at lower cost.

With all costs included (labour, overheads, margins) indicative industrial painting costs for commonly specified systems are:

1. Basic wire brush/Class1 blast and ROZP prime \$10.00/m².
2. Class 2 ½ blast + inorganic zinc primer \$20.00/m².
3. Class 2 ½ blast + inorganic zinc primer + epoxy topcoat \$28.00/m².
4. Class 2 ½ blast + inorganic zinc primer + urethane \$35.00/m².

NOTE: These are indicative average prices only and will vary regionally and depending on the design of the items being painted.

Powder coatings

Polyester powder coatings are the least costly of the high performance coatings for steel, and have a cost base not unlike that of galvanized coatings. High capital equipment costs are required to set up a powder coating facility, and the revenue is determined

by how many items of products can be processed on a powder coating line in a given time.

Powder coating is best suited for coating standard manufactured products. The size of the items that can be processed is also restricted by the booth and oven dimensions. Polyester powder coatings cost in the order of \$15.00/m² of product area, but will vary depending on the handling requirements and grades of powder specified.

Galvanized coatings

The parameters governing the cost of galvanized coatings are quite different to those determining paint costs.

Continuously applied galvanized coatings applied to sheet, wire and tube are applied in facilities with high capital and operating cost, with large volumes of steel being able to be processed very efficiently.

For this reason, the galvanized coating cost component of these products is relatively small and driven by the material (zinc) cost. In addition, these technologies apply relatively thin zinc coatings – usually less than 30 microns per side for a material cost of about \$0.50/m² of surface.

Continuous galvanizing processes are only used on relatively thin steel sections, with 3 mm being the typical maximum steel thickness involved in these processes, although some open sections up to 6 mm thick can be coated with proprietary processes.

Hot dip galvanized coatings applied to fabricated steelwork are priced on the basis of the tonnage that can be processed through the galvanizing bath. Surface area is thus not as significant in galvanizing costs. Thin sections that can be loaded into galvanizing jigs at high loading density will attract a relatively low galvanizing cost, while 3-D structural fabrications containing heavy universal sections may be more costly to process.

Hot dip galvanized coatings are almost always costed on a \$/tonne basis. Typical galvanizing costs per tonne will range from \$450/tonne for heavy, simple elements such as columns and beams in large project quantities, to \$900/tonne for light fabrications. Items requiring double-end dipping will usually attract a 30% premium cost and small one-off fabrications (boat trailers, wrought iron, anchors etc) for non-account customers will be charged around \$1500/tonne.

The cost per square metre for hot dip galvanizing reduces quite significantly as sections become thinner. The following examples illustrate this:

- Medium structural steel – 10 mm average thickness.
- Galvanizing cost: \$550/tonne.
- Surface area per tonne: 25 m²/tonne.
- Cost/m²: \$22/m².
- Light fabrications - 3 mm average section thickness.
- Galvanizing cost: \$900/tonne.
- Surface area per tonne: \$85 m²/tonne.
- Cost/m²: \$10.60/m².

A fringe benefit of hot dip galvanizing, because it is an immersion process, is that all internal surfaces of hollow sections are coated uniformly. This may be an advantage or disadvantage, as the external surface area of a hollow section is only half that of an open section of the same section thickness.

Another fringe benefit of hot dip galvanizing compared to both paint coatings and continuously galvanized coatings is that the applied coating thickness almost always in excess of Australian Standard requirements, as the metallurgy of the process in the major controlling factor.

This is a bonus for the customer, as additional zinc pick-up on steelwork cannot be accurately predicted by the galvanizer, as it is influenced by the surface condition, section thickness and chemistry of the steel. It can add \$25-\$50/tonne to the galvanizer's material costs, with the added bonus for the customer of the extra zinc addition proportionately to the service life of the coating.

Metal sprayed coating

Applicators for these types of coatings in Australia are usually associated with the larger industrial painting companies because of the surface preparation requirements for the process. The cost of zinc metal-sprayed coatings is in the order of \$40-50/m². The sealing costs will be additional.

A major element on the cost of metal sprayed coatings is the requirement to apply them over steel abrasive blasted to the highest level of surface preparation – Sa Class 3 – which is a major component of the coating cost (\$15-20/m²).

CONCLUSION

The cost of fabricated structural steel averages \$3000/tonne or more, excluding its protective coating. Thus, the protective coating system will represent around 20-25% of the ex-workshop cost. The cost of high-performance coating systems add in the order of 10% to the cost of the finished steelwork, compared to basic coating systems.

In most cases, the higher cost, high performance coatings will always offer the best value in any life cycle cost analysis.



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Better than Band-aids – Wrapping Tape Solutions for Steel Protection

INTRODUCTION

Those who have worked in heavy industry will have encountered the humble petrolatum wrapping tape, used to protect steel plant and equipment, particularly pipes, valves and fittings. While hardly the most aesthetic of protective coating systems, the wax-impregnated bandages have done sterling service over many years in very aggressive environments.

While there are a number of suppliers of wrapping tapes, the company whose name is synonymous with this technology is Denso. The company has been supplying its products in Australia for nearly 40 years, with a manufacturing facility in Melbourne, VIC.

The wrapping tape concept was actually invented in Germany in 1928, which is about the time when Denso came to exist as a brand name for this 'wax impregnated bandage' for the Winn & Coates organisation, which remains in private ownership with the family who started the business over 120 years ago.

While petrolatum-based tape wrapping systems have been continually upgraded over the past 75 years, new forms of corrosion prevention have been developed, that provide better aesthetics along with improved performance.



This gas pipe junction was petrolatum tape wrapped in 1978 and remains in good condition in 2005 in a very aggressive environment, as indicated by the condition of the steel and concrete.

NEW WRAPPING TAPE BASED SYSTEMS.

Where wrapping tapes have traditionally been used on pipe work and similar circular forms, the development of sheet systems opens the applications to structural steel sections as well.

Where the application of maintenance coatings is concerned, the problems of dealing with chloride-contaminated surfaced still exist.

The Denso-recommended solution is to pre-treat the contaminated surface with a product for which Denso holds the license in Australia – HoldTight® 102. This product was developed in the USA by HoldTight Solutions, Houston Texas.

HoldTight® 102 is an additive that prevents flash rusting of wet abrasive- and water-blasted iron and steel surfaces and of dry-blasted surfaces in a pressurized wash down. It is claimed to effectively remove all salts, including chlorides, sulfates, phosphates, nitrates, etc., and other contaminants, including oil, grease, and blast residues. Independent tests done by Texas OilTech Laboratories and other agencies has supported these claims.

The following table is reproduced from the Texas OilTech report.

Sample Number	Removal method	Chloride Content – micrograms/cm ²	
		Before Blasting	After Blasting
1	Dry blasted	170.9	43.5
2	Wet blasted – abrasive + water	488.2	35.9
3	Wet blasted with HoldTight 102	534.4	<1.0
4	Wet blasted with HoldTight 102	1134.3	<1.0

Given a chloride-free surface, the Denso Steelcoat 400 System can be applied to steelwork of any form. It is recommended that residual chloride levels be below 50 micrograms/cm² prior to application of the system.

The Steelcoat 400 System is just that – a system that uses more than one type of Denso product to make up the full protection package, The components are;

- Denso Penetrating Primer.
- Denso Superlight Profiling Mastic.
- Denso Conforming Tape (for complex shapes).
- Denso Ultraseal Tape.
- Denso Acrylic Topcoat or Denso Epoxy Topcoat.

Current cost estimate for material cost only is approximately \$35.00/sqm.

This system is claimed to be highly surface tolerant requiring only that all dirt and salt deposits be removed by fresh water washing or hydroblasting. The Steelcoat system will tolerate slight condensation (eg no free water droplets). Heavy rust or scale should be removed with chipping hammers or power wire brushes to achieve St2 standard, (ISO 8501-1). Where millscale is present, abrasive blasting is required to remove mill scale.

By necessity, the Steelcoat 400 System has to be applied quickly, as the tapes need to be attached over the primed surface while the primer is still tacky – less than 2 hours after application.

The Denso Conforming Tape is used first to cover internal corners on angles and universal sections. Once these areas are covered, the outer protective film is removed from the Conforming Tape, allowing the Ultraseal tape to be applied over the steel surface. The MDS for the Steelcoat 400 System recommends that the Ultraseal tape be cut into 1 metre lengths for application to the steel surface.

This is easy to cut to width and easy to handle and a 25 mm overlap is recommended in a 'weatherboard' configuration on vertical surfaces. One-piece coverage is recommended on horizontal surfaces.

Ultraseal Tape is an acrylic coated non-woven synthetic fibre fabric, coated on one side with a polymer bitumen adhesive compound. It is necessary to topcoat the Ultraseal with either an acrylic or epoxy topcoat, dependent on the application, allowing colour to be added to the installation if required.

Applicators need to be trained in the use of the Denso Steelcoat 400 system, as special lay-up techniques are required on structural sections to ensure effective long-term performance of the system.

A CASE HISTORY

Maintenance problems in very aggressive environments are a challenge for facility owners and protective coating suppliers. Factories operating on a 24/7/365 basis have limited operational windows that allow effective maintenance coating to be done.

One of the most aggressive environments for steel is in hot-dip galvanizing pre-treatment facilities. The environmental conditions prevailing in these facilities include:

1. High atmospheric (humidity) moisture levels in the building arising from hot caustic and zinc ammonium chloride pre-treatment tanks.
2. High chloride contamination levels on steel surfaces arising from fumes from hydrochloric acid pickling tanks.
3. Low pH on most steel surfaces arising from hydrochloric acid fumes reacting with steam/moisture from hot preparation tanks. PH in moisture on superstructure steelwork pH 1 – 3.
4. Limited access. Most severely affected areas are over the pre-treatment tanks. Operational access required 50 weeks per year, usually on at least two shifts per day.
5. Some building design elements such as back-to-back bracing angles are difficult to access for conventional protective coating.

It is extremely difficult to obtain adequate surface preparation in these conditions. Over the past 30 years, traditional maintenance painting systems have not performed well, with some epoxy-based Industrial coatings lasting less than 6 months.

Petrolatum-based wrapping tapes (installed in one plant on pipes and valves in 1978) were found to be still in good condition during an inspection in 2005, where all other coating systems had been maintained or replaced at least 3 times during this period (28 years).

One other potential advantage of using a wrapping tape solution for the maintenance of galvanizing plants and other continuous metallurgical and manufacturing plant structures, is the short mobilisation time needed to set up, and the potential for doing smaller areas at a time when access is available without compromising the performance of the maintenance coating.

S U M M A R Y

One obvious advantage of a tape wrapping system is that 100% uniform coverage is guaranteed, along with a zero % holiday defects. The very thick (up to 3 mm) Denso coating system exceeds the applied dry film thickness of conventional industrial paint coating by an order of magnitude.

The applied cost of the coating will be determined by the application, as factors such as initial surface condition, access and site availability will determine the labour cost component.

The applied cost of Denso systems such as its Steelcoat 400 will almost always be higher than conventional industrial maintenance paint coatings applied on the same project. Asset owners need to evaluate the life-cycle costs of the respective coatings.



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Hot Dip Galvanizing and 'Difficult' Steels

INTRODUCTION

In Australia, over 300,000 tonnes of fabricated steel is galvanized annually. Almost all of this steel is standard grades of structural sections in the strength range from 200 MPa to 500 MPa.

There has been a trend over the past decade for Australian steelmakers to supply higher strength steel as part of their standard product range, with 250 MPa structural grades being upgraded to 350 MPa, and products such as RHS and SHS hollow sections also being made available in higher strength options.

Reinforcing bar strength has also been increased from what was the standard 410 MPa grade to the now standard 500 MPa grade.

Steels in this strength range will generally not give rise to any problems with their being hot dip galvanized, as hydrogen embrittlement problems do not affect steels below about 800 MPa yield strength.

However, cold working of these higher strength steels, or the use of high strength steels in fabrications, can result in embrittlement problems that can compromise the structural performance of the fabrications.

DIFFICULT STEEL TYPES

The most commonly encountered 'difficult' steel in hot dip galvanizing operations is quenched and tempered steel, typically represented in Australia with the Bisalloy range of Q&T steels. The chemistry of these steels is similar to standard medium carbon grades of structural steel, with a carbon equivalent of around 0.5 to 0.6.

It is the heat treatment of these types of steels that give them their high mechanical and wear properties, grades of Bisplate 80 or above are in the danger zone for hot dip galvanizing. It should be noted that it is the hydrogen arising from the pickling acids that gives rise to embrittlement and not the steel's contact with the molten zinc.

Heat treatable grades of high strength steel such as 4140 are also susceptible to embrittlement if they are heat treated to 800 MPa tensile or higher. This type of steel is sometimes specified for holding down bolts and for high se

It is the heat of the process that accelerates the embrittlement in a strain ageing situation, and other process such as welding can precipitate accelerated failure, independent of the galvanizing process.

Punching holes through thick section can also give rise to strain ageing and well established fabrication practices have recognised this, and require reaming of holes after punching in susceptible steels.

Stainless steel is rarely galvanized but may occasionally be inadvertently incorporated into fabrications. Many types of stainless steels are susceptible to liquid metal embrittlement and will fracture under load and their immersion in molten zinc should thus be avoided.



This section of chain fractured after galvanizing. It was found to be high tensile Herculloy-type chain (1200 MPa yield) rather than standard Grade 80 that was specified. The failure is a result of hydrogen embrittlement.



Spectacular hydrogen embrittlement failure of high strength quenched and tempered (1200 MPa) steel drill pipes. Note ungalvanized failed pipe as embrittlement occurs in the pickling process.



Suspected LMAC defect in angle frame with crack propagation from welded corner.

LMAC AND STRUCTURAL STEEL

Liquid Metal Assisted Cracking (LMAC) is a relatively rare phenomenon that occurs with heavier structural sections (universal beams) that have radiused sections cut from the web/flange connection to reduce the depth of the end of the beam. This is commonly called coping.

During the hot dip galvanizing process, cracking of the coped section has been found to occur, with one or more cracks propagating from the flame cut surface into the web.

LMAC problems with galvanized structural steel beams have not been experienced in Australia but have occurred in the USA, the UK and Asia.

Corrosion Management staff has gathered a large amount of recent research data on LMAC that has arisen from work done by steel institutes and galvanizers' associations in these locations. This will be collated into a comprehensive summary of LMAC information for the next issue of Corrosion management (May 2006).

In the preliminary review of this data, the random and relatively rare occurrence of LMAC appears to be associated with the steelmaking process and residual elements that report in the steels that have experienced LMAC problems. While not conclusive at this stage, there is a mounting body of evidence to suggest that electric furnace steels are most likely to experience LMAC,

while blast furnace steels are unlikely to be affected. This ties in with the Australian experience, where all locally made large structural sections are manufactured from steels derived from blast furnace sources.

The flame cutting of the steel, the section thickness of the web and the steel strength grade (MPa) also appear to contribute to LMAC.

S U M M A R Y

There is a good understanding throughout the hot dip galvanizing industry of issues associated with processing 'difficult' steels, specifically those in the higher (over 800 MPa) strength grades. It is possible to hot dip galvanize some of the quenched and tempered steels by avoiding the acid pickling process and abrasive blasting the steel immediately prior to galvanizing.

This has been done successfully on many occasions, with the only limitation being that the surface of the fabrication to be galvanized has to be accessible to the abrasive blasting process.

ASSDA News

Australian Stainless 2005 Reference Manual

The Australian Stainless Steel Development Association (ASSDA) has released the Australian Stainless 2005 Reference Manual – a 200 page technical resource for specifying and buying stainless steel.

The manual is an instantly accessible resource for Australian specifiers and is backed by free technical and supply advice, according to ASSDA executive director Richard Matheson.

“It is a comprehensive guide to sourcing and utilising stainless steel presented in a format which is quick and easy to use,” he said.

The manual uses clear, concise tables and diagrams to present a wealth of technical information on properties, grade selection, surface finishes, design and fabrication. High quality photos and illustrations identify different products, concepts and specifications.

An extensive, up-to-date, buyers’ guide allows rapid sourcing of any stainless steel product or service provider for any industry application – from kitchen splashbacks to yacht fittings.

Published every two years, the manual is an essential publication for architects, engineers, purchasing officers and specifiers connected with the building and manufacturing industries.

The 2005 Reference Manual is available in book or CD format and can be purchased by downloading an order form from the ASSDA website www.assda.asn.au

Low Nickel Austenitic Stainless Steels – ASSDA Technical Note

The most common grades of stainless steel are 304 and 316, which are particularly popular because their austenitic microstructure results in an excellent combination of corrosion resistance, mechanical and physical properties and ease of fabrication.

The austenitic structure is the result of the addition of approximately 8–10% nickel. Nickel is not alone in being an austenite former; other elements that are used in this way are manganese, nitrogen, carbon and copper.

The cost of the common stainless steels is substantially determined by the cost of ingredients. The cost of the chromium that is the essential “stainless ingredient” is not high, but additions of elements that improve the corrosion resistance (especially molybdenum) or that modify the fabrication properties (especially nickel) add very much to the cost.

Costs for nickel have fluctuated from US\$5,000 or US\$6,000 in 2001 to US\$15,000 per tonne in 2004.

Similarly, molybdenum has dramatically increased from approximately US\$8,000 per tonne in 2001 to around US\$50,000 per tonne in 2004.

These costs impact directly on the two most common grades: 304 (18%Cr, 8%Ni) and 316 (17%Cr, 10%Ni, 2%Mo). The impact is most keenly felt in grade 316, which has suffered an increase to its cost premium above 304.



The 2005 Australian Stainless Steel Development Association's reference manual is available on CD on request.

Other grades such as the duplex 2205 (22%Cr, 5%Ni, 3%Mo) and all more highly alloyed stainless steels are also affected.

A common evaluation of corrosion resistance of stainless steel grades is the Pitting Resistance Equivalent (PRE), where this is usually evaluated as $PRE = \%Cr + 3.3 \times \%Mo + 16 \times \%N$. A neat equation, but it is only a guide.

The PRE gives a guide to ranking of grades, but is not a predictor of resistance to any particular corrosive environment. What is apparent is that pitting corrosion resistance can be increased not only by molybdenum, but also by chromium or nitrogen additions. These are much cheaper

than molybdenum. Despite its high PRE factor, nitrogen has limited effect on corrosion resistance because of low solubility, i.e. <0.2%.

The microstructure of the steel is largely determined by the balance between austenite forming elements and ferrite forming elements.

On the austenite forming side carbon, manganese, nitrogen and copper are all possible alternatives to nickel. All these elements are lower cost than nickel. Manganese acts as an austenite former but is not as effective as nickel, and Cr-Mn steels have higher work hardening rates than do apparently equivalent Cr-Ni steels.

As is the case for the PRE, the Ni-equivalence formulas are a guide but do not tell the full story; each element acts in slightly different ways, and it is not possible to fully remove nickel and replace it with, for example, copper or nitrogen.

Carbon is a very powerful austenite former, but has only limited solubility in austenite, so is of limited value in a steel intended to be fully austenitic.

Although not recognised by the PRE formula, nickel has positive effects on resistance to some corrosive environments that manganese does not.

There can also be synergy between the elements. Addition of nitrogen has the double effect of forming austenite and of increasing the pitting corrosion resistance. Also, manganese is a strong austenite former in its own right, but also has the effect of increasing the solubility of nitrogen.

Manganese is therefore a viable alternative to nickel, ranging from a minor addition to an almost complete replacement.

Some Cr-Mn-Ni grades were sufficiently developed over 50 years ago, at other times of high nickel cost, to be allocated AISI grade numbers. 201 (17%Cr, 4%Ni, 6%Mn) and 202 (18%Cr, 4%Ni, 8%Mn) are high manganese alternatives to the straight chromium-nickel grades 301 and 302, and are still included in ASTM specifications as standard grades.

Their consumption over time has been low relative to their Cr-Ni equivalents. The reasons for the poor take-up of these lower cost grades have been:

- Very high work hardening rate (this can be an advantage in some applications).
- Slightly inferior surface appearance – considered unacceptable for certain applications.
- Additional production costs – higher refractory wear in melting in particular.
- Corrosion resistance is lower in some environments, compared to Cr-Ni grades.

Take-up has often been because of technical advantages of 200-series in niche applications, not cost-driven. The last decade has seen the rise of some new contenders in the Cr-Mn-Ni austenitic group. The main development work has been in India and the principal application has been kitchenware – cooking utensils in particular.

The very high work hardening rate of the low nickel / high manganese grades has been acceptable to a point in this application, but additions of copper have also been made to reduce this problem.

In India and China there is substantial demand in for the Cr-Mn-Ni grades, often referred to generically as “200-series” stainless steels. Other centres of production are Taiwan, Brazil and Japan. Alloy development has resulted in a range of austenitic grades with nickel contents ranging from 1% to 4% and up to over 9% manganese.

None of these grades are included in ASTM or other internationally recognised standards as yet.

The growth rate in production of these low-nickel austenitic grades has been very rapid. The most recent data published by the International Stainless Steel Forum (ISSF) shows that in 2003 as much as 1.5 million tonnes (7.5% of the world’s stainless steel) was of this type.

As at the start of 2005 the future is unclear. Although it seems logical that there should be a place for the low nickel austenitic grades, the practical issues may mean that grade selectors will instead choose to either continue to use the higher cost Cr-Ni grades, or to seek lower cost alternatives amongst the ferritic or duplex grades.

C R E D I T S

ASSDA would like to thank Mr Peter Moore, Technical Services Manager of Atlas Specialty Metals, for the contribution of this article. This Technical Article is an extract from the Grade Selection section of the Australian Stainless 2005 Reference Manual.

For more information about stainless steel, contact the Australian Stainless Steel Development Association on 07 3220 0722 or visit www.assda.asn.au

Rusting Iron Cleans Up Toxic Spills

Rusting iron could offer an environmentally friendly way to stop toxic chemical spills in their tracks and make subsequent cleanup safer, says Fresh Innovator Dr Andrew Feitz.

He and fellow researchers from the University of New South Wales and the University of California, Berkeley have found that molecular-sized nanoparticles of iron rust extremely fast.

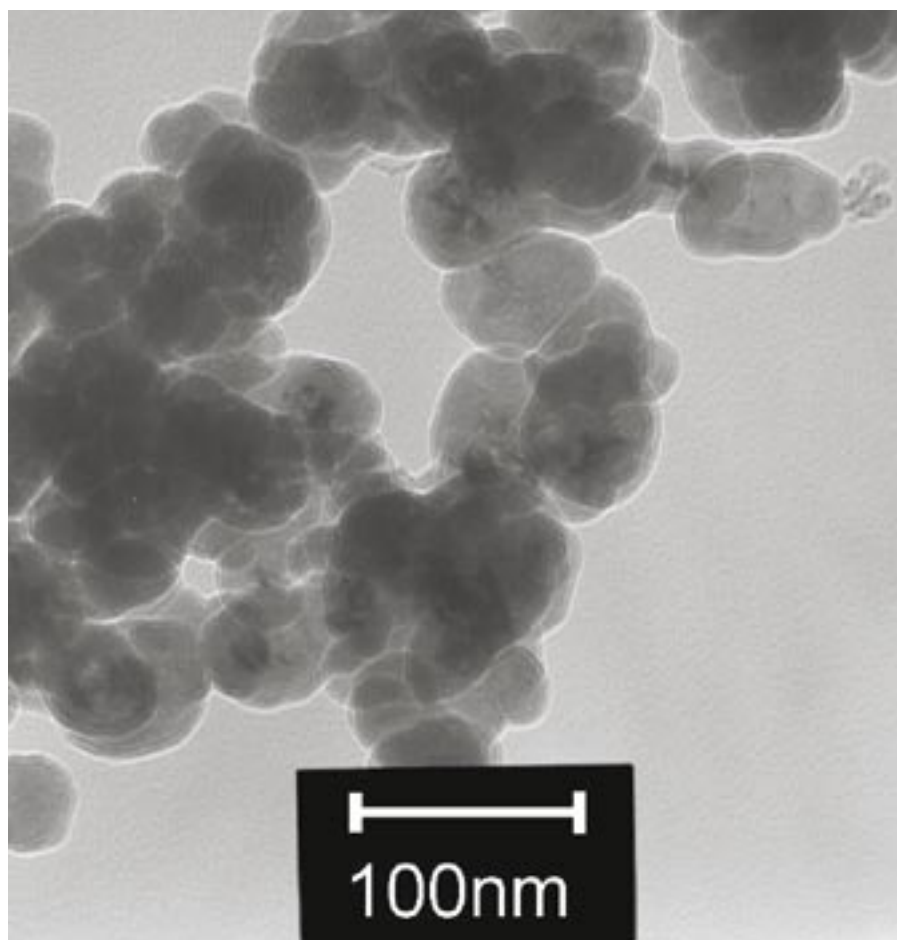
In the process they produce powerful compounds, called oxidants, capable of breaking down almost all pesticides, industrial waste chemicals and other toxic organic compounds normally resistant to cleanup.

“Normally, these incredibly powerful oxidants can only be produced using hazardous chemicals or high energy UV light. But we’ve discovered how to make nanoparticles of iron that are so small they rust almost instantly in air,” Dr Feitz says.

Iron naturally rusts in the presence of air and water. But using particles 1000 times smaller than the width of a human hair greatly accelerates the process. In addition, the researchers have discovered a much cheaper way to make iron nanoparticles than was previously possible.

The nanoparticles can neutralise toxic chemical spills from leaky containers, dropping and breaking bottles or during freight accidents.

The present method of dealing with such spills involves either hosing it away, or using an absorbent similar to cat litter to mop it up. Neither of these methods actually destroys the chemicals or reduces their toxicity.



These iron nanoparticles are less than 50 nanometres in diameter. 1 micron = 1000 nanometres. 1 mm = 1000 microns.

Dr Feitz is developing an iron nanoparticle spray that can be used on spills in the workplace, on farms or at emergency scenes.

His innovation has won him a place at Fresh Innovators — a national initiative to bring the work of 16 early-career inventors to public attention. After training in Sydney, the Innovators are talking to the media, schools and business about their ideas. One of the 16 will win a study tour to the UK courtesy of the British Council Australia.

For further information, contact Andrew Feitz via Niall Byrne on 0417 131 977 or by email at andrew.feitz@unsw.edu.au

<http://www.scienceinpublic.com/freshinnovators/2005/andrew/andrewfeitz.htm>

Book Review

Galvanized Steel

Reinforcement in Concrete

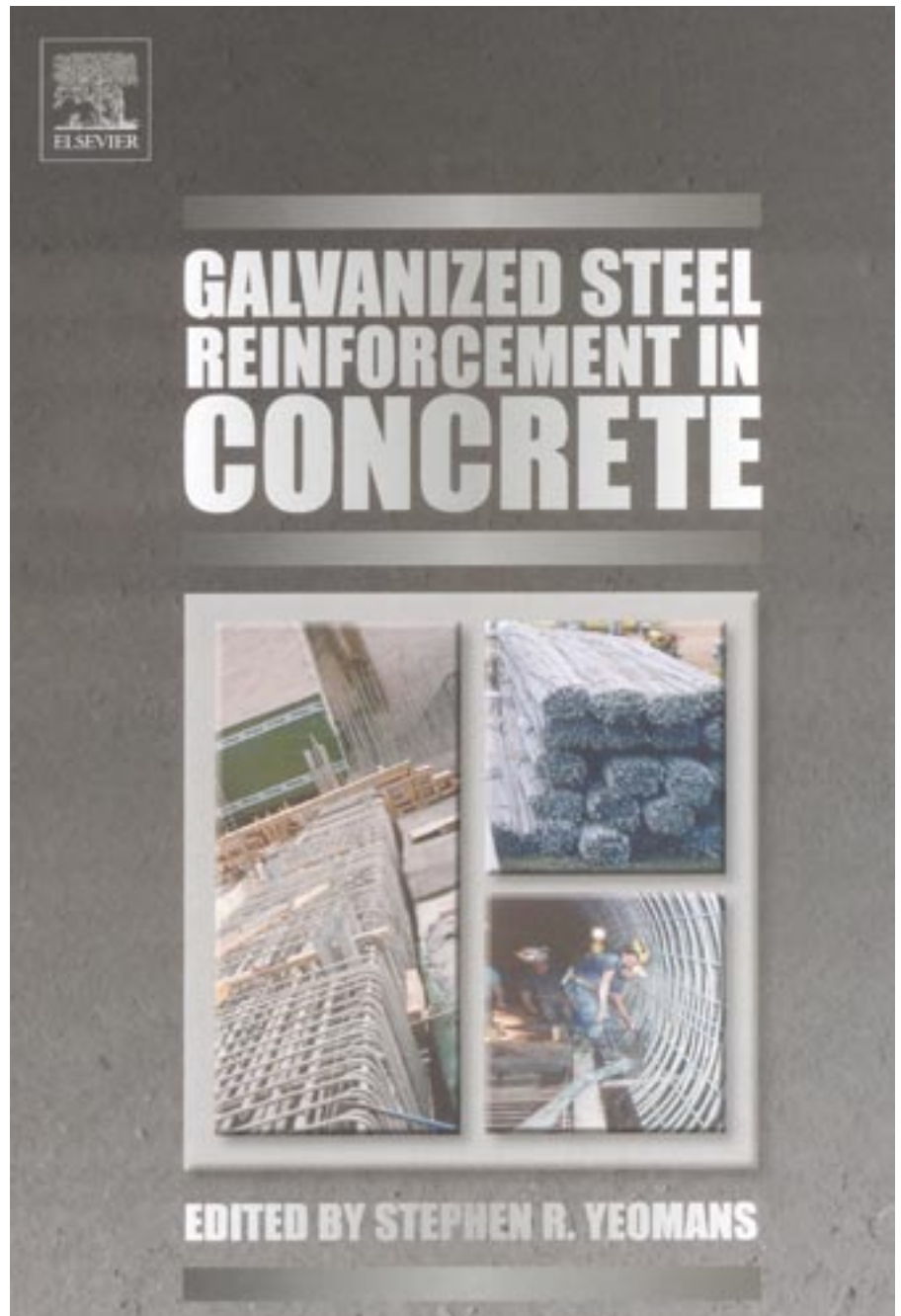
The use and performance of galvanized steel in concrete has a long history, but the most recent single document collating information on the subject was published in 1981 by the International Lead-Zinc Research Organization (ILZRO).

Dr. Stephen Yeomans, who is the leading authority on the subject in Australia, has edited a new publication on the subject on behalf of ILZRO, which has been published in 2004 by Elsevier.

Dr. Yeoman's is an Associate Professor at the Australian Defense Force Academy (University of NSW) and has a long and distinguished career in civil engineering with particular interest in the durability on concrete through the performance of steel reinforcement. In addition to his work on the subject in Australia, Dr. Yeomans has undertaken major research in the USA investigation the performance of reinforcing bar in bridge decks.

Galvanized Steel Reinforcement in Concrete brings together the work of a number of international experts in the field to deliver 9 comprehensive chapters. These cover concrete chemistry, design for durability, corrosion of metals in concrete, the performance of zinc coatings in concrete, electrochemical issues, bond strength of galvanized rebar and a number of case histories.

The book has almost 300 pages with detailed text that is comprehensively supported by diagrams, micrographs and photographs and can be considered to be the bible on this specialised subject.



Galvanized Steel Reinforcement in Concrete is available direct from Elsevier Australia Customer Service.

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