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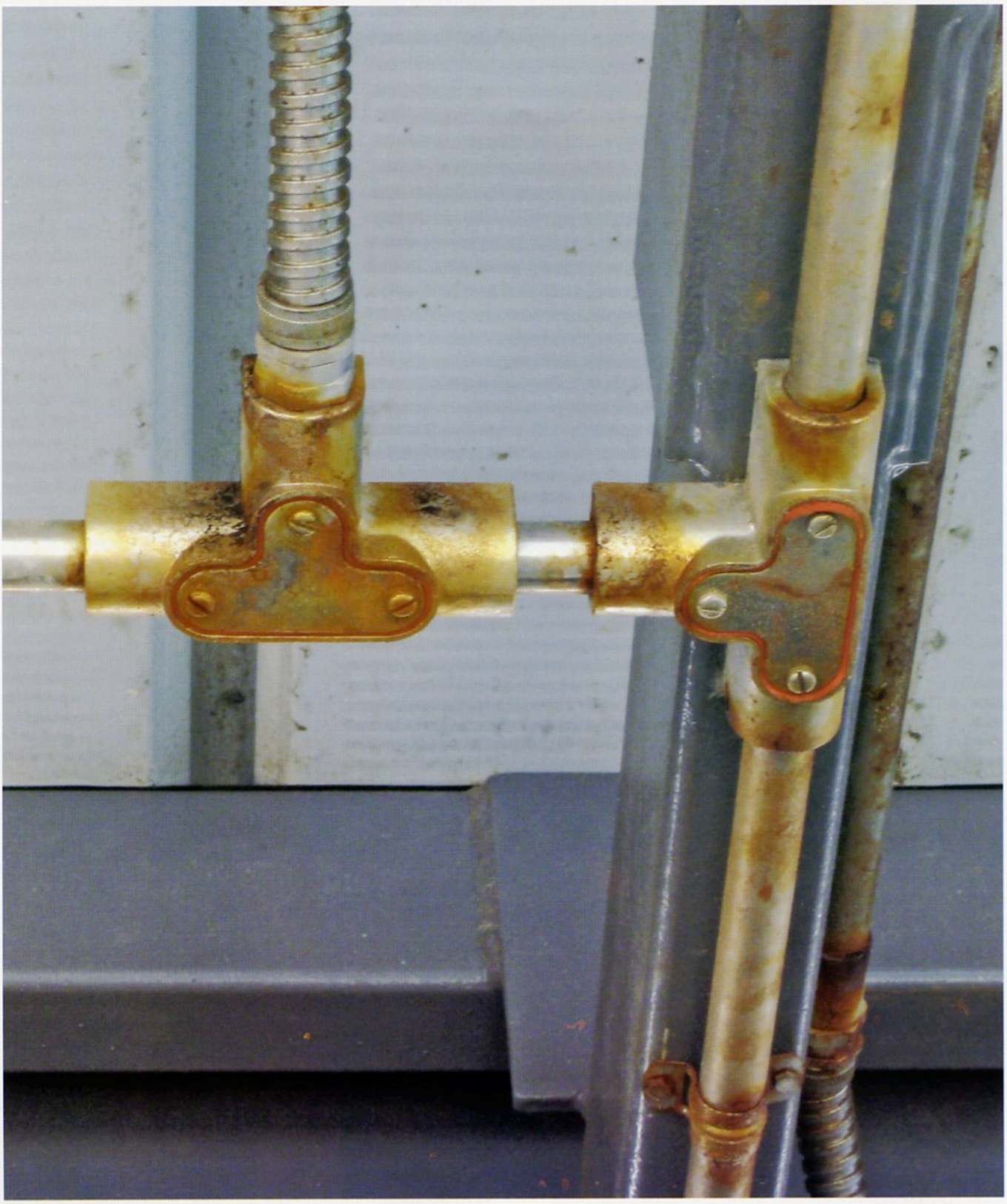
# CORROSION IN THE 'UNDERWORLD'



*Stainless steel is not immune. These 304 and 316 SS conduit fittings are distressed after less than 12 months on a floating gangway structure on Sydney Harbour.*

## INTRODUCTION

When materials are evaluated for their durability, specifically metals and their protective coatings, it is conventional to put samples of the metals or coatings being tested on standard exposure racks in an outdoor environment that will be representative of the conditions being evaluated.

The most corrosive sites are invariably located near the surf coast. There are well established exposure test sites at Point Fairy in Victoria and at Belmont, a southern suburb of Newcastle, NSW. Both these sites have a severe marine classification and are used by a number of materials and coating manufacturers to evaluate the performance of their products.

There is another location, not necessarily near the surf coast and often overlooked that imposes a very high level of corrosion stress on materials and coatings that are used there. This area is the sheltered zone on the exterior of structures that is not subject to the normal environmental wash-down that occurs in fully exposed location. This is the 'underworld' of corrosion zones that can increase corrosivity by a multiple of 4x or more.

## THE UNDERWORLD

Many external building elements are sheltered from above. Lintels, decking, awnings and structural components are among the products affected. Conventional wisdom indicates that these sheltered areas would be less susceptible to corrosion stress, and in many cases, they are.

However, two factors can change this equation. The first is the presence of airborne chlorides arising from ocean surf. The second is the local climate, particularly in temperate areas experiencing colder winters and lower overnight average temperatures.

In the latter case, the Dew Point of metal surfaces becomes an important factor in that it will determine how long the surfaces remain wet. Table 1 shows the temperature and relative humidity at which water will condense on a surface. The temperature is shown in the first column in °C and the relative humidity is listed in the top row in percentage (%).

*Total powder coating failure on this bayside verandah stanchion within 2 years on sheltered area of the verandah.*

**Table 1**

| | 30% | 34% | 38% | 42% | 46% | 50% | 54% | 58% | 62% | 66% | 70% | 74% | 78% | 82% | 86% | 90% | 94% | 98% |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **34°C** | 13.4 | 15.4 | 17.3 | 18.9 | 20.4 | 21.8 | 23.1 | 24.3 | 25.5 | 26.6 | 27.6 | 28.6 | 29.5 | 30.4 | 31.3 | 32.1 | 32.9 | 33.6 |
| **32°C** | 11.7 | 13.7 | 15.5 | 17.1 | 18.6 | 20.0 | 21.3 | 22.5 | 23.6 | 24.7 | 25.7 | 26.7 | 27.6 | 28.5 | 29.3 | 30.1 | 30.9 | 31.6 |
| **30°C** | 10.0 | 11.9 | 13.7 | 15.3 | 16.8 | 18.1 | 19.4 | 20.6 | 21.7 | 22.8 | 23.8 | 24.7 | 25.6 | 26.5 | 27.3 | 28.1 | 28.9 | 29.6 |
| **28°C** | 8.2 | 10.1 | 11.9 | 13.5 | 14.9 | 16.3 | 17.5 | 18.7 | 19.8 | 20.9 | 21.9 | 22.8 | 23.7 | 24.5 | 25.4 | 26.2 | 26.9 | 27.6 |
| **26°C** | 6.5 | 8.4 | 10.1 | 11.7 | 13.1 | 14.4 | 15.7 | 16.8 | 17.9 | 19.0 | 19.9 | 20.9 | 21.7 | 22.6 | 23.4 | 24.2 | 24.9 | 25.6 |
| **24°C** | 4.7 | 6.6 | 8.3 | 9.8 | 11.3 | 12.6 | 13.8 | 15.0 | 16.0 | 17.0 | 18.0 | 18.9 | 19.8 | 20.6 | 21.4 | 22.2 | 22.9 | 23.7 |
| **22°C** | 3.0 | 4.8 | 6.5 | 8.0 | 9.4 | 10.7 | 11.9 | 13.1 | 14.1 | 15.1 | 16.1 | 17.0 | 17.9 | 18.7 | 19.5 | 20.2 | 21.0 | 21.7 |
| **20°C** | 1.2 | 3.1 | 4.7 | 6.2 | 7.6 | 8.9 | 10.1 | 11.2 | 12.2 | 13.2 | 14.2 | 15.1 | 15.9 | 16.7 | 17.5 | 18.3 | 19.0 | 19.7 |
| **18°C** | | 1.3 | 2.9 | 4.4 | 5.8 | 7.0 | 8.2 | 9.3 | 10.3 | 11.3 | 12.3 | 13.1 | 14.0 | 14.8 | 15.5 | 16.3 | 17.0 | 17.7 |
| **16°C** | | | 1.1 | 2.6 | 3.9 | 5.2 | 6.3 | 7.4 | 8.4 | 9.4 | 10.3 | 11.2 | 12.0 | 12.8 | 13.6 | 14.3 | 15.0 | 15.7 |
| **14°C** | | | | 0.8 | 2.1 | 3.3 | 4.5 | 5.5 | 6.6 | 7.5 | 8.4 | 9.3 | 10.1 | 10.9 | 11.6 | 12.3 | 13.0 | 13.7 |
| **12°C** | | | | | 0.3 | 1.5 | 2.6 | 3.7 | 4.7 | 5.6 | 6.5 | 7.3 | 8.1 | 8.9 | 9.6 | 10.3 | 11.0 | 11.7 |
| **10°C** | | | | | | | 0.7 | 1.8 | 2.8 | 3.7 | 4.6 | 5.4 | 6.2 | 6.9 | 7.7 | 8.4 | 9.0 | 9.7 |

*Airborne salt is a major driver of corrosion and accumulates in sheltered areas. The height above sea level can have a big influence on salt deposition as this photo of salt mist illustrates.*

The lower the air temperature and the higher the humidity, the lower the temperature at which the moisture will be deposited on the surface. Thus at higher humidities, the Dew Point will be reached at surface temperatures not far below that of the air.

## FACTORS AFFECTING SURFACE TEMPERATURE

With metal structures, there are a number of factors that control their surface temperature. These include:

- Whether they are shaded
- Whether they are in contact with structures that have a large thermal mass and slow response to temperature changes (Concrete)
- Whether they are subject to contact with locally humid air (from air conditioning systems)
- How they are ventilated

Some or all of these factors will determine how long metal surfaces will remain wet, and the presence of moisture on any metal surface will increase the corrosion stress on it. In cooler climates, the Time of Wetness (TOW) on certain parts of structure may be 100% at certain times of the year, and while the presence of condensation itself may not be particularly bad, when combined with soluble salts, active electrolytes can be formed that can significantly increase metal corrosion rates.

## PERFORMANCE OF WET METALS

The majority of metal construction products likely to be subjected to sheltered corrosion conditions are painted or galvanized steel, and aluminium.

Aluminium is least affected by contact with pure water (condensation) and in most cases, aluminium building products are powder coated or anodized to improve their atmospheric corrosion resistance and steel is rarely used without a protective coating.

Zinc (galvanized) coatings, however, do not perform well in contact with pure water, particularly in their 'youth' period before the stable carbonate films form, that provide this relatively reactive metal with its excellent atmospheric corrosion resistance.

The familiar 'white rust' phenomenon that affects galvanized coatings when they are stacked in damp, poorly ventilated conditions are a manifestation of this and is a result of zinc (Zn) reacting with water ($H_2O$) to form zinc hydroxide [$Zn(OH)_2$]. This bulky, white and permeable oxide layer allows more moisture to penetrate to the zinc's surface, allowing the zinc-water reaction to continue.

Where soluble salts, including chlorides and sulfates, are deposited on sheltered metal surfaces and are not washed off by normal weather cycles, they can accumulate on the sheltered surfaces. When the surfaces become damp through condensation, highly concentrated salt solutions will be formed.

Even low levels of chloride deposition some distance from ocean surf or other sources of airborne chlorides can result in progressive accumulation of surface chloride salts to levels that are in the danger zone.

Sea water is about 1.1% sodium , 1.9% chloride, 0.3% sulfate and 0.13% magnesium. This equates to a 'salt' content of average sea water of about 3.5%. When sea salt is deposited in sheltered areas all the excess water evaporates, leaving only the salts containing their water of crystallisation behind.

When metal surfaces become damp, these salts re-dissolve and can produce salinity levels on the surface 10x higher than those of sea water. In addition, these tend to be hydroscopic, and may attract moisture at humidity levels and ambient temperatures that are well outside the Dew Point zone.

The presence of sulfates from industrial pollution can result in a significant increase in corrosion stress on steel, should it be exposed in an unprotected state in sheltered locations.

Even stainless steel can be adversely affected in sheltered application where high levels of marine aerosols exist, including the 316 grades that have generally good performance in marine conditions.

## DESIGN SOLUTIONS

The use of impermeable coatings is an obvious solution to providing long-term durability for metal surfaces that are in sheltered locations exposed to long periods of wetness or the accumulation of soluble salts.

Australian Standard AS 2699.3:2002, *Built-in components for masonry construction – Lintels and shelf angles (durability requirements)* has recommended (and mandatory) coating classes for the full range of exposure classifications that are classified on the basis of the airborne salt deposition.

The exposure classifications are shown in Table 2.

**Table 2**

| Exposure Classification | Airborne Salt Deposition |
|---|---|
| R0 | nil mg/m²/day |
| R1 | 10 mg/m²/day |
| R2 | 20 mg/m²/day |
| R3 | 60 mg/m²/day |
| R4 | 300 mg/m²/day |

*This large open roof structure located north of Adelaide SA shows the effects of chloride induced corrosion stress after 2 years on the windward (bottom) and leeward (top) sides of the main roof beams.*

AS 2699.3 recognises the need for a higher level of corrosion prevention for lintels, which are invariably used in sheltered locations on the exterior of structures.

The Standard requires that for R0, R1 and R2 exposure classifications, galvanized coatings on steel lintels complying with AS/NZS 4680 or AS/NZS 4791 be used that have a minimum coating mass of 300 g/m².

For R3 exposure classifications. AS/NZS 4680 compliant galvanized coating must be used that have a minimum coating mass of 600 g/m².

For R4 exposure classifications, stainless steel Grade 316 or 316L is specified, or where galvanized lintels are used, a duplex coating is specified over the galvanized coating. This consists of 50 microns of a two-pack non-inhibitive epoxy primer (to AS/NZS 3750.13) plus 200 microns of two-pack epoxy micaceous iron oxide (to AS 3750.14).

In coastal application, orientation has a dramatic influence on corrosion stress. The seaward-facing side of structures will 'cop it' while the leeward side of the same structure may have a very low level of corrosion stress on its sheltered surfaces.

Simply providing a barrier to the ingress of deposition of corrodents in sheltered parts of a structure can successfully control corrosion of metal building components. Even vegetation can be beneficial in capturing salt aerosols, as they can only be deposited once, and will be washed off into ground water once they fall on an exposed surface.

A good example of the effect of salt concentration and design comes with the ubiquitous boat trailer. All boat trailers used in coastal regions of Australia are regularly immersed in salt water and their owners usually rinse them off in fresh water are use. In spite of this good housekeeping, it is not uncommon to see early corrosion occurring on the sub-structure of the trailer, particularly along its centreline.

Many diligent boat owners also cover their boats with tarps when stored, while other are stored under cover or garaged.

There are almost always residual salts on the boat hull. In cooler or humid weather condensation accumulates on the hull and drips down off the keel, depositing extremely concentrated salts solution on the trailer.

In shaded or sheltered storage conditions, the condensation conditions will last much longer than if the boat is stored in the open in well ventilated conditions.

A simple test is to check your boat hull during cooler or humid weather and see if there are any water droplets accumulated on the hull. Have a taste - they are likely to be extremely salty.

## SUMMARY

Where any metal components are used in sheltered locations, and salt aerosols are able to accumulate on the their surfaces, a higher level of prevention from corrosion will be required to deal with this condition, and particular attention should be paid to fasteners used in these locations, as the coatings on fasteners, unless diligently specified, will rarely meet the durability needs of the structure.


*Orientation is critical in sheltered areas. These galvanized signposts show the clearly defined corrosion stress on the rusty (southerly) side of the posts facing the ocean 400 m distant.*

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# CORROSION MANAGEMENT

**COVER**

*Phil Layton, Industrial Galvanizers Newcastle Marketing Manager, demonstrates the flexibility of a finished Steel-Flex guide post.*

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

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Corrosion in the 'Underworld'

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Unusual Galvanized Coating Defects

# Smart Steel Safety Solution