

# Conservation of iron and steelwork in historic structures and machinery

## Maintenance handbook

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# 1. Background

This handbook has been prepared to provide guidance on the basic principles and techniques involved in the preservation of historic iron and steelwork standing outdoors in New Zealand. The suitability of different processes and coating materials for the protection of heritage structures and machinery are discussed. Marine structures, shipwrecks and artefacts in museum storage are not specifically included.

## 2. Corrosion

### 2.1 INTRODUCTION

Corrosion is not a new problem; it has existed since man first began to make and use metals. It has been stated that worldwide, 1 tonne of steel is converted to rust approximately every 90 seconds. The deterioration of iron and steel is a natural process through which these man-made materials are converted back to their original form as oxides of iron. To preserve historic iron and steel relics, the electrochemical reactions that occur on the surface of metals need to be interrupted. This can be achieved by:

- Keeping the surface dry, either by covering the surface with an impermeable barrier coating or by enclosing the relic in a watertight structure and preventing condensation.
- Changing the surface condition by chemical or electrical means, so that it remains in a 'passive' state, e.g. by coating it with a paint containing inhibitive or sacrificial pigments, or by using cathodic protection when the relic is immersed or buried in soil or damp concrete.
- Insulating it from sources of electrical current, such as more 'noble' or anodic materials, e.g. copper, which can cause galvanic or bi-metallic corrosion, or stray current corrosion. A continuous, non-conductive coating will help to insulate the more electrically active parts of a surface (e.g. welded or stressed areas) from the less active or more anodic parts.

### 2.2 CORROSION FUNDAMENTALS

The corrosion of metal is essentially an electrochemical reaction. To stop it or slow it down, it is desirable to understand the basic principles of how corrosion occurs. The process is the same as is involved in a battery, where stored chemical energy is released as electrical current when materials change their form. Iron and steel are made from iron ore in a reduction process, which uses a lot of energy (c. 3 tonnes of coal are used to make 2 tonnes of iron). This process is reversed by natural oxidation, which can occur simply

by the contact of ferrous metals with air and water, and which is powered by the energy released from the conversion of iron back to its natural form as iron ore or rust. Mild steel corrodes more rapidly than wrought iron and cast iron, as more energy is used in its manufacture.



Figure 1. Stamper battery, Bendigo Reserve, Otago.

Water provides a path for ion transfer between anodes (the areas where metal is lost) and cathodes (the other surface areas), where released electrons are consumed to form oxides and hydroxides. The wetter the environment, the faster the reaction rate, which partly explains why bare steel sitting outdoors on the West Coast of New Zealand can corrode at  $> 25 \mu\text{m}/\text{year}$ , whereas in Central Otago corrosion occurs at  $< 10 \mu\text{m}/\text{year}$  (AS/NZS 2312). The pictured stamper battery in the Bendigo Reserve, Central Otago (Fig. 1) has undergone very little corrosion.

For corrosion to occur, oxygen (from air) is also required to allow oxides to form at the cathodes. Therefore, corrosion is very slow if steel is deeply buried or submerged. If, on the other hand, the conductivity of surface water is increased by dissolved salts, especially chlorides, the current flow and hence the corrosion rate is increased. When iron and steel are kept dry, corrosion will cease. Conversely, surfaces that are shaded by vegetation or in contact with soil, and thus remain damp for longer periods, will corrode at a faster rate than those that dry more quickly.

As in a battery, there is potential difference (measured as a voltage) between the anodes and cathodes that drives the current flow. On a steel surface, the crystalline structure, effects of local stress (from bending, welding, etc.) and different levels of oxygen (due to surface contamination) result in sufficient differentiation to create this potential. Corrosion current can also be caused by an external source of potential, such as when the structure is in electrical contact with a more cathodic material, e.g. copper. If the joint is bridged by conductive liquid (known as an electrolyte), this will set up what is virtually a battery, where the steel becomes the anode. According to Faraday's Law, corroding steel will generate a current of  $0.11 \text{ A}/\text{kg}$  metal lost each year; conversely, an earth leakage current of just  $1 \text{ mA}/\text{year}$  will remove approximately  $9 \text{ g}$  (or  $70 \text{ mm}^3$ ) of metal at the exit point.

This process can be reversed when steel (or iron) is in contact with a more anodic material such as zinc, aluminium or magnesium. In this case, the steel becomes the cathode and is protected as the zinc corrodes. This is the principle of cathodic protection, where sacrificial anodes are used to protect boat hulls or buried pipelines. Zinc is also used to protect steel in this way by applying it as a coating, e.g. by electroplating, hot dip galvanizing, or using metallic zinc dust in priming paint.

For a more detailed discussion of corrosion mechanisms, refer to one of the standard reference texts listed in the Bibliography.

### 2.3 CORROSION ENVIRONMENTS

As well as increasing the conductivity of the electrolyte, marine salts, especially chlorides, also act as corrosion catalysts, as they disrupt protective surface films (e.g. they will initiate pitting of aluminium and so-called 'stainless' steel). When wind-borne salts are deposited on metal surfaces, the salts will absorb moisture if the relative humidity is  $> 70\%$ , as this is sufficient to form a conductive layer between anodes and cathodes, allowing the electrochemical reaction to continue on apparently dry surfaces (Duncan & Ballance 1988; Spence et al. 1992). This explains why the corrosion of metals is more rapid in areas close to the sea and can be up to seven times more severe on surfaces that are sheltered from rain washing (King & O'Brien 1995). Edges and crevices are worst affected because of the phenomenon known as 'evaporative concentration'—as moisture evaporates, any dissolved salts become concentrated in the locations that stay wet the longest.

The performance of protective coatings on structures will depend on the corrosivity of the macro-environment, which is classified using an international scale specified in the International Standard ISO 9223 and also discussed in the joint Australian/New Zealand Standard AS/NZS 2312. 'C5' is the most severe classification, and is defined as where corrosion occurs at a rate of  $> 50 \mu\text{m}/\text{year}$  in the first year; this typically occurs along the coast and extending 0.1-1 km inland, depending on prevailing winds and the existence of surf beaches. At 10-50 km inland, corrosion will be  $< 25 \mu\text{m}/\text{year}$ , and in very sheltered dry areas, such as Central Otago, it will be  $< 10 \mu\text{m}/\text{year}$ . However, micro-environmental effects on shaded or sheltered surfaces will increase these rates and so need to be considered when specifying the protective coating. In addition, if pitting occurs, typically it may be up to three times greater than the average rate of corrosion.

### 2.4 CORROSION PREVENTION

A simple way to reduce or arrest corrosion is to modify the environment around the iron or steel. The removal of oxygen is usually impractical; one exception to this is the removal of oxygen from water used in power station boiler tubes, which is achieved by using a scavenging chemical such as hydrazine.

Figure 2. Robey winding engine at the Big River Mine.



Moisture can be prevented from contacting the surface in a number of ways. The ultimate solution is to relocate the iron and steel into a dry environment or build an enclosure around the item, as was done for the Robey winding engine at the Big River Mine, just south of Reefton (Fig. 2). However, in coastal locations, shelters that are not fully enclosed can actually accelerate corrosion by preventing rain from washing wind-borne marine salts from contaminated surfaces.

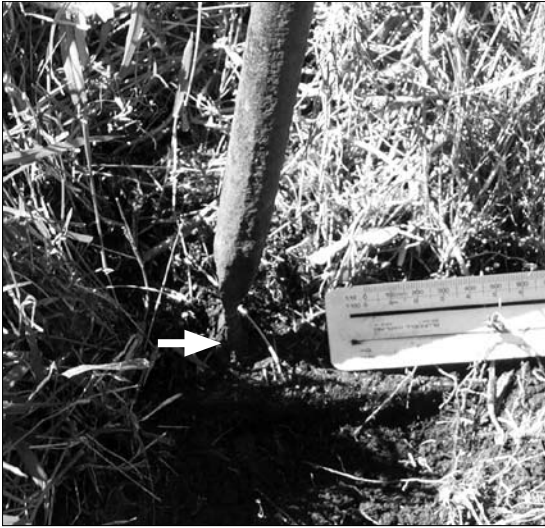


Figure 3. Example of 'ring-bark' corrosion .

The 'time-of-wetness' controls the rate of corrosion and can be reduced by providing drain holes in members, or sloping surfaces of bases to eliminate ponding, and by removing adjacent vegetation to prevent shading and promote drying. Items should be mounted clear of the ground or on a bed of free-draining gravel that is kept free of weeds. If an iron or steel item is in contact with timber or concrete, any crevice should ideally be sealed to prevent the entry of moisture. If it enters the ground, the interface with the soil or foundation also requires some form of barrier protection, to prevent 'ring-bark' corrosion where it enters the soil, as illustrated in Fig. 3. In most environments it is also beneficial to keep surfaces clean, as deposits of dirt, algae and lichens will retain moisture, increasing the time of wetness, and will also

provide sites of differential aeration, which create potentials that drive the corrosion reaction.

In special circumstances it is also possible to chemically modify or 'passivate' the surface (e.g. by using vapour phase inhibitors or inhibitive pigments in paint), to provide a highly alkaline environment (e.g. by using a concrete encasement), or to electrically change its potential by using an impressed or sacrificial cathodic protection. It should be noted that cathodic protection systems will only protect steel that is buried or immersed, as an electrolyte is required to complete the electrical circuit between the structure and the anodes. However, the more usual technique to prevent corrosion is simply to apply a protective waterproof or barrier coating to the item.



## 3. Protective coatings

### 3.1 MECHANISMS

Coatings can provide protection through any combination of the following mechanisms:

- **Barrier action:** This has two effects. Firstly, it slows down the rate at which moisture and oxygen can reach cathodic areas of the metal and prevents the anodic reaction that releases electrons from occurring, as no moisture is available for the balancing reaction to occur at the cathode, during which the released electron is consumed to form oxides and hydroxides. Secondly, the barrier coat insulates the anode from adjacent or external cathodes, making the electrical circuit incomplete. Since all coatings are permeable to some degree, leaf-like pigments of micaceous iron oxide, glass or aluminium flake are sometimes added to form overlapping scales within the layer of paint, effectively increasing the distance moisture needs to travel to penetrate the coating. Different resins have different permeabilities: water-borne acrylics have the highest (which is why they are used on concrete to allow it to breathe and not blister); oil and alkyd paints (synthetic paints thinned with turpentine) have intermediate permeability; and high-performance vinyls, epoxies and polyurethanes have the lowest.
- **Sacrificial protection:** This is where zinc metal is used as a solid coating (through galvanizing, electroplating, or using a thermal metal spray) or as closely packed metallic particles in a zinc-rich paint.
- **Passivation:** This is achieved by incorporating slightly soluble corrosion-inhibiting chemicals, such as zinc phosphate, as pigments in metal priming paint. These are dissolved by moisture travelling through the film and inhibit the anodic or cathodic corrosion reactions, and thus 'passivate' the metal surface.

### 3.2 SURFACE PREPARATION

Since nearly all coatings are permeable to some degree, it is important that the surfaces are cleaned to remove any salts that could draw moisture through the film by osmotic action and could also disrupt passive surfaces. The former can result in blistering and eventual rupture of the coating, and the latter can result in pitting. In addition, some salts are capable of forming a thin but very conductive layer on the surface of otherwise dry steel, by adsorbing moisture from the atmosphere (i.e. are hygroscopic).

Ideally, rust and iron scale should be fully removed before protective coatings are applied. This is essential to obtain the full benefit of primers pigmented with metallic zinc dust, as the zinc needs to be in electrical contact with the metal substrate to provide sacrificial (cathodic) protection. Where the metal has been exposed to marine salts, it is also necessary to remove any scale,

so that water-soluble salts that would otherwise be trapped in the bottom of any pits in the metal surface can be removed. Failure to do this will result in the early breakdown of the coating in damp environments. Removal is best achieved by slurry blasting, where an abrasive medium is introduced into a jet of water, or by alternate water blasting and dry abrasive blasting. Addition of a surfactant (e.g. a non-ionic detergent) to the washing water can assist in 'wetting' of the surface and improving rinsing efficiency. High- or ultra-high-pressure water jetting, where nozzle pressures of above 70 MPa (10 000 psi) or 210 MPa (30 000 psi) respectively are used, are also effective at removing salts from pitted steel.

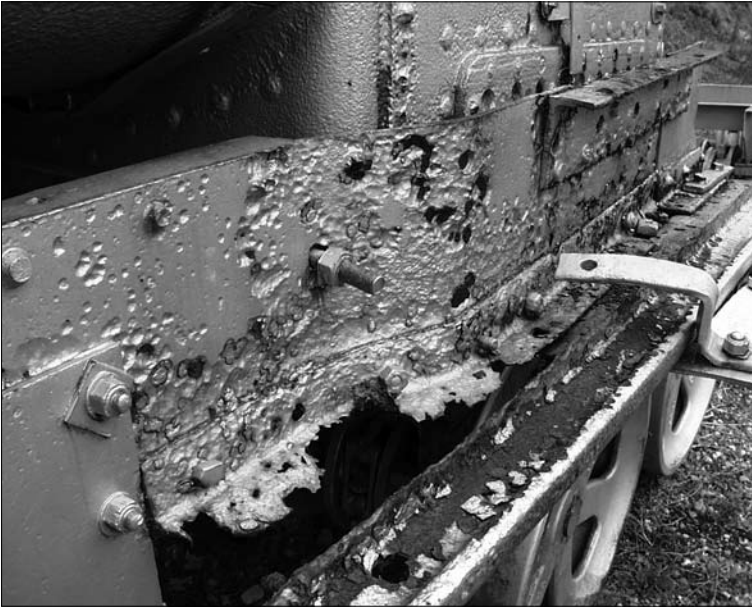


Figure 4. Premature failure of the painted surface on the Davidson Locomotive, West Coast.

Because salts can be concentrated in pits under rust, they cannot be effectively removed by low-pressure rinsing unless the rust is removed first. This is why the so-called rust-converters are not effective on corroding iron and steel near the coast. When using these acid-based materials, it is necessary to ensure that any unreacted acid is removed by rinsing and is prevented from getting into crevices. The removal of both visible and non-visible surface contaminants, which has traditionally been achieved by a cycle of abrasive blasting and rinsing, is therefore a critical step in maintenance painting; otherwise premature failure of the coating may occur, as shown in Fig. 4.

A typical maintenance painting specification clause will require cleaned surfaces to be primed as soon as possible after cleaning and before re-rusting occurs, to minimise the risk of recontamination. However, unless chemical testing for salts is also carried out, there is the risk that some salts may still be on the surface and could be painted over. A practical procedure to avoid this is to leave the first batch of cleaned steel overnight for observation before painting. If any salts are still present, the pits will turn black, indicating that a three-stage process of blast, rinse and re-blast is required. It has been found to be beneficial to leave contaminated steel overnight in a damp environment after blasting, as this allows the chlorides to move out of the pits, enabling them to be more easily removed by subsequent cleaning.

While abrasive blast cleaning by dry blasting or wet slurry blasting is ideal for rust removal and also creates a surface profile that anchors the protective coating, the complete removal of rust is not always practical and abrasive blasting can also be damaging to thin sections. In these situations, the surface should first be scraped and brushed with hand or power tools, then thoroughly rinsed to remove as much embedded salt as possible. In this situation, it is important not to polish or burnish the surface. A rough surface improves the adhesion of all coatings by creating a mechanical anchor and also increases the effective surface for chemical bonding. Once dry, hand-prepared surfaces should be treated with a penetrating sealer or primer and/or a surface tolerant barrier coat.

For a more comprehensive discussion on cleanliness standards used in surface preparation work, refer to AS/NZS 2312 or the reference Standards listed in the Bibliography.

### 3.3 COATING TYPES

Protective coatings can be categorised in various ways, including:

- Method of protection: Sacrificial, inhibitive or barrier action, as previously discussed.
- Chemical type: Metallic or non-metallic, with further subdivisions into inorganic or organic.
- Generic type: Type of resin or 'binder' (e.g. wax, oil, alkyd, acrylic, bituminous, epoxy or urethane). These are discussed in the following sections.
- Method of 'cure': Solvent evaporation or chemical reaction, with further subdivisions into oxidation or polymerisation with or without heat.
- Type of solvent: Water, organic solvents or 'solventless'.
- Function: The 'primer' provides good 'wetting' of the substrate, passivation and adhesion; the 'tie coat' gives compatibility and adhesion with existing coatings where no primer is required; the build or undercoat gives impermeability; and the 'finish coat' gives colour, gloss, UV resistance if exposed to sunlight, and chemical and solvent resistance if subject to graffiti, allowing its removal by solvent cleaning.

### 3.4 METALLIC COATINGS

Tin, zinc, cadmium and chromium are commonly used metallic coatings. They are applied as a thin layer (typically 5–15 µm) by electroplating to provide a barrier to corrosion. Zinc or aluminium and their alloys may also be applied by a thermal spray process (i.e. arc or flame spray) to suitably abrasive blast-cleaned steel and will also provide sacrificial (galvanic) protection where the barrier layer is damaged. For further information on thermal spray, refer to ISO 2063.

Zinc may also be applied to iron and steel by the 'hot-dip' galvanizing process (refer to AS/NZS 4680), where a layer of relatively soft, pure zinc over a very hard zinc-iron alloy coating (typically 50–100 µm thick) is formed on the immersed surface. Preparation for galvanizing involves dipping in a bath of acid to remove rust before rinsing, fluxing and dipping in a bath of molten zinc. As the zinc is maintained at between 445°C and 465°C, it is important that enclosed items are drilled to allow the venting of steam on immersion and drainage of molten zinc on withdrawal. There is also the risk of distortion when items are asymmetrical or when thick and thin materials are combined.

Metallic coatings are mainly used for new steelwork at the time of fabrication, although thermal sprayed metal may be used *in situ* for the long-term protection of large items such as axles or steel beams.

### 3.5 INORGANIC COATINGS

Silicates and titanates are relatively modern coatings that, unlike organic coatings, are not based on carbon compounds and so have a much higher resistance to heat and sunlight. They tend to be used for the protection of steel exhaust flues, but inorganic zinc silicate (IZS) has also been widely used both as a sacrificial primer in high-performance paint systems and as a stand-alone long-life protective coating (e.g. on tanks and bridge beams). Items need to be prepared by abrasive blasting to a 'near-white' condition or an 'Sa 2½' standard. For further information on IZS, refer to AS/NZS 3750.15.

### 3.6 'SOFT' COATINGS

Coatings based on natural or synthetic wax and grease provide a soft, flexible barrier to moisture and are widely used to give temporary corrosion protection to machined parts that are kept in storage and in enclosed automotive body panels. Some formulations can also be directly applied to hand-cleaned rusting metal that is not subject to physical damage or weathering. Examples of proprietary formulations include 'Goldseal', 'Tectyl 506' and 'Res-Q-Steel'. These are relatively low-cost materials that are applied at a thickness of up to 1 mm. However, they are not recommended for surfaces that can be accessed by the public. Other thinner, wax-based coating materials that have water-displacing properties include Castrol's 'Rustilo DWX' and Shell's 'Ensis' fluids. Various manufacturers (e.g. Denso) produce a range of mastics and impregnated wrapping tapes based on petrolatum wax, which are widely used to protect buried steelwork or items that are in damp, sheltered environments.

### 3.7 OIL-BASED COATINGS

Plant and fish oils have been used in protective coatings since Roman times. They contain polyunsaturated fatty acids that can react with oxygen from the air to cross-link, which then provides a solid film (i.e. cure by oxidation). Boiled linseed oil mixed with lead oxide was used to protect iron-work in Victorian times and became the standard priming material for steel in the first half of the 20th century (e.g. the 'PWD No 2' formulation in New Zealand). Use of the faster drying lead-based derivatives 'HD441' and 'Seachrome' have only been discontinued relatively recently because of toxicity and environmental concerns. Linseed, tung, castor and fish oils are capable of acting as drying oils, and all have been used for making paints. Their most valuable property is their low viscosity and ability to penetrate crevices and saturate the surface of hand-cleaned steel. However, they have relatively low resistance to moisture vapour and chemicals compared with paints based on synthetic resins, and also provide nutrients for the growth of fungus and bacteria.

Examples of semi-drying oil products that can be overcoated with alkyd paint to improve their durability are Wattyl's 'Killrust Fishoilene' and Altex's 'RIPO (Rust Inhibiting Penetrating Oil)'.

### 3.8 BITUMINOUS COATINGS

Various types of waterproof coating have been made from coal tar and/or asphalt applied as a molten material or dissolved in solvent and applied as a paint. Pitch obtained from natural coal tar was used by the Vikings to caulk their ships and the first patent for coal tar obtained by coking coal was granted in 1681 in England. Asphalts can be mined from seams that are similar to coal and are also obtained during the refining of petroleum. Coatings are black due to the presence of colloidal carbon, and have been widely used over the last 200 years to provide excellent low-cost barrier protection to buried or immersed steelwork. Tars are also used as an inexpensive 'extender' in the manufacture of solvent-resistant coatings such as coal tar epoxy and tar urethanes. Tar enamel coatings are not normally used for items that are exposed to sunlight, as their surface 'chalks' (forms fine powder on surface) and 'alligators' (cracks), and also softens at temperatures above 38°C. Asphaltic coatings are more liable to chalk, and have lower water and solvent resistance, but because they are less prone to alligating they are more commonly used in roofing applications. All bituminous coatings are difficult to overcoat due to their tendency to 'bleed through' finish coats, and can only be maintained with tar- or oil-based coatings. Because of their tendency to soften when warm, they are best removed by water jetting rather than abrasive blasting. Typical bituminous coatings (water-based emulsions or solvent-based products) are found in the 'Flintkote' range of coatings available from Shell NZ Ltd.

### 3.9 ALKYD PAINTS

In the past, natural resins such as kauri gum were dissolved in solvent to produce 'lacquers' and were heated with drying oils to produce 'varnish'. Since 1927, alkyds—a range of synthetic resins made from drying oils—have been available. Alkyds are now the most commonly used binders for air-oxidising paints. Alkyd paints are the easily applied, turpentine-thinned enamels which are commonly used for painting timber and steel. Metal primers are pigmented with rust-inhibiting chemicals such as zinc phosphate, which has largely replaced zinc chromate (which is carcinogenic when its dust is inhaled). Zinc chromate, in turn, replaced the toxic but more effective lead-based pigments.

To reduce their permeability and improve weatherability, finishing paints for steelwork are often pigmented with micaceous iron oxide (MIO). This naturally occurring flake-like material is used in alkyd enamel paints such as Dulux 'Ferrodor', which was widely used as a topcoat for many road and railway bridges, and other industrial steel structures throughout the Commonwealth in the late 20th century.

Alkyd paints are generally not suitable for immersion or application to concrete as they have poor alkaline resistance. Oil-based coatings should also not be applied directly to galvanized surfaces, as they may delaminate (due to a reaction with the zinc, forming weak zinc soaps). Their main use is as decorative paints, but they are also able to provide long-life protection to iron

and steel in mild to moderate environments. Recommended primers/MIO finish coats for hand-prepared steelwork include Akzo Nobel's 'Interprime 198'/'Interlac 192', Altex's 'High Build Rust Barrier'/'Isotal FerroX', and Resene's 'Rust-Arrest'/'Mica Bond'.

### 3.10 EPOXY COATINGS

Epoxy coatings are based on cross-linked polymers that are formed by the reaction of an epoxy resin with a variety of different curing agents. As a group, these have good chemical, solvent and water resistance, and excellent adhesion. They can also provide high-build coatings with little or no solvent. However, these 'two pot' materials have a limited 'pot-life' after mixing and can be difficult to recoat when fully cured. Their surface chalks more readily than alkyds, and they generally require favourable conditions for application and curing (i.e. dry and temperatures above 13°C). Coal-tar epoxy used to be widely used as an effective and economical barrier coat for immersed steelwork; however, its use has been largely discontinued because of the carcinogenic properties of the coal tar pitch used in its manufacture.

Around 1990, a group of 'surface tolerant' products known as epoxy-mastics (see AS 3750.1) were introduced for the maintenance painting of steel structures for which ideal surface preparation could not be achieved. The first on the market was Carboline's aluminium-pigmented 'Carbomastic 15'. A New Zealand product developed for the maintenance of corroding galvanized iron roofs is Resene's 'Alumastic'. Similar products are now available from most manufacturers. However, their performance as a barrier coat is dependent on obtaining a continuous film of adequate build (which is best achieved by spray painting) and on the standard of surface preparation.

Epoxy primers may be pigmented with finely ground zinc metal as a type of organic, 'zinc-rich' primer (see AS/NZS 3750.9) that is commonly used to repair damaged galvanizing. They are also used as an alternative primer to inorganic zinc silicates as part of many long-life industrial coating systems in which the zinc reduces undercutting of the film at points of damage and extends its life. Zinc-rich primers are particularly useful in marine environments.

### 3.11 URETHANE COATINGS

Urethane resins are another type of cross-linked polymer used for protective coatings, which have better weatherability and flexibility than epoxies. They can be mixed with alkyds (e.g. they often form the basis for aerosol 'spray' paints), but normally occur as one of the two categories discussed below.

#### 3.11.1 'Two pack' urethanes

'Two pack' urethanes (refer to AS/NZS 3750.6) are used as architectural, marine and automotive finish coats, as they are one of the best finish coats for retaining gloss and colour. They are often modified with acrylic to improve their self-recoatability (e.g. Resene's 'Uracryl' range) or may be used

unmodified as anti-graffiti coatings, where maximum solvent resistance is required during the removal of unwanted paint with solvents. Respiratory protection is required when spraying to prevent the inhalation of hazardous isocyanate aerosols, which are present before the coating cures.

### **3.11.2 Moisture cure urethanes**

Moisture cure urethanes (MCUs; refer to AS/NZ 3750.18)) are single-pack products that are available as clear coat materials and are commonly used to finish internal timber floors. They are also used in the full range of industrial coatings, e.g. as penetrating primers, zinc-rich primers, (refined) tar-based immersion coatings and MIO-pigmented finishing coats. While relatively expensive, MCUs can be applied under most weather conditions, including at low temperatures and high humidities, and have early shower and immersion resistance. In addition, their cure can be accelerated to allow rapid recoating. MCU systems are widely used to 'encapsulate' old lead-based coatings, e.g. for maintenance painting on old steel bridges. A well-known brand is the 'Wasser' range of coatings, available from Fortec Paints, and used since 1999 for maintenance painting of the Auckland Harbour Bridge.

## **3.12 VINYL AND CHLORINATED RUBBER**

Vinyls and chlorinated rubber are also single-pack 'non-convertible' products, which have good resistance to freshwater, marine and chemical environments. Co-polymer vinyls are still used as maintenance coatings on galvanized steel structures, and from 1960 to 1990 'solution' vinyl multicoat systems were widely used in New Zealand on immersed steelwork, e.g. in the interior of penstocks. Chlorinated rubber paints have very similar properties and both have excellent self-recoatibility properties as they 'cure' by solvent evaporation. These are now less widely used because of their relatively high solvent content and the higher cost of resin manufacture due to environmental constraints.

## **3.13 'ACRYLIC' COATINGS**

Water-borne acrylic coatings are generally only used as decorative finish coats on steel, as they are relatively permeable (and so are more prone to algal build up on shaded surfaces) and solvent sensitive. MIO-pigmented versions are available, e.g. Resene's 'Hi Glo Micaceous', while coloured acrylics have very good resistance to fading and chalking when exposed to sunlight. Solvent-borne single-pack or 'catalysed' acrylics are also available as durable 'isocyanate-free' alternatives to urethane finish coats.

### 3.14 RUST 'CONVERTERS'

Rust converters are strongly promoted by their manufacturers as alternatives to abrasive blast cleaning. However, despite superficially strong evidence in their favour, no reliable, independent proof is currently available to show that any of them are more cost-effective than traditional paint coatings, and most are markedly inferior in performance. A correspondence from the Department of Scientific & Industrial Research to the Ministry of Works & Development in 1983 concluded that tolerant inhibitive primers are to be preferred when blast cleaning is not possible. The Australian and New Zealand standard AS/NZS 2312 also cautions against their use. Because tannin-based materials are often cited in conservation literature, a comment on their use was sought from Dr Rob Francis of Melbourne, who did his PhD thesis at Monash University on rust 'conversion' materials. He provided the following statement:

'Tannic acid and other tannin based (so-called) rust converters are of limited use for treating rusted steel. There is a reaction between the tannin and ferric ions to produce a black-purple colouration on the surface, but the protection offered is limited. They do have the advantage that they are relatively safe to use, environmentally attractive and unlikely to damage adjacent materials such as wood. If the item is kept under dry conditions, such treatment may be acceptable. However, for exterior or other damp or wet environments, such coatings will quickly break down. They have no effect on salts in the rust, which is the major reason for continued rusting. They are porous and allow oxygen and moisture through the coating. Their adherence is poor, and subsequent coatings are not bonded strongly to the steel. Moreover, underneath a paint or coating, the unreacted tannin absorbs moisture causing osmotic blistering.'

### 3.15 VAPOUR PHASE INHIBITORS (VPI)

Vapour phase inhibitors (VPI) are also known as volatile corrosion inhibitors (VCI). They are materials with a low vapour pressure that sublime and are chemically adsorbed onto a metal surface to form a thin protective layer of crystals that is one or two molecules thick. They dissolve to form a thin protective film in the presence of minute quantities of moisture. They are typically used in enclosed spaces to provide protection during long-term storage, and can be supplied impregnated into coatings, wrapping tapes, foam emitters or powders that can be blown or fogged into a space. They have potential application in the preservation of old boilers, where the vapour can be prevented from escaping into the atmosphere. A major US manufacturer of these products is the Cortec Corporation, which is represented in New Zealand by Savcor ART NZ Ltd.



### 3.16 'APPROVED' COATINGS

In 1997, the NZ Paint Approvals Scheme was harmonised with the Australian Paint Approval Scheme (APAS, formerly known as the Government Paint Committee or GPC). APAS is administered by the Australian Government Analytical Laboratories (part of CSIRO), based in Melbourne. The schemes have since merged and APAS maintains a List of Approved Products (over 3500) that are made by 'Recognised Manufacturers' in Australia and New Zealand. These manufacturers have accredited quality systems and manufacturing procedures, and their approved coatings have been found to comply with the criteria and performance requirements of their relevant specification. Further information on the scheme can be found at [www.apas.gov.au](http://www.apas.gov.au) (viewed 23 June 2008).

It is recommended that coatings be obtained from an APAS-recognised manufacturer and, where available, APAS-approved coatings should be preferred. However, while the use of 'approved' coatings is desirable, it is often more important that the surface be correctly prepared and the coating correctly applied.

Appendix 1 contains contact details of New Zealand paint manufacturers and distributors, whose products have been mentioned in this handbook.

### 3.17 FURTHER READING

An excellent general reference for the preservation of above-ground iron and steel that was recently updated and is readily available is the *Guide to the protection of structural steel against atmospheric corrosion by the use of protective coatings*, which was published as AS/NZS 2312 in 2002. This, along with its 2004 Amendment, may be purchased from Standards New Zealand, or borrowed or inter-loaned via a public library. A companion document to AS/NZS 2312 and recommended reading is the HERA Report R4-133 (Clifton 2005), *New Zealand Steelwork Corrosion Coatings Guide*, which is available from the NZ Heavy Engineering Research Association in Manukau City. Other key references on protective coatings are included in the Bibliography.

## 4. Conservation

### 4.1 CONSTRAINTS

The following factors need to be considered when preserving historic iron and steel structures and fittings:

- **Access:** Many sites are remote with difficult access, which limits the use of compressed air tools for surface preparation (e.g. abrasive blasting). Rotary wire brushes could be powered by a mobile generator, but many locations, such as the sawmill engine for the Big River Quartz Mine near Reefton, may be limited to preparation by hand tools such as scrapers and wire brushes. Remote access also makes rapid curing systems preferable, so that a primer and finish coat can be applied in the same day.
- **Deterioration:** Many relics, especially in coastal locations, are in an advanced state of decay. Successful preservation will require the removal of salts from pits that may have been previously painted over. In some cases, modification or reconstruction will be necessary to prevent structural failure.
- **Climate:** High-rainfall areas, such as the West Coast, have limited weather windows during which maintenance can be undertaken and may require the use of moisture-tolerant coating systems. In marine climates, surfaces sheltered from rain will need to be thoroughly washed to remove wind-borne salts before treatment.
- **Appearance:** The conflict between preserving rusting surfaces in a corrosive environment and retaining their current appearance needs to be resolved. It is recommended that surfaces be restored to their original appearance using modern coatings that are more durable (where the fabric is still in sufficiently good condition).
- **Hazardous material:** Much historic iron and steelwork was primed with toxic, lead-based paint and, in more recent times, with zinc chromate-pigmented material. Appropriate care is required to protect workers, the public and the environment when removing this material.
- **Budget constraints:** A lot of restoration work is undertaken by voluntary organisations, which have limited budgets for purchasing high-performance materials, employing industrial painting contractors or hiring suitable equipment. In these situations, systems that have lower durability but that can be readily applied and frequently maintained may be more appropriate.

Some recommended protective coating specifications are listed in Appendix 2.

## 4.2 INITIAL ASSESSMENT

When assessing an item for conservation, it is important that the following information is obtained:

- **Material type:** Attempt to identify or describe the different materials involved, e.g. if magnetic and covered in red rust, it is probably ferrous material, but is it cast iron, wrought iron or steel (or perhaps a mixture)?
- **Location:** Record the map reference and note how accessible the site is, e.g. how close to wheeled access or a formed track. Also note any constraints in bringing in equipment or providing power for maintenance.
- **Environment:** Is the item in sun or shade, exposed to drying winds or sheltered, subject to wind-borne surf spray or onshore winds, or exposed to high humidity from cloud, fog or ponded water? How easy will it be to modify this, e.g. by clearing grass or weeds, or removal of re-growth of scrub or bush to reduce the 'time of wetness'?
- **Support:** Is the item partially buried in the ground, embedded in concrete, bolted to a base, or free standing?
- **Transport:** Is it practical to move the item to an engineering workshop for maintenance? Establish the weight and dimensions of the largest component.
- **Condition:** Record the level of deterioration with photographs. This will assist in deciding whether restoration is feasible or what type and level of preservation is appropriate.

## 5. Case histories

### 5.1 FORT DORSET OBSERVATION POST

The Fort Dorset Observation Post is located on a hill near the Pass of Brenner, overlooking the entrance to Wellington Harbour. Figure 5 shows the view out to Pencarrow Head Lighthouse; the perforated steel edge beam that supports the concrete roof slab can be seen in the foreground. The roof is a cantilevered structure and so does not have any props (presumably because these could interfere with military observations). There has been a significant loss of section at the point of maximum stress in the cantilever beam, which is a potentially hazardous situation.

Figure 5. View from the Fort Dorset Observation Post out to Pencarrow Head Lighthouse, Wellington.



This site is a classic example of severe corrosion of structural elements on which protective coatings have not been maintained, located close to the sea and in a sheltered micro-environment where wind-borne salts are not removed by rain-washing.

### 5.2 STAMPER BATTERY

The Central Otago environment is at the lower end of the scale of corrosivity. Figure 6 shows mill scale on a steel washer on the 'Come-in-Time' stamper battery in the Bendigo Reserve area, which is still largely intact after over 100 years. At this site, corrosion is much less of a problem than the theft of components that can be carried away.



Figure 6. A steel washer on the 'Come-in-Time' stamper battery in the Bendigo Reserve Area, Central Otago.